The Structural Change in the Supply Chain of Oil Palm
– A Case of North Sumatra Province, Indonesia

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Abstract — **In this paper, we analyze the structural change in the supply chain of oil palm in North Sumatra, Indonesia, especially after the financial crisis of the late 20th century.**

We first describe the past and present market structure and conduct of oil palm industries in North Sumatra with an industrial organization approach based on our field study. The analysis reveals that the supply chain of oil palm in North Sumatra has changed such that farmers had more power to determine FFB prices over crushing companies, especially from 2001 through 2004. However, farmers lost bargaining power during 2007-2008 due to a decrease in palm oil demand, plunging of palm oil prices, and a regulation imposed upon crushing companies by the Ministry of Agriculture.

To analyze such structural changes empirically, we test the existence of Asymmetric Price Transmission (APT), in which the speed of adjustments of the output price after the input price increases or decreases is different; the existence of APT implies the existence of market power. We apply the (Momentum) Threshold Autoregressive ((M-)TAR) model to estimate APT. According to the estimation results, crushing companies had more power to determine FFB prices over farmers until around March 2002. This situation changed such that farmers had more bargaining power from around April 2002 to around April 2007 before the power became balanced. The structural change test also shows these time points as optimal structural change points.

The APT estimation, however, has little rigorous theoretical background, and the concept of APT is not necessarily related to market power. Hence, we next analyze the market power of crushers and farmers both theoretically and empirically. The estimation result of market power indicates that the farmers had no market power before the third quarter of 2002, but they did have market power from the next quarter to the first quarter of 2008, after which time they again lose market power. These empirical results are consistent both with each other and with the descriptions of the structural change.

Finally, we conclude and draw some implications for farmers, crushers, and consumers of palm oil.

Keywords— **Indonesian palm oil, market power, Asymmetric Price Transmission (APT), (Momentum) Threshold Autoregressive ((M-)TAR) model.**

I. INTRODUCTION

Since 2004, palm oil has become the most produced of all vegetable oils, followed by soybean oil. According to FAOSTAT, world palm oil production in 2008 was 38.9 million tons, which is about 30 percent of all vegetable oil produced. The two major producers of palm oil are the countries of Indonesia and Malaysia. Indonesia became the world's largest palm oil producer in 2006, with a global share of about 43 percent in 2008.

In Indonesia, Sumatra Island has been the main production area of palm oil since the colonial period. On the island, North Sumatra province led Indonesia's palm oil production until approximately 2005[1] in terms of both oil palm-planted areas and crude palm oil (CPO) production (DGE [1]). CPO production from North Sumatra totaled 1.00 million tons in 1984 out of Indonesia's total production of 1.15 million tons. In 2008, it produced 2.74 million tons out of 17.54 million tons. CPO production in North Sumatra has increased, although the production in Indonesia outpaced North Sumatra.

Fig. 1 shows the change of CPO production in North Sumatra for each sector: government-owned companies, private companies, and smallholders. CPO production in North Sumatra had been led by the government-owned company, PT Perkebunan

[1] Riau province has been the largest CPO producer, and North Sumatra has been the second largest since 2006.

Nusantara (PTPN). Oil palm-planted areas of PTPN expanded from 1968 with a government investment policy and World Bank assistance. Starting in 1986, CPO production by private companies increased as the

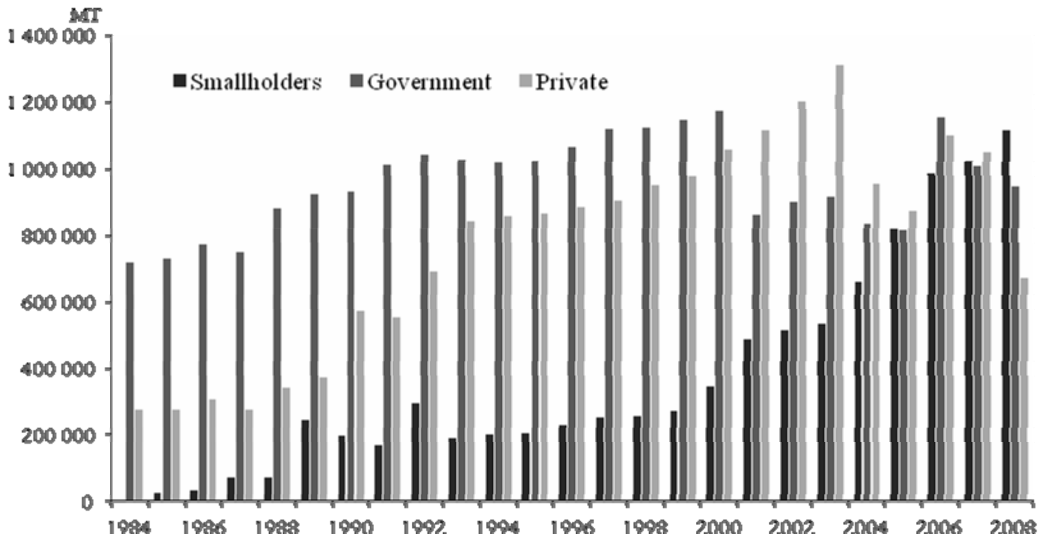

Fig. 1 CPO Production by Each Sector in North Sumatra

Source: DGE [1]

government encouraged private companies to develop oil palm-planted areas and establish crushing factories (Larson [2] and Casson [3]).

In recent years, however, the share of smallholders' oil palm in CPO production has increased in North Sumatra. Smallholders are mostly mentioned in the literature as the "plasma" of the Nucleus Estate and Smallholder (NES) scheme, which was implemented by the government from 1979 to 2001 to foster oil palm smallholders[2]. The increase in CPO production by smallholders was not ascribed to these plasma farmers, but to independent smallholders, who have no direct linkage to nucleus companies. Unlike the plasma farmers, independent smallholders have no obligation to sell Fresh Fruit Bunches (FFB) to their designated crushing companies. An appearance or increase in independent smallholders might cause changes in the market structure of FFB.

In this paper, we analyze the structural change in the supply chain of oil palm (FFB) in North Sumatra, especially after the financial crisis during the end of 20th century. This supply chain includes the production of FFB, the distribution of FFB, and the crushing of FFB for producing CPO. Although the government-owned and private companies are able to produce, distribute, and crush FFB in their own chains, smallholders (both plasma and independent) are generally unable to crush, or sometimes distribute, FFB. We focus on the supply chain such that smallholders produce FFB, smallholders or middlemen distribute FFB, and crushing companies (both government-owned and private) crush FFB, which they purchase from smallholders or middlemen. The share of smallholders in CPO production has increased and reached about 40 percent in both North Sumatra and Indonesia in 2008; however, the intracompany transactions are not easy to analyze and may be assumed to be stable over time.

Several previous studies postulate that crushing companies act in a less competitive manner to

[2] NES was a governmental policy of immigration and smallholder cultivation in conjunction with the financial support of the World Bank, Asia Development Bank, and the Indonesian government, in which 2 ha of farmlands (plasma area) plus, in some cases, additional land for cash crops and houses, are allocated for smallholders around the company-owned farmland (nucleus area). Details are in Larson [2], Casson [3], Zen et al. [4], Vermeulen and Goad [5], Barlow et al. [6], etc.

determine FFB prices rather than farmers. For example, Maryadi et al., [7] analyze the FFB price determination process in South Sumatra and conclude that, although by law, the FFB purchasing price should be determined by the pricing team, nucleus companies actually determine the prices based on their own calculation. They also point out that the calculation of costs remains unclear and that the ratio of FFB purchasing price and the FFB-based ex-factory price of CPO is set low, which leads to the underestimation of the amount of money farmers receive. Susila [8] shows that FFB purchasing price decreased in 2001 compared to the crushing capacity in Riau and West Sumatra due to overproduction, and the farmers who were not in plasma areas had less power to determine the FFB price and quantity than did buyers. Zen et al. [4] also point out that plasma farmers can sell FFB at higher prices and obtain higher profits than non-plasma farmers. Furthermore, Chalil [9] estimates the market power of the CPO industry in Indonesia and finds that private companies had market power, while government companies, which held higher market share and were highly vertically integrated, did not. These existing studies assume the NES scheme, which, in these days, is nonexistent in North Sumatra, where FFB prices are basically determined in the market and cover a period of time up until the early 2000s. Therefore, the current situation is not reflected, such as the impact of the increase in independent smallholders.

This paper is organized as follows. In section II, we describe the FFB collecting mechanism, market structure, pricing mechanism, and market conduct of oil palm industries in North Sumatra by using the industrial organization theoretic approach. We also interviewed farmers, middlemen, and a crushing company in Medan, the capital city of North Sumatra, in October 2009, and held similar interviews in Jambi province in May 2010[3]. In section III, to analyze empirically the structural change in the supply chain, we conduct an estimation of asymmetric price transmission (APT), the existence of which has been studied to associate the imperfect competition market. We use the (Momentum) Threshold Autoregressive ((M-)TAR) model, which is widely used in empirical analyses. In section IV, a theoretical model of market power is described, and the related empirical analysis is conducted to test the degree of market power and its changes. This analysis is performed because the (M-)TAR model lacks rigorous theoretical background, and the concept of APT is not necessarily related to market power. In section V, we discuss the relationship among market structure, APT estimation, and market power estimation to conclude this analysis. Finally, we show some policy implications drawn from the conclusion.

II. SUPPLY CHAIN OF OIL PALM IN NORTH SUMATRA

We first overview the FFB collecting mechanism in North Sumatra. The main purpose of this section is to ascertain who holds bargaining power over FFB prices and how the situation has changed, which will be analyzed empirically in the subsequent sections.

A. FFB Collecting Mechanism

The harvested FFB are transported to crushing factories within one to two days. Because FFB are perishable, they need to be crushed soon after harvested to avoid quality deterioration and a decrease in oil content.

The FFB harvested in the plantations of independent smallholders are delivered to various crushers depending on certain conditions, which include offered prices, the quality crushers request, distance to factories, and other constraints. One of the critical constraints is the amount of FFB sales. According to our field study, in some areas, the minimum sales volume is predetermined, in which case smallholders whose sales volume is less than 15 tons are unable to sell FFB directly to crushers. In this case, smallholders need to sell FFB to middlemen, and

[3] In Medan, we interviewed a small farmer and a relatively large farmer in Langkat district in the west of Medan, a middleman in Galang district in the east of Medan, who collects FFB from farmers to sell them to crushing factories, and a medium-scale crushing company in Medan, regarding the FFB collecting system, market structure, pricing mechanism, and market conduct. In Jambi, we conducted similar investigations with large farmers and a middleman in Batanghari district and a small farmer who was a plasma and now is an independent in Muara Jambi district.

then the middlemen sell them to crushers. In other areas, smallholders can sell FFB directly to crushers if they pay a certain amount of fees to the subsidiary of the crushers or cooperatives, even if they sell less than 15 tons at a time. However, because farmers need to use large trucks to transport FFB to crushing factories, from a standpoint of transportation costs, direct sales are limited to relatively large farmers and most small farmers need to sell FFB to middlemen.

B. Market Structure

In Fig. 2 we can confirm that the number of farmers has increased, especially after 2000 and 2004, whereas the number of crushing companies was 116 in 2000 and decreased to 86-92 in and after 2002. During this time, the number of farmers in North Sumatra grew from around 50,000 to 80,000 in 2000 and continued to increase starting in 2004. The number of farmers reached more than 150,000 in 2006.

As mentioned in the previous section, Fig.1 shows the change of CPO production of smallholders, government-owned companies, and private companies. Because processed FFB quantity is basically proportional to CPO production, the figure also reveals the share of each sector in the FFB market. According to the figure, the FFB production of smallholders has increased since 2001, whereas the production of the government-owned and private companies has decreased since 2001 and 2004, respectively. This finding suggests that crushing companies cut back the procurement of FFB from their own plantations and increased purchasing from smallholders in the industry level. This behavior might have led to an increase in demand of FFB from independent smallholders, and hence, the increase in the market share of smallholders in the FFB market, especially from 2001-2004.

In our field study, the large farmer in Langkat district observed 5 factories in his neighborhood in October 2009, while there were only 2 factories 15 years prior. This farmer believes the number of crushing factories has increased due to the expansion of plantation acreage and that it will continue to increase as the acreage expands. The middleman in Galang district recognizes that the number of crushers

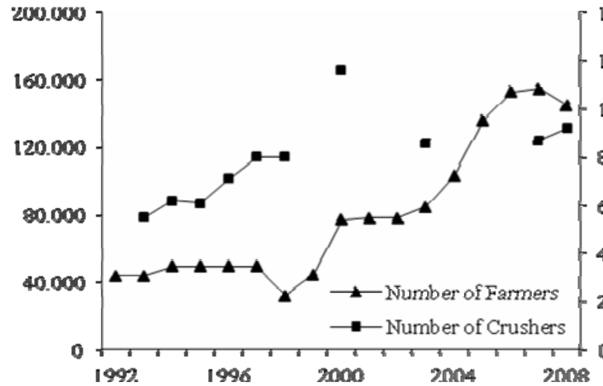

Fig. 2 Number of Farmers and Crushers in North Sumatra

Source: DGE [1]

has increased and that the competition among crushers has been severe in recent years. Furthermore, the medium-scale crusher in Medan answered that, especially in recent years, even large crushing companies did not have the power to determine FFB prices because the number of crushing factories increased. In addition, because the CPO is also faced with competition from other substitute goods, the crushing industry is in a tough competitive environment.

Our interviews also revealed that the number of middlemen has increased in the past 10 years. Although official statistics on middlemen are not available, the farmer in Langkat advised that the number of middlemen increased especially when FFB prices were high, which implies that new entrants accompany high CPO prices. The middleman in Galang is aware that the competition is becoming fierce and that he should maintain his volume of FFB by the loan system as described below.

According to the field study, competition among crushing companies and among middlemen has become increasingly fierce. Although one statistic shows that the number of crushing companies has not increased very much, the number of crushing factories that farmers see seems to have grown. In addition, competition among farmers has been less fierce since 2001-2004 because the demand for FFB produced by independent smallholders has increased, and the market share of such farmers has also increased.

C. Pricing Mechanism and Market Conduct

Here, we present an overview of the pricing mechanism of the FFB purchasing price of crushing companies, which is the same as the sales price of farmers or middlemen. Then, we consider the market conduct of each actor in the oil palm supply chain.

Maryadi et al., [7] explain that especially under the NES scheme, FFB purchasing price is calculated from FOB prices of CPO and PKO (Palm Kernel Oil) minus processing costs, depreciation, and administrative costs. Furthermore, because the NES scheme is rarely implemented in North Sumatra these days, the purchasing price of FFB is basically determined by a market mechanism. A crushing company in Medan recognizes that the determination of the purchasing price of FFB is transparent. They first calculate a price idea based on a formula for computing the price, which takes into account the production and processing costs. Then, they discuss the price idea with the farmers' representatives once per week and determine the purchasing price based on the discussion. In this sense, FFB price is determined by negotiations between buyers and sellers, referring to CPO price, which is dependent on both domestic and international CPO supply and demand[4].

Based on our interviews with middlemen and farmers, the middlemen's margin seems to be constant. The middleman in Medan advised the margin is around Rp.300-400/kg. The smaller farmer in Langkat also advised the margin of his familiar middleman is stable, around Rp.400/kg. The middleman in Jambi concurred; his margin is constant at about Rp.240/kg, and he shows his receipts from the crushing factories to the farmers. Although the margin is constant, the middleman in Medan tries to secure as many FFB as possible by loaning farmers money because crushers pay him more (less) when the sales volume is more (less) than the contracted quantity. The middleman in Jambi also lends money to farmers for buying fertilizer. Thus, some middlemen try to attract farmers by offering value added services, and they make a profit from the services instead of charging more for distributing FFB.

Assuming the constant margin of middlemen, then who has more power to determine FFB prices? As shown in the market structure, farmers have an increased number of options for selling FFB, whereas crushers have faced increasing competition with each other, especially from 2001-2004, even though the numbers of both crushing factories and farmers increased. The farmer in Jambi, who was a plasma and is now independent, informed us that the purchasing prices of a government-owned nucleus company was usually less than those of other private factories. The implication is that independent farmers have more options for selling FFB compared to plasma farmers and have a potential opportunity to receive higher prices for FFB from crushers. We infer that crushers have lost power and that farmers have gained power in determining FFB prices since the 2001-2004 period.

The crushing company in Medan also recognizes that it is not easy to set lower prices because farmers and middlemen exchange price information frequently and they always choose the factories that offer the highest prices. This situation is also evident from the interviews with farmers; small farmers obtain price information from neighboring farmers and workers at harvest time, whereas larger farmers receive such information from several crushing companies on a regular basis.

Such a situation, however, might change around 2008 due to a decrease in worldwide CPO demand and the plunge of CPO prices in the latter half of 2008. The world recession and sudden drop in commodity prices seemed to affect CPO and FFB prices and, hence, the bargaining power of oil palm farmers. As crushers reduced the amount of FFB purchased and imputed the lower prices to upstream industries, farmers were forced to accept the lower prices of FFB.

Another reason for the decrease in farmers' power to determine FFB prices may be due to a regulation imposed by the Ministry of Agriculture in 2007. In February 2007, the Ministry of Agriculture passed a

[4] The domestic CPO market was regulated in 1978-1991; the government intended to impose a CPO price ceiling and to allocate supplies of CPO to domestic refineries through quantitative export restrictions (Larson [2]). The trade restrictions were removed in 1991 and an export tax was introduced instead in 1994. Because the CPO market was liberalized in 1991, we assume CPO price is determined by supply and demand in domestic and world markets.

regulation limiting the number of entrants of crushers with no plantations, based on national law No. 18 in 2004. According to this regulation (No.26/Permentan /OT.140/2/2007), for new crushers to obtain permission to build factories, at least 20 percent of FFB must come from the crusher's plantation. Further, after obtaining permission, plantation companies need to have partnerships with smallholders in at least 20 percent of the total planted area.

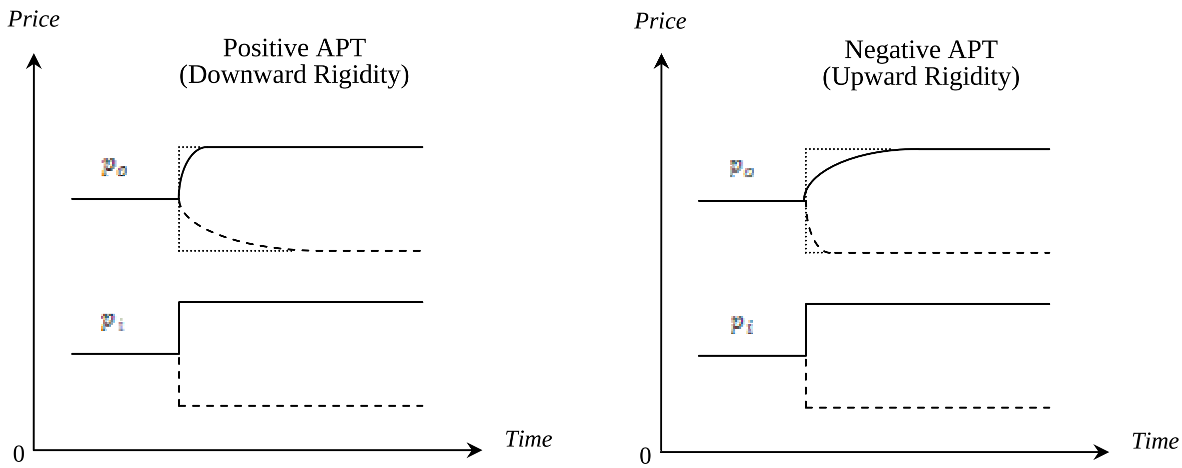

Fig. 3 Positive and Negative APT

Source: Authors (referred to Meyer and Von Cramon-Taubadel [11])
Note:

1) p_i and p_o represent input price and output price, respectively.
2) Solid lines represent the price increase and dotted lines represent the price decrease.
3) Price change of p_i is shown to occur at the kinked point of p_i , which is followed by the change of p_o.

Before this regulation was in effect, the number of crushers without plantations had increased. For example, as of 2005, 6 out of 9 factories in Jambi had no plantations (InforDev [10]). These factories could have offered farmers higher FFB prices than those with their own plantations because the costs of starting and operating plantations were not required. The crushing company in Medan also advised that smaller factories could be more competitive due to lower fixed costs. However, after the inception of the crushing industry regulation concerning new entrants without plantations, FFB prices offered to sellers might decrease because the crushers without plantations either incur additional costs to obtain plantations or withdraw from the business. Thus, there might be a reduction in the farmers' power to influence FFB prices.

In summary, according to the market structure and conduct in North Sumatra, we infer that the crushing companies lost power, and oil palm farmers increased their power to determine FFB prices after 2001-2004. However, farmers might have lost this power in 2007-2008. We examine these scenarios by subsequent empirical analyses of APT and market power.

III. ASYMMETRIC PRICE TRANSMISSION

A. What Is APT?

In this section, APT is used as one method for empirically analyzing the structural change in the supply chain of oil palm in North Sumatra. This concept is closely related to market power as described hereinafter. Based on the survey of Meyer and von Cramon-Taubadel [11], we employ the concept of APT in this paper as follows.

Let us consider a price transmission in a stage of the supply chain where input price is the industry representative's purchasing price from the upstream industry and output price is the industry representative's sales price to the downstream industry. Price transmission is said to be asymmetric if the speed of adjustments of the output price after the input price increases or decreases is different. In particular, APT is positive if the output price adjusts more rapidly when the input price increases than when it decreases. A positive APT means that the squeezed margin restores more quickly than does the stretched

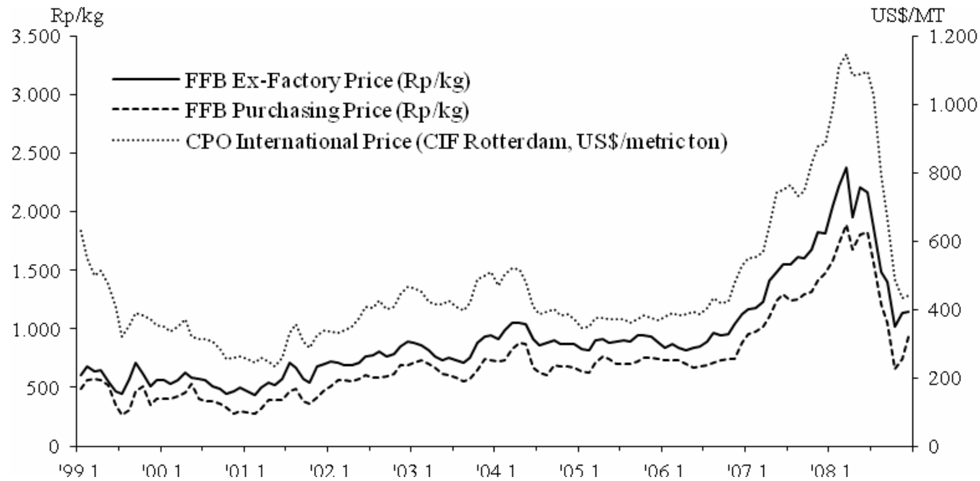

Fig. 4 FFB Prices and CPO International Price

Source: See the text.

margin. It also indicates that the price transmission has downward rigidity. In contrast, negative APT denotes that the output price adjusts more rapidly when the input price decreases than when it increases. Thus, the stretched margin is restored more quickly than the squeezed margin, and the price transmission has upward rigidity. We show the conceptual diagram of positive and negative APT in Fig. 3.

Possible causes of APT include the existence of market power, adjustment costs, search costs, and so on. Most previous studies focus on the relationship between the existence of market power and positive APT, although the explanations lack rigorous theoretical underpinning (Meyer and von Cramon-Taubadel [11]). Even though some theoretical approaches exist, such as Kovenock and Widdows [12], Damania and Yang [13], and Bunte and Peerlings [14], the number of theoretical studies on APT is limited, and the analytical results largely depend on the functional forms that researchers assume. In addition, a theoretical model that can be applied to empirical models, such as the (M-)TAR model, has not been developed yet.

In the empirical studies of APT, the (M-)TAR model has widely been used because it can test positive and negative APT with less data. Plus, it takes into consideration the stationarity of time series data and conducts co-integration tests. Previous empirical studies of APT that use the (M-)TAR model include Abdulai [15], Ghoshray [16], Gonzales et al. [17], and Hassan and Simioni [18]. These empirical analyses, however, lack the background of economic theory and rarely find the relationship between market structure and APT in a rigorous manner.

B. Empirical Analysis– Data and Unit Root Test

The empirical analysis of APT uses two sets of price data in North Sumatra, i.e., FFB purchasing prices of crushing companies (p_b) and ex-factory prices of CPO (p_s, FFB base). p_b comes from PT Smart. p_s is calculated by using the following equation (Maryadi et al. [7]):

$$p_s = P_{CPO} \times ER_{CPO} + P_{PKO} \times ER_{PKO}, \qquad (1)$$

where P_{CPO} and P_{PKO} represent FOB prices of CPO and PKO, respectively, and ER_{CPO} and ER_{PKO} are the extraction rates (the quantity extracted from 1 unit of FFB) of CPO and PKO, respectively. The extraction rates vary with the age of the palm trees. Because the palm plantations on Sumatra Island have a long history dating back from the colonial period, many trees are over 10 years old with high productivity compared to other emerging regions such as Kalimantan Island. Hence, we adopt the extraction rates of 10- to 20-year-old trees with the highest productivity specified by law, which are 21.25 percent for CPO and 5.00 percent for PKO (Maryadi et al. [7]). FOB prices are calculated from the price data from PT Smart minus export tax, which represents the FOB prices at Belawan port without export tax. p_b and p_s include 120 samples of monthly data from January 1999 to December 2008. These prices are shown in Fig. 4 with CPO international prices.

Provided the crushing costs are constant throughout the sample period, the relationship between p_b and p_s at time t is expressed as follows:

$$p_{s,t} = cost + p_{b,t} + \mu_t, \tag{2}$$

where μ_t is the i.i.d. error term. According to Engle and Granger [19], if $p_{s,t}$ and $p_{b,t}$ are in a non-stationary process and $\Delta p_{s,t}$ and $\Delta p_{b,t}$ are in a stationary process, i.e., they are first difference stationary (I(1)) variables, then the coefficient of the regression of $p_{s,t}$ on $p_{b,t}$ may have a bias due to a spurious correlation. If the residual $\{\hat{\mu}_t\}$ is stationary, however, then $p_{s,t}$ and $p_{b,t}$ are said to be cointegrated. Therefore, we need to conduct unit root tests and cointegration tests on $p_{s,t}$ and $p_{b,t}$. We use the logarithm of both variables in the following analyses.

According to the result of unit root tests shown in Table 1, $\ln p_{s,t}$ and $\ln p_{b,t}$ should be I(1) variables. Hence, estimating Equation (2) may be a spurious regression. The regression result is:

$$\ln \hat{p}_{s,t} = \underset{(10.46)}{1.118} + \underset{(52.78)}{0.869} \ln \hat{p}_{b,t} + \hat{\mu}_t, \tag{3}$$

where the parentheses represent t-statistics.

Next, we test the cointegration relationship between $\ln p_{s,t}$ and $\ln p_{b,t}$, using the (M-)TAR model introduced in the next section.

Table 1 Unit Root Test

Variable	ADF		PP		
	$Z(t)$	$p - Z(t)$	$Z(\rho)$	$Z(t)$	$p - Z(t)$
$p_{b,t}$	-1.459	0.553	-4.550	-1.492	0.537
$\Delta p_{b,t}$	-8.397***	0.000***	-74.761***	-8.144***	0.000***
$p_{s,t}$	-1.284	0.637	-3.406	-1.326	0.617
$\Delta p_{s,t}$	-9.377***	0.000***	-93.151***	-9.308***	0.000***

Notes:
1) In ADF tests, $Z(t)$ is the Dickey-Fuller test statistics, and p - $Z(t)$ is the MacKinnon's approximate ρ statistics.
2) In PP tests, $Z(\rho)$ is the Phillips-Perron's ρ statistics, $Z(t)$ is the Phillips-Perron's t statistics, and p - $Z(t)$ is the MacKinnon's approximate ρ statistics.
3) *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

C. Estimations of APT using (M-)TAR Model

In a TAR model, a cointegration test is performed by using $\{\hat{\mu}_t\}$ of Equation (3) in the following equations (Enders and Siklos [20]):

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1 - I_t)\rho_2\mu_{t-1} + \sum_{i=1}^{T}\gamma_i\Delta\mu_{t-i} + \varepsilon_t \tag{4}$$

$$I_t = \begin{cases} 1 & \text{if} \quad \mu_{t-1} \geq \tau \\ 0 & \text{if} \quad \mu_{t-1} < \tau \end{cases} \tag{5}$$

where I_t is the Heaviside indicator function, and τ is the super-consistent estimator of threshold μ_{t-1} calculated following Chan [21]. ε_t is the white noise disturbance term, which satisfies the following conditions:

$$\mathrm{E}(\varepsilon_t) = 0, \qquad \mathrm{E}(\varepsilon_t^2) = \sigma^2, \qquad \mathrm{E}(\varepsilon_t\varepsilon_j) = 0\ (t \neq j). \tag{1}$$

The necessary and sufficient condition of $\{\hat{\mu}_t\}$ to be stationary is as follows (Petrucelli and Woolford [22]):

$$\rho_1 < 0, \qquad \rho_2 < 0, \text{ and } (1 + \rho_1)(1 + \rho_2) < 1, \tag{7}$$

for any τ.

T is the lag order that satisfies the conditions of Equation (6) and (7) and minimizes the BIC (Bayesian Information Criteria).

A cointegration test is performed by testing $\rho_1 = \rho_2 = 0$; i.e., if the null hypothesis of $\rho_1 = \rho_2 = 0$ is rejected then $\ln p_{s,t}$ and $\ln p_{b,t}$ are said to be cointegrated. APT can be tested in the same model to compare the absolute values of ρ_1 and ρ_2. If $\rho_1 = \rho_2$ is rejected and $|\rho_1| < |\rho_2|$, then it is shown that the negative discrepancies from the equilibrium error

Table 2 TAR and M-TAR Model Estimation

Range	TAR				M-TAR			
	ρ_1	ρ_2	Φ	Asym.	ρ_1	ρ_2	Φ	Asym.
1999.1-2008.12	-0.449***	-0.357***	15.09***	0.40	-0.270***	-0.817***	2.75***	11.02***
(1-120)	(-4.12)	(-3.63)		(0.30)	(-3.38)	(-5.66)		(0.001) +
1999.6-2008.7	-0.397***	-0.501***	15.66***	0.42	-0.330***	-1.015***	22.64***	11.27***
(6-115)	(-3.69)	(-4.21)		(0.519)	(-3.95)	(-5.45)		(0.001) +
1999.11-2008.2	-0.319***	-0.465***	11.2***	0.79	-0.308***	-0.856***	14.95***	6.04**
(11-110)	(-2.72)	(-4.00)		(0.375)	(-3.53)	(-4.18)		(0.016) +
2000.4-2007.9	-0.502***	-0.393***	12.19***	0.36	-0.354***	0.803***	14.54***	4.05**
(16-105)	(-3.70)	(-327)		(0.552)	(-3.61)	(-4.01)		(0.047) +
2000.9-2007.4	-0.613***	-0.256**	11.97***	3.71*	-0.539***	-0.206	11.55***	3.04*
(21-100)	(-4.44)	(-2.07)		(0.058) -	(-4.61)	(-1.36)		(0.085) -
2001.2-2006.11	-0.610***	-0.244*	9.53***	3.21*	-0.571***	-0.146	10.19***	4.29**
(26-95)	(-3.97)	(-1.81)		(0.078) -	(-4.42)	(-0.91)		(0.042) -
2001.7-2006.6	-0.569***	-0.170	9.95***	4.17**	-0.495***	0.124	11.12***	6.04**
(31-90)	(-4.30)	(-1.18)		(0.046) -	(-4.68)	(0.54)		(0.017) -

Notes:
1) ρ_1 and ρ_2 are the adjustment coefficients in equation (4).
2) Φ is the F statistics of the test of the null hypothesis $\rho_1 = \rho_2 = 0$. Rejection regions are based on Enders and Siklos [20].
3) Asym. is the F statistics of the test $\rho_1 = \rho_2$.
4) + means positive APT and – means negative APT.
5) *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

adjust more rapidly than the positive discrepancies. The implication is that the shock that decreases the margin adjusts more rapidly than the shock that increases the margin. That is, the price transmission shows downward rigidity, called positive APT. However, if $\rho_1 = \rho_2$ is rejected and $|\rho_1| > |\rho_2|$, then the positive deviations adjust toward the equilibrium error more rapidly than do the negative deviations. The shock that increases the margin adjusts more rapidly than the shock that decreases the margin. This results in negative APT, which indicates upward rigidity of price transmission. In the case of this paper, positive APT corresponds to possible crushers' market power and negative APT corresponds to possible farmers' market power.

The M-TAR model is the same as Equation (4) and (5) except that μ_{t-1} in Equation (5) is replaced with $\Delta\mu_{t-1}$. The TAR model and M-TAR model correspond to the two asymmetric adjustment processes, i.e., Deepness and Steepness, respectively (Sichel [23]). In both models, however, $|\rho_1| < |\rho_2|$ indicates positive APT and when $|\rho_1| > |\rho_2|$, negative APT.

In the (M-)TAR model, the estimations with approximately less than 50 samples may cause possible small sample bias. Therefore, we need to estimate the model within several time period classifications if we are to find the structural changes of APT in limited periods. Table 2 shows the representative estimation results of the (M-)TAR model within different time periods. These results indicate that $|\rho_1| < |\rho_2|$ significantly from January 1999 to August 2008, which implies positive APT, and $|\rho_1| > |\rho_2|$ significantly from September 2000 to April 2007, which implies negative APT. Then, after April 2007, APT tended to be positive again. We also estimated the same models using various divisions of time periods, and then synthesized the movement of APT as one indicator[5], as shown in Fig. 5. In this

[5] The indicator is derived as follows. Let $APT_{i,t}$ be a "value of APT" weighted by the number of subsamples (denoted by n_i)

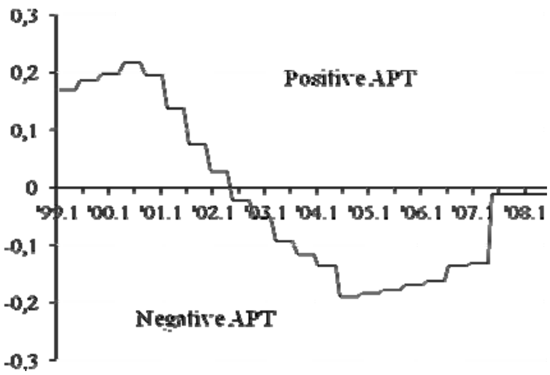

Fig. 5 Change of APT

Source: Authors

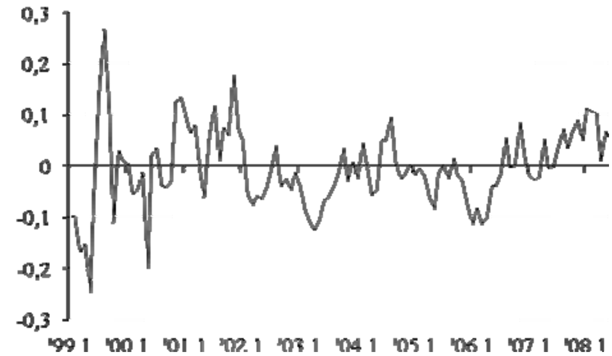

Fig. 6 Structural Change Test

Note: The dotted lines represent the estimated optimal structural change points; June 2000, January 2002, and June 2007.

figure, we find positive APT until around July 2000. Then it moved toward negative APT starting in August 2000 until it became completely negative from around April 2002 to April 2007. After 2007, the price transmission seems to be symmetric.

We also tested the structural changes with the residual series obtained from the regression of Equation (3). The results of the structural change test based on the method of Bai and Perron [24] indicated that the optimal structural change points are June 2000, January 2002, and June 2007 (Fig. 6). These correspond well to the structural change points of APT, which were derived from the estimation results of the (M-)TAR model shown in Fig. 5.

The APT estimation results imply that crushers had more power to determine FFB prices from January 1999 to around March 2002. The situation changed around April 2002 and farmers had more power until around April 2007. After that, neither farmers nor crushers had bargaining power. Thus, the structural change proposed in the previous section is empirically confirmed in terms of APT.

IV. MARKET POWER

Although the (M-)TAR estimation result implies that the farmers had power to determine the FFB price from around April 2002 to April 2007, the relationship between APT and market power is not assured because the empirical model of APT is not designed to estimate its theoretical model. Furthermore, although the explanation that the positive APT is caused by the exercise of market power appeals intuitively, rigorous theoretical explanations have not built general consensus as we mentioned in the previous section. Hence, we are motivated to estimate market power directly and establish the relationship of market power estimation with an APT estimation. In this section, we review the theoretical model of market power, estimate the degree of market power based on the theoretical model and discuss the correspondence to the APT estimation results.

A. The Model

We illustrate a structural model, which is developed by Just and Cern [25], Bresnahan [26], and Lau [27], and is concisely explained by Buschena and Perloff [28] and Perloff et al. [29]. To focus on the industry-

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in subsample i at time t (month). $APT_{i,t} = 1/n_i$ for every t if positive APT in either TAR or M-TAR model is significantly detected at least at the 10% level. Otherwise, $APT_{i,t} = -\frac{1}{n_i}$ if negative APT, and $APT_{i,t} = 0$. The indicator is derived by summing $APT_{i,t}$ for i. Various subsamples are chosen so that n_i is not smaller than 50 to avoid small sample bias and to mitigate the bias of the number of $APT_{i,t}$, which takes the value of 0, in each t.

level market structure, we assume that all firms are identical and the products are homogeneous.

$$q = q(p, z), \qquad (8)$$

where q is the FFB demand, p is the FFB sales price, and z is a vector of exogenous variables that affect the FFB demand. The cost function of FFB production is

$$c = c(q, w), \qquad (9)$$

where w is a vector of exogenous variables affecting the FFB production cost. The profit function of the farmers is

$$\pi = pq - c. \qquad (10)$$

Introducing a conduct parameter, λ, to nest various market structures, the first-order condition of profit maximization for the farmers is written as

$$p + \lambda p_q q = MC, \qquad (11)$$

where p_q is the partial derivative of p with respect to q, and MC is the marginal cost. The left-hand side of Equation (11) is defined as "effective" marginal revenue (Perloff et al. [29]). λ takes from 0 to 1, reflecting the degree of market power; $\lambda = 0$ when the farmers behave competitively as $p = MC$, and $\lambda = 1$ when they use all their potential monopolistic market power because $MR = MC$. If $0 < \lambda < 1$, then they exercise an intermediate level of market power.

To estimate the market power parameter, λ, we need to estimate Equation (8) and (11) simultaneously. The functional forms are selected as follows:

$$q_t = \alpha_0 + \alpha_1 p_t + \alpha_2 p_t z_{1t} + \Sigma \alpha_i z_{it} + \varepsilon_{1t}, \qquad (12)$$

where z_{1t} is one of z and ε_{1t} is the i.i.d. error term. The cross term is necessary in order to identify λ. The marginal cost function is

$$MC_t = \beta_0 + \beta_1 q_t + \Sigma \beta_i w_{it} + \varepsilon_{2t}. \qquad (13)$$

By using these functional forms, the optimality condition (11) is written as

$$p_t = \beta_0 + \beta_1 q_t + \Sigma \beta_i w_{it} + \lambda\left(\frac{-q}{\alpha_1 + \alpha_2 z_{1t}}\right) + \varepsilon_{3t}. \qquad (14)$$

The FFB demand function facing the sellers is

To test possible structural changes of market structure, we can incorporate dummy variables in λ such that

$$\lambda = \lambda_0 + \Sigma \lambda_i D_i, \qquad (15)$$

where D_i are dummy variables that take on the value 1 during a specific time and 0 before that time. For example, if we use quarterly data and assume that the market structure has changed in the first quarter of 2000 and the second quarter of 2005, then $\lambda = \lambda_0 + \lambda_1 D_1 + \lambda_2 D_2$, where $D_1 = 1$ from 2000Q1 and $D_1 = 0$ before the quarter, and $D_2 = 1$ from 2005Q2 and $D_2 = 0$ before the quarter. In this case, the market power parameter, λ, before 2000Q1 is λ_0, $\lambda = \lambda_0 + \lambda_1$ from 2000Q1 to 2005Q1, and $\lambda = \lambda_0 + \lambda_1 + \lambda_2$ during and after 2005Q2.

In the subsequent empirical analysis, Equation (12) and (14) are estimated with two possible structural changes incorporated in Equation (15). The structural change points are selected according to the empirical results of APT.

B. Estimation of Market Power

Considering the correspondence with the APT estimation results and data availability, we use quarterly data from the first quarter of 1999 through the fourth quarter of 2008 to estimate the degree of market power of farmers. The endogenous variables are price and quantity. The FFB sales price data are calculated by averaging each three monthly data points whose source is the same as that of the APT estimation. The FFB quantity (or demand) data are generated by disaggregating the annual data using Denton's method[6]. To disaggregate the annual data, this method uses a different quarterly data point as an indicator. We choose real GDP of Indonesia as an indicator. Although we are forced to use an indicator of limited relevance to the FFB production, the movement of the disaggregated data looks rather natural responding to the original annual data. The annual data are calculated from the CPO production in North Sumatra with the constant extraction ratio of

[6] We used the "Denton" package in Stata. This methodology is based on Bloem et al., [30] and Denton [31].

21.25 percent, according to Maryadi et al. [7]. The annual CPO production data are obtained from DGE [1].

The exogenous variables in the demand equation are real GDP of Indonesia, real GDP of China, oil price index, food price index, and time trend. The real GDPs of Indonesia and China are deflated by the local consumer price index (2005=100). Because significant seasonal trend is detected in real Chinese GDP, the data are seasonally adjusted. The nominal GDP, CPI

Table 3 Summary of Variables

Variables	Mean	Std. Dev.	Min	Max
Endogenous variables				
Real price of FFB in North Sumatra (Rp/kg)	2281.68	610.53	1308.98	4114.39
Quantity of FFB (1,000 metric tons)	3159.79	332.38	2750.67	3973.38
Exogenous variables				
Real GDP of Indonesia (billion Rp)	654207.80	141070.90	431751.00	985592.00
Real GDP of China (billion Yuan)	3232.94	761.64	2072.85	4351.13
Commodity fuel (energy) price index	84.64	48.95	23.91	223.77
Food price index	101.04	25.12	77.14	174.82
Real wage in rural areas (Rp/half day/person)	15.81	5.30	7.88	25.55
Real TSP fertilizer price in North Sumatra (Rp/kg)	2947.10	531.99	2345.85	4489.57

Source: See the text.

and price index data are obtained from the International Financial Statistics (IFS) of the IMF. The exogenous variables that we use in the optimality equation are wage and fertilizer. We use the wage of harvesting in a half day per person in rural areas of Indonesia. The data source is BPS [32]. The data of TSP fertilizer in North Sumatra up until 2007 are available from BPS [33]. We generate the data in 2008, however, by extrapolating the international TSP index data from the World Bank. Both wage and fertilizer data are deflated by CPI. The means and standard deviations of all variables are shown in Table 3.

According to the findings in the APT estimation, possible structural change points should be in 2000-2003 and 2007-2008. However, because the estimation methods, data used, and the frequency of the data are different between APT and market power, the structural change points are not necessarily the same. Hence, we can be flexible in choosing the structural change points. The first possible structural change point is in 2002 when the APT changed from positive to negative. The second possible structural change point is in 2008 because the sudden FFB price decrease that year might squeeze the price cost margin of farmers. Therefore, we conducted the simultaneous estimation of Equation (12) and (14) by using 2002Q4 and 2008Q2 as the structural change points in Equation (15), so that D_1 and D_2 are dummy variables that take 1 on from 2002Q4 and 2008Q2, respectively.

The estimation result of the structural model using three-stage least squares (3SLS) is shown in Table 4. λ_0 is 0.022 with p-value 0.163, which means λ_0 is not significantly different from 0 even at the 10% level. Thus, farmers had no market power before 2002Q4. However, λ_1 is 0.035 and significantly different from 0; the null hypothesis of $\lambda_0 + \lambda_1 = 0$ is rejected at the 5% level. In this case, the farmers had market power over the crushing companies from 2002Q4 to 2008Q1, although the value of the market power parameter is small (0.087). Furthermore, λ_2 is -0.070 and significant at the 10% level; $\lambda_0 + \lambda_1 + \lambda_2 = 0$ is not rejected (λ decreases to 0.017). In other words, the farmers lost their market power from 2008Q2 to 2008Q4. This result is mostly consistent with the APT estimation: the starting point that farmers had market power corresponds to the point that APT changed from positive to negative. The time point that the farmers lost market power should be close to that of the APT estimation.

Other than market power parameters, FFB sales quantity and wage have significant effects on FFB sales price in the optimality equation. Intercept dummy variables in both equations are also significant at the 5% level, which supports the fact that FFB demand decreased in 2008 and that the FFB price level was significantly higher in 2007-2008. We can point out, however, that except for the intercept dummy variable, variables in the demand equation are insignificant. Signs are also different than expected in

China's GDP and oil price index, although the coefficients are not significant.

Table 4 Market Power Estimation in Structural Model by 3SLS

Demand Equation (FFB Demand)				Optimality Equation (FFB Sales Price)			
Intercept	1551.562		(0.237)	Intercept	4524.142	***	(0.001)
FFB Sales Price	-0.145		(0.687)	FFB Sales Quantity	-1.713	***	(0.001)
Indonesia's Real GDP	0.001		(0.461)	Real Wage	106.750	*	(0.096)
China's Real GDP	-0.051		(0.883)	Real Fertilizer Price (TSP)	0.125		(0.601)
Oil Price Index	-2.976		(0.457)	Dummy Variable (1 after 2007Q1)	852.426	**	(0.040)
Food Price Index	13.901		(0.277)	λ_0	0.022		(0.163)
Dummy Variable (1 after 2008Q1)	-725.163	**	(0.044)	λ_1	0.035	***	(0.006)
Time Trend	15.409		(0.629)	λ_2	-0.070	*	(0.051)
Time Trend × FFB Sales Price	-0.004		(0.689)				
F-statistics	5.52			F-statistics	7.76		
p-value	0.00			p-value	0.00		
R^2	0.489			R^2	0.419		
F test							
$\lambda_0 + \lambda_1 = 0$	5.820	**	(0.019)	$\lambda_0 + \lambda_1 + \lambda_2 = 0$	0.130		(0.723)

Note: Parentheses indicate p-values. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

V. CONCLUSION

In this paper, we analyzed the structural change in the supply chain of oil palm in North Sumatra, Indonesia, especially after the financial crisis, based on field surveys and empirical analyses. The key findings are as follows.

First, we considered the past and present market structure and conduct of oil palm industries in North Sumatra with an industrial organization approach, based on our field study. The analysis revealed that the supply chain of oil palm in North Sumatra had changed such that farmers had more power to determine FFB prices over crushing companies especially from 2001-2004. However, farmers lost their bargaining power in 2007-2008 due to the decrease in palm oil demand, a plunge in palm oil prices, and a regulation imposed on crushing companies by the Ministry of Agriculture.

Secondly, the price transmission from FFB purchasing prices to ex-factory prices was estimated by using the concept of APT and by applying the (M-) TAR model. According to the estimation results, crushing companies had more power than the farmers to determine FFB purchasing prices until around March 2002, then the situation changed so that farmers had more power in determining FFB sales prices from around April 2002 to around April 2007. After this time, power became balanced. The structural change test also found these historical change points, in addition to the point when the crushers' power started to decline, as the three optimal structural change points.

Thirdly, because the APT estimation has little solid theoretical background, we analyzed market power both theoretically and empirically. The estimation result of market power showed that the farmers had no market power before the third quarter of 2002, but they did from the next quarter to the first quarter of 2008; they again had no market power after the second quarter of 2008. Farmers in North Sumatra obtained market power possibly through the increase in planted areas and fierce competition among crushing factories. The Ministry of Agriculture's regulation and a sharp price drop in 2008, however, caused excess profits to shrink, which led to the disappearance of farmers' market power.

Our analyses also produced evidence regarding the relationship between APT estimation and market power estimation. Furthermore, findings from both the field studies and empirical results supported and corresponded to each other. Previous studies only provided analytical descriptions or conducted APT and market power estimations independently. Hence, little was discussed concerning the relationships between descriptive and quantitative analyses or between APT and market power estimations. From this perspective, this paper may have some contributions to the study of oil palm industries in Indonesia, APT, and market power.

We draw the following implications from our research. First, farmers became better off around 2002 from the perspective of APT and market power because they earned excess profits through the power to determine prices or a strictly positive price-cost margin. As we assume that the margins of middlemen are constant based on our interviews, farmers received all the benefits. Second, although either crushers or farmers have benefited when positive or negative APT existed, the excess profits of FFB/CPO producers may have caused an efficiency loss in the economy. Hence, under the existence of APT or market power in the supply chain of FFB, palm oil consumers such as cooking oil producers, the oleochemical industry, and other end users, even importers, may need to pay more than under no APT or a perfectly competitive market. Third, Indonesia has potential to expand oil palm production due to its vast, cultivable land. It seems increasingly difficult, however, to enter into and profit from the crushing industry due to severe competition and the bargaining power of farmers.

Because North Sumatra has been a representative and the largest palm oil-producing province for a long time, this paper focuses on this province even though other emerging provinces and regions may have different characteristics. One possible future area of research could be conducting and comparing similar types of analyses on other provinces to help understand their differences. Another possible area for future research is to compare the price transmission and/or market power of palm oil exporting countries and importing countries.

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