Economia
agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 27, Iss. 1, Art. 1, pp. 1-42 - ISSNe 1972-4802 DOI: 10.3280/ecag2025oa18605

Economia agro-alimentare / Food Economy

ECONOMIA AGRO-ALIMENTARE *FOOD ECONOMY* An International Journal on Agricultural and Food Systems
2020, Vol. 22, Issue 1

FrancoAngeli La passione per le conoscenze

ISSN 1126-1668 ISSNe 1972-4802
2020, 22 (1) SIE

Simultaneous Equation of Concentration, Efficiency, and Competitiveness of Indonesia's CPO Industry: Impacts and Policies

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Abstract

This study simultaneously analyzed the industrial concentration measured using CR4, technical efficiency measured using Stochastic Frontier Analysis (SFA), and competitiveness using the Revealed Comparative Advantage (RCA) approach of the CPO industry in Indonesia. The study uses time series data from 2001 to 2020, sourced from the Central Statistics Agency (BPS), the World Bank, and UN Comtrade. This study uses a simultaneous model approach of Two Stage Least Squares (2SLS). The results show that the efficiency of the technique has a negative and significant impact on industrial concentration. The market concentration measured by CR4 shows a positive and significant relationship with competitiveness. Large companies that dominate the market are able to create price stability and encourage innovation, which ultimately improves the profitability and quality of CPO. RSPO policy is negatively correlated with concentration levels, the high cost of certification can be a barrier for new companies to enter the market. Biodiesel policy opens up new opportunities, the push to meet domestic demand can reduce the pressure to innovate.

Article info

Type:
Article
Submitted:
31/10/2024
Accepted:
06/01/2025
Available online: 03/04/2025

JEL codes:
C30, L10, O13

Keywords:
Competitiveness Concentration
Crude Palm Oil Industrial Technical
Efficiency
Simultaneous
Equation Model

Managing Editor: Valeria Borsellino Søren
Marcus
Pedersen

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Introduction

Crude Palm Oil (CPO) is one of the mainstay products in Indonesia as a major contributor to the division. Indonesia in international trade, is the largest producer of CPO, which is usually used in the manufacture of food, cosmetics, and biodiesel. The data also shows that the value of Indonesia's CPO exports continues to increase (Figure 1), also supported by previous findings that the competitiveness of Indonesia's CPO industry continues to increase (Khatiwada *et al.*, 2021; Gaskell, 2015). However, although the market share and demand for CPO continue to increase, there are various obstacles faced. Changes in CPO prices play a very important role in maintaining competitiveness. These fluctuations are caused by external factors such as climate change and geopolitical factors. In addition, the CPO industry is also required to implement sustainability with existing certifications.

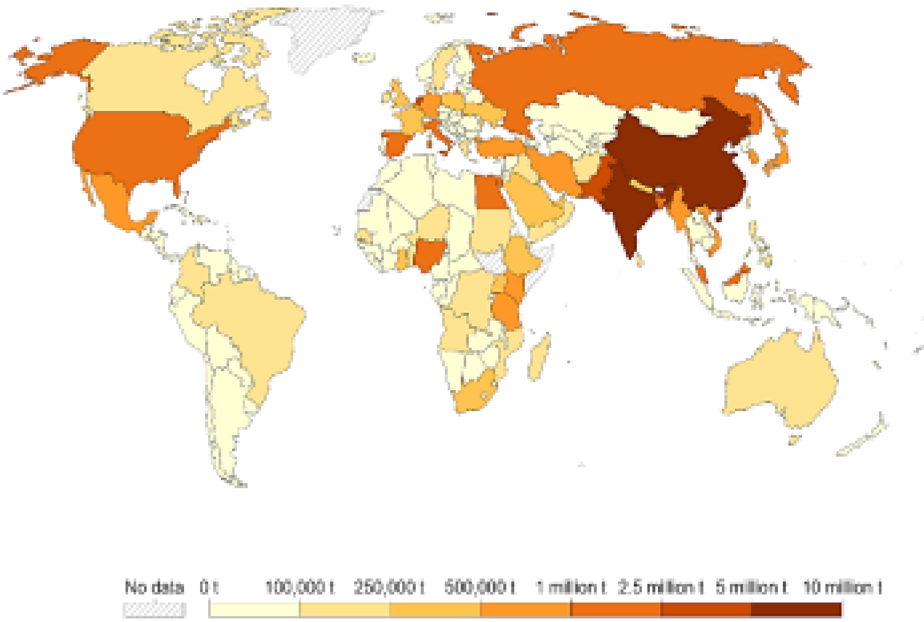
Figure 1 - The Value of Indonesia's CPO Exports

Source: UN Trade (2001-2021).

The economy in Indonesia is quite impactful if CPO prices fluctuate. This challenge extends to Indonesia's CPO export destination countries, such as China, India, and Pakistan, with large populations also increasing demand for CPO (see Figure 2). Several factors are also suspected to be the potential cause of CPO price fluctuations. There are allegations related to the existence of cartels, the implementation of the biodiesel (B30) policy, the impact of corruption and collusion, and the ban on the use of CPO by the European Union (Halimatussadiah *et al.*, 2021; Innocenti & Oosterveer, 2020). CPO's main competitor products such as sunflower oil are also suspected to be the cause that can affect CPO's competitiveness. In recent years, the emergence of COVID-19 has also been the cause of price fluctuations and a decline in global CPO demand. Malaysia as Indonesia's main competitor is also often examined by previous research as a factor that hinders Indonesia's competitiveness.

The price of cooking oil in Indonesia is very volatile, allegedly affecting the technical efficiency and competitiveness of the CPO industry. Land area also plays a role in palm oil production, demonstrating a complex relationship with industrial concentration, production efficiency, and global competitiveness (Pye, 2019). In answering the problems of the CPO industry, Indonesia must prioritize production efficiency and strive for innovation in the supply chain to remain competitive in the global market. There are many research results that state that there is a simultaneous relationship between the factors discussed earlier. Murti (2017) analyzing the simultaneous relationship between CPO prices, Indonesian CPO exports, vegetable oil demand, CPO consumption, and Biodiesel utilization shows that several exogenous variables can affect the main endogenous variables, and shows simultaneous factors. Recent research by Othman *et al.*, (2023) discussing how the competitiveness of exports in the Malaysian CPO industry is affected by European Union (EU) environmental regulations, the results revealed that EU environmental regulations have a positive impact on the competitiveness of the palm oil industry. These results are consistent with Porter's hypothesis, which states that stricter environmental regulations can fuel innovation to the cost of non-compliance. Other research by Alii *et al.*, (2021), comparing the export performance and export competitiveness of Indonesia's CPO trade in the Chinese and EU markets. According to him, the difference in the competitiveness of Indonesia's CPO exports in the Chinese and EU-25 markets is due to the Roundtable on Sustainable Palm Oil (RSPO) policy. Rosyadi *et al.* (2021) how various factors affect the intensity and competitiveness of crude palm oil (CPO) exports. The results show that the importer's gross domestic product (GDP) and export quantity have a significant and positive effect on the intensity of Indonesia's CPO exports, while the GDP and the economic distance of exporters have a significant and negative effect. Factors that have a positive and significant effect on competitiveness are the value of soybean imports and the Roundtable on Sustainable Palm Oil (RSPO) certification, while Malaysian CPO exports and the population of importing countries have a negative effect on the competitiveness of Indonesian CPO. Based on previous research, this study will fill the gap by simultaneously analyzing the relationship between concentration, efficiency, and competitiveness of Indonesia's CPO industry, which has never been explored before.

Figure 2 - World Crude Palm Oil Imports



Source: Food and Agriculture Organization of the United Nations (2019).

By integrating key variables in a simultaneous equation model, this study provides a new foundation for understanding the complex interactions between concentration, efficiency, and competitiveness of the CPO industry. The study also opens the door for further research in this area by identifying potential areas for further research. By highlighting the complexity of the relationships between variables and using sophisticated analytical methods, this study contributes significant novelty in the scientific literature related to the CPO industry. Therefore, we answer the following questions:

1. How is the concentration, efficiency, and competitiveness of the Indonesian CPO industry?
2. How does the relationship between concentration, technical efficiency, competitiveness, RSPO policy, CPO prices, cooking oil prices, global prices of sunflower oil, the export value of Indonesian and Malaysian CPO,

the price of Indonesian industrial solar power, and the Biodiesel policy affect the Indonesian CPO industry?

The rest of this research is as follows. Literature reviews are checked in Part 2. Part 3 explores the data, methodology, and identification of the Simultaneous Equation System. Variable movements, empirical results and discussions are reported in Section 4. Part 5 explains the conclusions and policy implications for the Indonesian CPO Industry.

1. Literature Review

The Structure, Conduct and Performance (SCP) paradigm is one of several analytical frameworks used in the analysis of industrial organizations. This paradigm is used to show the relationship between Structure, Conduct and Performance of the industry in the market. Referring to the analysis model from the previous theory Martin (1989) regarding structure, behavior, and performance (SCP) that there are various frameworks and perspectives explained, namely: "Harvard Tradition", "Chicago-UCLA School", "Contestable Market", "Game Theory", "New-Harvard Tradition" and "Strategic Behavior" perspective.

The traditional view is that the high concentration of an industry will encourage the formation of a high level of collusion between companies in the industry, thus facilitating the formation of a monopoly market structure in the industry. This creates high prices, especially if the profits of these companies increase if they are supported by continuous production. The traditional New-Harvard approach to the SCP model states that each component interacts with each other, i.e., market performance depends on market behavior. Furthermore, the market structure depends on fundamental factors, namely demand and production, including demand, substitution, seasonality, economic growth rate, location, number of orders, development methods and technologies, raw materials, product consistency, product elasticity, location, economies of scale and economic reach. The basic conditions of structure, conduct, and performance affect government policies. According to Martin (1989), the framework of industrial organization is always developed, there is a very simple causal relationship in a linear model. With the model developed, it matches the impact and mutual influence between structure, conduct, and performance in the real world.

Market structure, as a vital component in the context of the industry, indicates stability that tends to persist in the corporate environment, influenced by market behavior and performance (Tremblay, 2012). Market structure analysis aims to understand how this affects industry behavior and performance. The market structure includes industry characteristics such as company size, number of competitors, level of competition, and market type (Scherer, 1980), all of which have a significant impact on efficiency, innovation, and industrial competitiveness. Concentration Ratio (CR) according to Bikker and Haaf (2002). Concentration Ratio (CR), according to Bikker and Haaf (2002), is used to measure concentration levels using structural models to explain the competitive performance of an industry resulting from market concentration. It is used in the measurement of concentration degrees with structural models in explaining the competitive performance of the industry as a result of market concentration. CR is defined as the percentage of the overall industrial output produced by the largest firms.

In economic analysis, efficiency is divided into two main aspects, namely productive efficiency and allocative efficiency (Lipsey, 1990). Industrial efficiency, as a result of the market structure, can be measured relatively. Farrel (1957) introduces the concept of technical efficiency, which reflects the company's ability to produce maximum output from a given input, and allocative efficiency, which assesses the company's ability to be in optimal input allocation to achieve the desired output. In measuring performance, Stochastic Frontier Analysis (SFA) is one of the methods used in estimating production limits (frontiers) and also measuring the level of production efficiency. The idea of SFA began with two articles published independently by two teams of authors, namely Meeusen & van den Broeck (1977) and Aigner *et al.* (1977), followed by the third article by Battese & Coelli (1992). The three ideas have similarities with each other, namely discussing the error structure formed in production frontier modeling. The model is expressed in the form of the following equation (Coelli *et al.*, 2005).

In international theory, this study highlights several relevant concepts. Adam Smith's theory (1776) in Cho (2003) explained that a country will increase in wealth if it is in line with the increase in skills and efficiency of the involvement of the country's workforce and population in the production process. Comparative advantage theory of Ricardo (1817) in Cho (2003), explaining that a country trades even though it does not have an absolute advantage, or in other words does not have an absolute disadvantage against other countries in the production of two goods trade can still be profitable if countries have absolute losses in the production of goods with smaller absolute losses. Theory Heckscher and Ohlin (1991) in Salvatore (2017) developing an economic model by stating the cause of the difference in productivity due to the difference in the proportion of labor, capital, and land factors owned by a country. The Heckscher-Ohlin theory is known as "The Proportional Factor Theory" where countries with relatively high production factors and low production costs will specialize production to export.

The most common measure of competitiveness used by previous studies is using the Revealed Comparative Advantage (RCA) calculation, which was first introduced by Ballasa (1965). The RCA method is able to measure the comparative advantage that a country has in terms of exports to similar

products that other countries are capable of producing. The RCA approach helps to compare a country's performance in international trade, so it can also be considered by policymakers.

Previous research has examined the palm oil industry and its derivative products such as CPO. Tandra *et al.* (2022), showing that vegetable fats and oils are able to have a positive and significant effect on competitiveness, GDP per capita and the application of RSPO have negative effects. Setyadewanta *et al.* (2016) stated that CPO commodities can be replaced with other vegetable oils such as soybean oil and sunflower. The study also states that the increase in the exchange rate is able to reduce the price of palm oil. More studies by Othman *et al.* (2021), stating that the tax provided by the EU is positively correlated with the competitiveness of CPO. Rosyadi *et al.* (2021) explained that the GDP of importing countries and the number of exports have a positive effect on competitiveness.

Research results by Islamiya *et al.* (2022) shows that the productivity of the CPO industry has declined in Indonesia. However, this decline tends to be smaller in mid-sized companies compared to large companies. Anam & Suhartini (2020) also evaluate the technical efficiency of the use of DEA, allocative, cost, and scale of palm oil companies in Indonesia. The findings show that some regions in Indonesia have low and efficient cost allocation. Nur *et al.* (2022) analyze the technical efficiency of palm oil exports and evaluate the export potential of Malaysia and Indonesia with the SFA approach. Indonesia shows a higher technical efficiency score than Malaysia. Malaysia and Indonesia have different market dominances with great export potential to countries such as China, India, Thailand, and the United States.

There are three previous studies that examined Indonesia's competitiveness as a sample, in the study Ramadhani & Santoso (2019) stated that Indonesia is more competitive in international trade than Malaysia. Indonesia's CPO export market is growing faster. Meanwhile, a study by Ali *et al.* (2019) shows that the competitiveness of Indonesian CPO exports in the United States market is higher than that of India. Furthermore, research by Fatma *et al.* (2019) shows that Indonesia has a strong competitive advantage over the United States, the Netherlands, Malaysia, China, and Singapore. According to him, competitiveness is greatly influenced by the openness of trade and the export value of competitors.

Several previous studies have used the 2SLS simultaneous equation model as a research method to analyze the simultaneous relationship between structure, efficiency, and competitiveness. The Simultaneous Equation Framework was used to study the relationship between structure, behavior, and performance in U.S. manufacturing in the 1980s and 1990s in research Delorme *et al.* (2002). The results show that the structure of the industry does not depend on the current performance of the industry. Second, little evidence has been found that industrial behavior is influenced by the

structure of the industry. Furthermore, the performance of the industry does not depend on the behavior of the industry, although it is sensitive to the structure of the industry. McCafferty & Bhuyan (2012) tested the relationship between concentration and market forces in the U.S. brewing industry using a contemporary simultaneous Structure-Behavior-Performance (SCP) approach. The analysis period is from 1980-2009. Using a modified SCP model, it was found that higher levels of concentration in the industry had led to higher levels of profitability as measured by the Lerner index.

2. Materials and methods

The purpose of this study is to examine the simultaneous influence between industrial concentration, technical efficiency, and competitiveness of the CPO industry in Indonesia. The data in this study uses a type of secondary data obtained from the publication of several institutions such as the Central Statistics Agency (BPS), UN Comtrade, and the International Monetary Fund. This study uses a simultaneous model approach from the Two Stage Least Squares (2SLS) type. The data used in this study includes parameters such as the number of companies, the area of oil palm land, global CPO prices, sunflower oil prices, and international trade data, including global CPO prices, the total value of Malaysian and Indonesian CPO exports, cooking oil prices, and policies in supporting CPO industry governance.

Table 1 - Variable Operational Definition

Variable	**Definition**	**Formula/Unit**	**Source**
Concentration Ratio of the Four Largest Companies (CR4) A measure of market concentration that calculates the combined market share of the four largest companies in a given industry.	Concentration calculations using CR4 are based on research by Boyle (1973). $CR_n = \sum^{n}_{i=1} X_i$ T_j Where: CR_n: Concentration Ratio for n largest	companies. X_i: Sales (or output) of the i-th year company in the industry. T_j: Total sales (or total output) of all companies in the industry j. Σ: Summing symbol, summing from the	1st company to the nth largest company. Central Statistics Agency of the Republic of Indonesia

Technical Efficiency is measured using the Stochastic Frontier Analysis (SFA) method

Competitiveness (RCA)
The econometric method is used to measure the technical efficiency of an organization or company by considering uncontrollable factors such as environmental

factors, government policies, and luck factors. The SFA calculation is based on the formula submitted by Meeusen & van den Broeck (1977) and Aigner *et al.* (1977), followed by the third article by Battese & Coelli (1992).

Competitiveness is the ability of companies, regions, countries, or between regions to increase income by utilizing productive and sustainable labor and other resources to face competition by maximizing the potential of their superior products (Porter, 1990). RCA calculations refer to UN Trade & Development (2024).

$$\ln Y_t = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + (V_i - U_i)$$

where:

$\ln Y_t$: The natural logarithm of the output (Y) at time t.
β_0: A constant or intercept in a production function. $\ln X_i$: Natural logarithms of the i input (e.g., labor, capital, raw materials). V_i: random error component that follows a symmetrical (usually normal) distribution.
U_i: component of technical inefficiencies, which is always a positive value.

$$RCA = \left(\frac{X_{ik}}{X_{im}}\right) / \left(\frac{X_{wk}}{X_{wm}}\right)$$

Where:
X_{ik}: Export of K Commodities from Country i.
X_{im}: Total exports of all commodities from country. X_{wk}: K Commodity Exports from all over the world (W).
X_{wm}: Total exports of all world Commodities.

Central Statistics Agency of the Republic of Indonesia

UN Trade

Roundtable on Sustainable Palm Oil
(RSPO)
RSPO is certified to promote sustainable palm oil production by developing and
promoting green, social and economic practices.
Policy rspo.org *9*

	market.	
International CPO Prices (PCPO)		
Packaged Cooking Oil (PCO) Prices	The price of Indonesian packaged cooking oil refers to the price of cooking oil packaged in ready to-use packaging and produced in Indonesia.	Rupiah (IDR) Central Statistics Agency of the Republic of Indonesia
Global Sunflower Oil Prices	The price of sunflower oil is measured in US dollars per ton, according to conventions commonly used in international trade.	US Dollars per Metric Ton International Monetary Fund
International CPO price refers to the price of CPO traded in the international	USD World Bank	

Export Value of Indonesian CPO (XCPO)	The value of Indonesia's CPO exports is the total value of all palm oil (CPO) exports carried out by Indonesia in a certain period of time. This value includes the selling price of CPO and its derivative products, minus export costs such as shipping costs, insurance, and export duties.	certain period of time. CPO Export Value = CPO Export Volume x CPO Export Price – Export Cost	Export Cost *10* UN Trade UN Trade
Malaysian CPO Export Value (EXM)	The value of Malaysia's CPO exports is the total value of all palm oil (CPO) exports carried out by Indonesia in a	CPO Export Value = CPO Export Volume x CPO Export Price –	

Land (LL)	The area of oil palm plantations includes agricultural land used to plant oil palm trees and produce oil palm fruits which are then processed into CPO.	Hectares	Central Statistics Agency of the Republic of Indonesia
Indonesian Industrial Solar Power (PSOLI) Prices	The price of diesel is measured in Indonesian currency units, such as Rupiah per liter or Rupiah per kilogram, according to the general unit used in industry.		and Mineral Resources of the Republic of Indonesia
Biodiesel (BD) Policy	The policy stipulates that the main raw material for biodiesel is CPO, which is produced from palm oil. Rp Ministry of Energy	Dummy	Ministry of Energy and Mineral Resources of the Republic of Indonesia

Source: Author's Compilation (2024).

According to Gujarati (1993), the simultaneous equation method is a method for solving a group of linear equations consisting of two or more variables. In this method, the equations are solved simultaneously and variable values are generated that satisfy all the equations in the system. There are two types of variables that are included in simultaneous equations: endogenous, that is, variables (whose values) are determined in the model; and predetermined, namely variables whose values are determined outside the model. Endogenous variables are considered stochastic, while predetermined variables are needed as non-stochastic.

2.1. *Identify Simultaneous Equation Systems*

Model identification is needed to determine the estimation method to be carried out. The identification will show whether or not it is possible to obtain structural parameters, a system of simultaneous equations from reduced form parameters. The identification of the simultaneous equation model in this investigation is as follows:

CR4 = f (RCA, E, PCPO, RSPO, PCO, BD, XCPO)
E = f (CR4, LL, BD, PSOLI)
RCA = f (CR4, E, PCPO, PSFO, RSPO, BD, EXM)

$$CR4_t = \alpha_0 + \alpha_1 E_t + \alpha_2 RCA_t + \alpha_3 RSPO_t + \alpha PCO_t + \alpha_5 PCO_t + \alpha_6 BD_t + \alpha_7 XCPO_t + \varepsilon_{1t} \quad (1)$$

$$E_t = \beta_0 + \beta_1 CR4_t + \beta_2 LL_t + \beta_3 BD_t + \beta_4 PSOLI_t + \varepsilon_{2t} \quad (2)$$

$$RCA_t = \gamma_0 + \gamma_1 CR4_t + \gamma_2 E_t + \gamma_3 PCPO_t + \gamma_4 PCPO_t + \gamma_5 RSPO_t + \gamma_6 BD_t + \gamma_7 XM_t + \varepsilon_{3t} \quad (3)$$

Where:
Formula (1) is the equation model for Concentration; Formula (2) is the equation model for efficiency, and Formula (3) is the model for competitiveness measured using RCA. RCA stands for Competitiveness; CR4 stands for Industrial Concentration Ratio; E is Technical Efficiency; PCPO shows Global CPO Prices; PSFO refers to the global Sunflower Oil Price; RSPO is the RSPO Dummy; BD represents the Biodiesel Policy Dummy; EXM is Malaysia's CPO Export; XCPO represents Indonesian CPO Exports; PSOLI is the Price of the Solar Power Industry in Indonesia; PCO is the Price of Cooking Oil; LL represents the Area of Oil Palm Land in Indonesia; and ε represent the term error.

Endogenous Variables = RCA, E, CR4.
Exogenous Variables = PCPO, PSFO, RSPO, BD, EXM, PCO, XCPO, PSOLI, LL.

Table 2 - Order identification results

Equation K k M Information Identification CR4 9 5 3 K – k > m – 1 Overidentified E 9 3 2 K – k > m – 1 Overidentified RCA 9 5 3 K – k > m – 1 Overidentified

Source: Data processed (2023).

Based on Table 2, it shows that the three structural models are overidentified equations so that they can be continued by estimating using simultaneous equations using the Two-stage Least Squares (2SLS) method.

In addition, the rank condition of identification in econometric analysis is a condition in which a simultaneous linear regression model can be identified or estimated consistently.

Table 3 - Rank Condition

Type Con Stant	Endogenous Variable Coefficients	Exogenous Variable Coefficient (Predetermine)

CR4 E RCA PCPO PSFO RSPO BD EXM PCO LL XCPO PSOLI 1 $-\alpha_0$ 1 $-\alpha_1$ $-\alpha_2$ $-\alpha_3$ 0 $-\alpha_4$ $-\gamma_6$ 0 $-\alpha_5$ 0 $-\alpha_7$ 0 2 $-\beta_0$ $-\beta_1$ 1 0 0 0 0 $-\beta_3$ 0 0 $-\beta_2$ 0 $-\beta_4$ 3 $-\gamma_0$ $-\gamma_1$ $-\gamma_2$ 1 γ_3 $-\gamma_4$ $-\gamma_5$ $-\gamma_6$ $-\gamma_7$ 0 0 0 0

Source: Data processed (2023).

In the equation model (1) does not involve PSFO, EXM and LL and PSOL1, it is obtained that at least a matrix A of the order 2x2 has a determinant not equal to zero, namely:

$$|A| = \begin{vmatrix} 0 & -\gamma_4 \\ -\beta_2 & 0 \end{vmatrix} \neq 0$$

In model (2) not involving RCA, PCPO, RSPO, EXM, PCO and XCPO, it is obtained that at least a matrix B of order 2x2 has a determinant not equal to zero, namely:

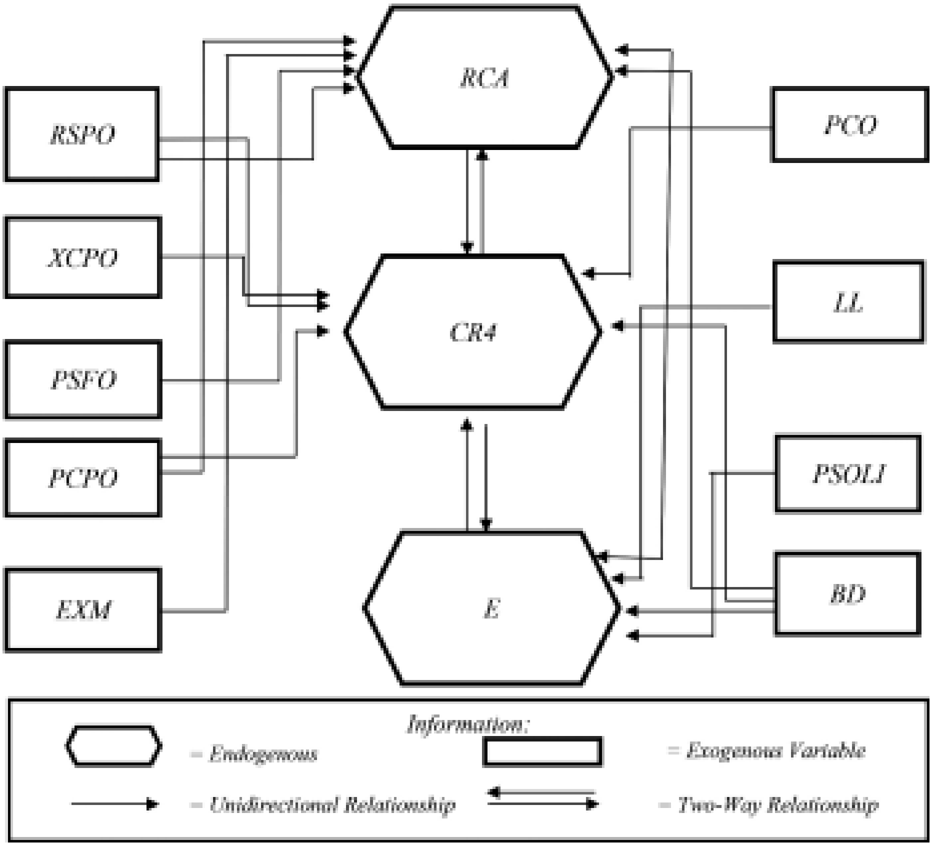
$$|B| = \begin{vmatrix} \alpha_2 & \\ 1 & \\ -\alpha_3 & \\ - & \gamma_3 \end{vmatrix} \neq 0$$

In model (3) not involving PCO, LL, XCPO, and PSOLI, at least a matrix C of order 2x2 is obtained with a determinant not equal to zero, namely:

$$|C| = \begin{vmatrix} 0 & -\beta_2 - \alpha_7 \\ & 0 \end{vmatrix} \neq 0$$

Thus models (1), (2) and (3) meet the order conditions so that they can be estimated by the Two-Stage Least Squares Method (2SLS).

Figure 3 - Framework for RCA, CR4, and E Simultaneous Equations along with other Exogenous Variables



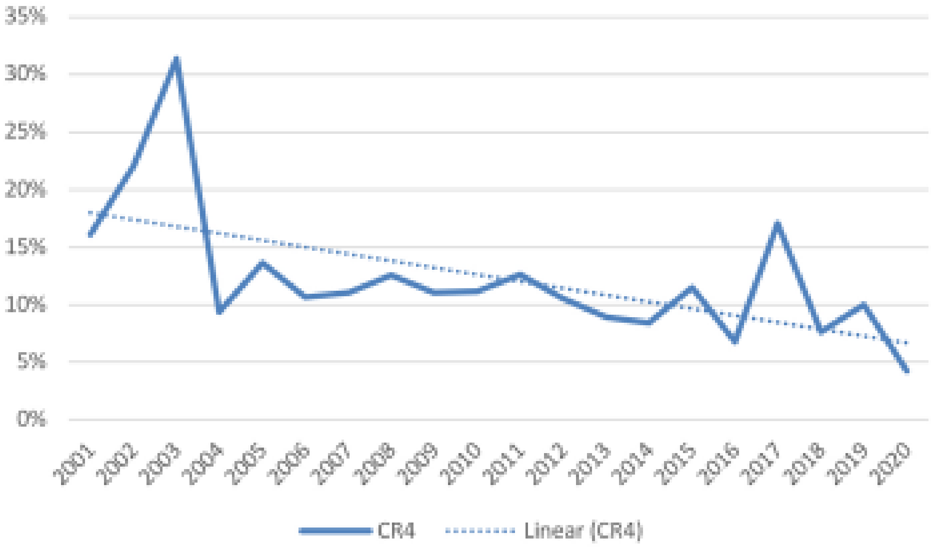
3. Results

3.1. *Endogenous Variable Motion Analysis*

The measurement of the concentration of the CPO industry in Indonesia is carried out through the Four Firm Concentration Ratio (CR4), an analysis method that measures the contribution of the four largest companies to the total industrial output. With an average CR4 value of 12.90 percent in the 2001-2020 period, it can be concluded that the CPO industry in Indonesia has a significant dominance, but still shows a very competitive market tendency towards oligopoly. The figure of 12.90 percent reflects the average

market share held by the four largest companies, giving the impression that the sector tends to create a competitive business environment, but with a tendency to have a few big players dominating.

Figure 4 - Concentration of Indonesian CPO Industry



Source: BPS Indonesia, Indonesian Industrial Agency, UN Comtrade (2024).

In the initial period (2001-2003), a significant increase in the concentration of the palm oil industry (CPO) was observed, peaking in 2003 with a Four Firm Concentration Ratio (CR4) of 31.37 percent. In 2003, there was an increase in export volume by 85.46 percent, reaching a total of 45,160,000 metric tons compared to the previous year. This increase is due to the growth of palm oil production. At this rate, large companies tend to have a significant impact on the total industrial production, reflecting their dominance in the market. However, the dynamics of the industry changed drastically in 2004, where there was a sharp decline of 9.34 percent. This decline indicates the industry's sensitivity to certain external factors. One of the main contributing factors is regulatory changes or fluctuations in global market conditions. Various changes in government and global policies related to CPO and fluctuations in international market demand are the main triggers for the decline in market concentration.

The decline in the concentration of the CPO industry in 2020 was also caused by the spread of the COVID-19 pandemic virus (Hafiz *et al.*, 2021).

Therefore, there are supply chain disruptions, changes in consumer lifestyles, a decrease in purchasing power and economic activity. Global CPO prices fell 6.32 percent due to the global oil trade war, which had an impact on industrial concentration. In addition, in Indonesia there is a shortage of cooking oil, so the price has soared.

Based on the category, if the technical efficiency measured using SFA is greater than 0.70, then it is included in the efficient category (cut-off value) (Darmawan, 2016; Abdul *et al.*, 2022; Hadiguna & Tjahjono, 2017). Based on Figure 5, the results of the calculation of technical efficiency show an average of 0.99. This means that the Indonesian CPO industry has managed to achieve very high technical efficiency by utilizing production inputs efficiently and effectively in producing maximum output.

Figure 5 - Results of Technical Efficiency of Indonesia's CPO Industry

1,00005

1,00000

0,99995

0,99990

0,99985

(%)

0,99980 0,99975 0,99970 0,99965 0,99960 0,99955

2001

2002

2003

2004

2005

2006

2007

2008

2009

2010

2011

2012

2013

2014

2015

2016

2017

2018

2019

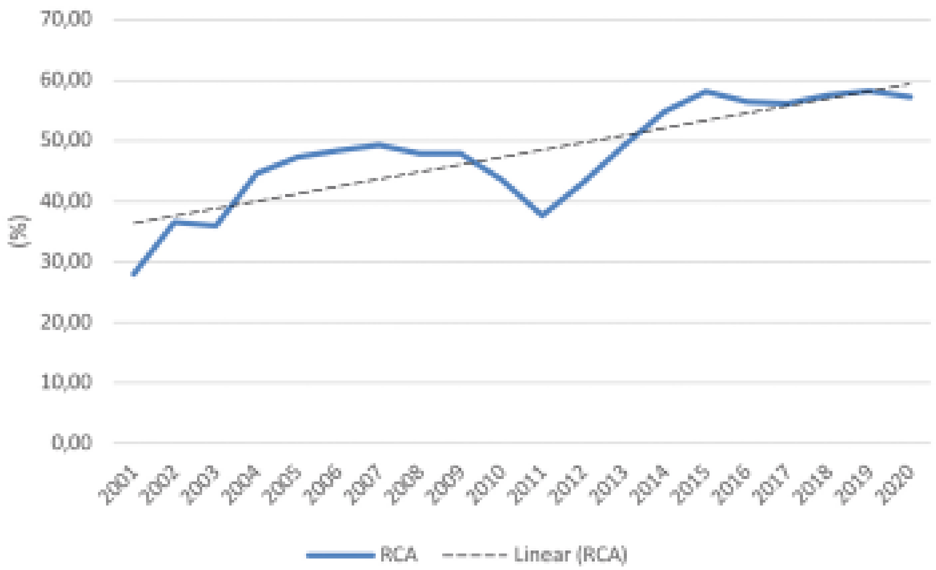
2020

Source: Central Statistics Agency of the Republic of Indonesia (2020).

Investment in more modern technology can strengthen the competitiveness of Indonesia's CPO industry (Harahap *et al.*, 2019). Modern technology makes the production process more efficient, from land cultivation to cultivation processes. For example, automation and the use of IoT (internet of things) technology in plantation monitoring can increase crop yields and reduce production costs. In addition, the existence of global criticism

to reduce environmental impact has also made CPO companies apply technology that supports sustainability, Indonesian CPO products are able to be more in demand in markets that care about environmental issues such as the EU.

Figure 6 - Competitiveness of Indonesia's CPO Industry



Source: UN Comtrade, 2001-2020.

The results of the calculation using the RCA method stated that Indonesia has a comparative advantage in CPO exports. The average RCA rate is about 47.88. According to theory, if the RCA number is more than 1, it means that Indonesia is quite dominating the global market. Indonesia is one of the largest palm oil producers in the world, with a very large area of oil palm plantations. Indonesia also has extensive CPO exports, especially to countries such as India, China, and European Union countries. The high RCA shows that Indonesia is able to meet the demand of the international market and compete with other vegetable oil products such as sunflower oil and soybean.

3.2. *Movement Analysis of Exogenous Variables*

The land area in Indonesia is always increasing, reaching 14 million hectares in 2020. This increase in palm oil area has led to an increase in

CPO production. This allows Indonesia to maintain its position as the first largest exporter to compete with Malaysia. CPO exports contribute greatly to state revenue (Pratama *et al.*, 2023). Indonesia is a large country with abundant resources, so it is expected to always be able to meet the demand of the global market (Hidayat *et al.*, 2023). However, the growth of oil palm land also poses challenges related to environmental and social sustainability, especially sanctions imposed by the world. Components of this challenge include deforestation, habitat degradation, and land conflicts.

The price of packaged cooking oil tends to increase consistently. First, the demand for cooking oil continues to increase in line with population growth and lifestyle changes which tend to lead to an increase in fried food consumption. Second, fluctuations in world crude oil prices have a direct impact on cooking oil prices (Sun *et al.*, 2023). For example, when world crude oil prices fall, cooking oil producers usually reduce production to avoid losses, which in turn can result in price increases. This occurred in late 2008 and early 2009, when world crude oil prices fell significantly due to the global financial crisis and falling demand from the largest consumer countries. In 2020, there was a significant increase in cooking oil prices in Indonesia, which then led to a shortage. Some of the factors that cause this condition are supply disruptions due to the COVID-19 pandemic which affects the cooking oil supply chain from production to distribution. However, in the long term, the general trend suggests that the price of packaged cooking oil tends to increase in line with factors such as inflation, production costs, and increasing demand.

Apart from Indonesia, Malaysia is the main competitor in the CPO production industry at the global level (Schouten *et al.*, 2023). As the countries with the largest CPO production in the world, the two have long competed to dominate the international market. Over the years, Malaysia has taken a leading position as a leading CPO producer. However, as time went on, its position gradually declined, while Indonesia emerged as the main competitor that managed to take over the dominant role in the industry. In observing the dynamics of the industry, it can be seen that both countries experienced a significant decline in CPO exports in 2009. However, the decline turned out to be sharper for Malaysia compared to Indonesia. Indonesia's CPO exports fell 19.37 percent, while Malaysia fell 37.58 percent in the same year. Ahead of 2021, projections show that Indonesia will become the world's largest CPO exporter, accounting for around 58 percent of the world's total CPO exports, while Malaysia only has a proportion of around 31 percent. This signals a shift in the landscape of the CPO industry, where Indonesia has succeeded in asserting its dominance and replacing Malaysia as the main exporter of CPO at the global level.

World CPO prices have experienced significant fluctuations over the past two decades, with upward and downward trends reflecting global market dynamics and fundamental factors in the palm oil industry. In that period, there was a considerable increase in CPO prices, starting from 2001 with a price of around US$ 287.4583 per metric ton, reaching the highest peak in 2011 with a price of US$ 1193.3700 per metric ton, then declining sharply in the following years, reaching a low point in 2015 at a price of US$ 663.3908 per metric ton. These price fluctuations are influenced by a variety of factors including global demand, production, changes in trade policy, and external factors such as weather conditions. In years where CPO prices are rising, this is often attributed to increased demand from key markets such as China and India, as well as factors such as changes in energy and public health policies that have led to increased biodiesel use. In 2011, data from Bloomberg showed that CPO prices on the Malaysian Derivatives Exchange and the Indonesia Commodity and Derivatives Exchange increased. This increase is triggered by the tightening of rules on the import of vegetable oil from China as well as the possibility of a CPO export tax war between Indonesia and Malaysia, which could lead to a decrease in supply and an increase in prices. However, when CPO prices fall, this can be caused by various factors, including increased global palm oil production, competition with other vegetable oils, and global economic uncertainty.

CPO is the main commodity with the highest number of demands in the world in terms of vegetable oils (Nurcahyani *et al.*, 2018). So, when there is a price change in CPO, it will have an impact on market behavior that triggers changes in other vegetable oil substitution patterns. During the research year, CPO prices fluctuated greatly. In 2009, when the global financial crisis occurred, it led to severe fluctuations in world vegetable oil prices. However, in that year, Indonesian and Malaysian CPO production increased significantly. The increase in production has an impact on suppressing world CPO prices. The implementation of the biofuel policy by the European Union in 2009 also affected the dynamics of the CPO market.

The price of industrial diesel in Indonesia is very uncertain because it is closely related to subsidies. One of the factors that affect the price of industrial diesel is the fluctuation of crude oil prices in the global market, because diesel is a derivative product of petroleum. If the price of crude oil increases, then it tends that the price of industrial diesel will also rise, and vice versa.

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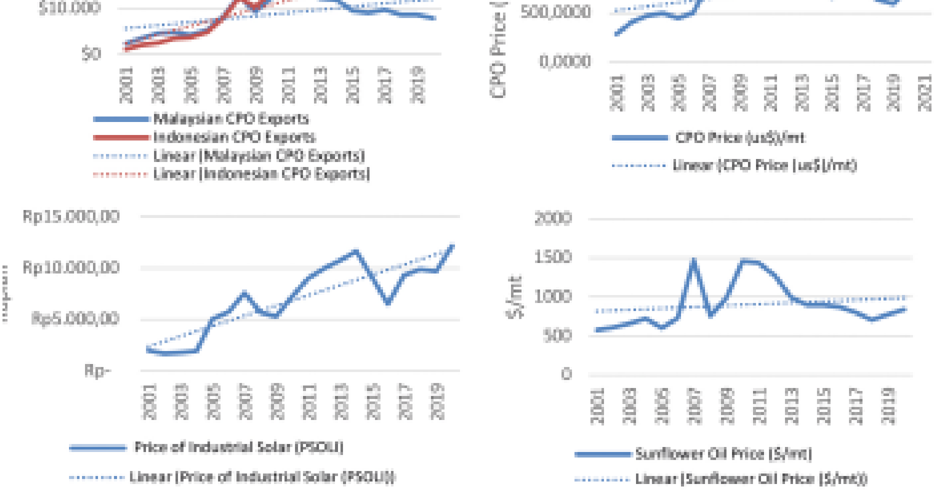

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Source: Central Statistics Agency of the Republic of Indonesia, Indonesian Industry Office, UN Comtrade, 2001-2020.

In the Indonesian context, fluctuations in industrial solar prices can also be influenced by domestic factors such as government policies related to energy prices and subsidies, infrastructure conditions, and demand and supply in the local market. The increase in industrial solar power in Indonesia was the highest in 2005, growing by 61.39 percent from the previous year. In 2005, there was a massive reduction in subsidies for oil, including industrial diesel, but with a lower rate of rejection, due to the introduction of a social

assistance compensation program for low-income households (Ichsan *et al.*, 2022). In April 2016 the government froze domestic gasoline and diesel prices even though international prices began to soar, as a result of which industrial diesel prices fell significantly by -39.37 percent (Chelminski, 2018).

One of the vegetable oils that is a competitor to CPO is sunflower oil (Parsons *et al.*, 2020). Pricing competition between vegetable oil commodities has triggered global trade conflicts among vegetable oils, affecting the competitiveness of the CPO industry (Hamulczuk *et al.*, 2021). The influence of competitor vegetable oil prices on CPO competitiveness has been studied by Inovia (2020); Gan and Li (2014). The price of sunflower oil in the period 2001-2020 has experienced considerable fluctuations. 2007 was the year when global demand for vegetable oils, including sunflower oil, increased. This is due to economic growth in developing countries, especially China and India, which has led to higher consumption of vegetable oils. This high demand makes the price of sunflower oil rise. Since 2010 the world price of sunflower oil has been declining. The arrival of more affordable sunflower oil from Russia and Ukraine has led to a decline in palm oil prices. Both major producers are taking advantage of the depreciation of their currencies to increase their market share. As a result, sunflower oil, which previously had a higher price, is now more economical than soybean oil and only slightly more expensive than palm oil (The Economic Times, 2024). Monitoring vegetable oil price trends and adjusting raw material procurement strategies are important for food industry practitioners to maintain cost efficiency and competitiveness of their products in the market. Consumers who are increasingly concerned about sustainability and environmental impact may prefer products that use vegetable oils with a lower carbon footprint. Therefore, food industry practitioners need to consider sustainability aspects in the selection of raw materials to meet the demand of increasingly environmentally conscious consumers.

3.3. *Descriptive Statistics*

Table 4 shows the range of values for each variable studied, showing significant variation between the highest and lowest values. As an illustration, the RCA variable shows an average of around 47.89, while the BD variable records an average of around 0.25. The results of slope and curtosis data show variations in the characteristics of variable distribution. For example, the CR4 variable has a positive slope (1.65) which indicates a right-skewed distribution, while the PCPO (CPO price) has a negative slope (–0.58) indicating a left-skewed distribution. Other variables tend to be more symmetrical. In addition, the kurtosis values of CR4 (6.07) and PCPO (2.58) above 3 showed significant pointedness in the data distribution, signaling a thicker tail. These results need to be considered in further statistical analysis.

Table 4 - Descriptive Statistics

CR4 E RCA PCPO PSFO RSPO BD EXM PCO XCPO PSOLI LL Mean 0.13 0.99 47.89 6.62 6.76
0.65 0.25 22.80 9.19 22.89 8.70 15.96 Median 0.11 0.99 48.15 6.62 6.71 1.00 0.00 22.94 9.46 23.35 8.912
15.98 Maximum 0.31 1.00 58.24 7.08 7.29 1.00 1.00 23.58 9.65 23.64 9.40 16.49 Minimum 0.04 0.99
27.98 6.11 6.36 0.00 0.00 21.57 8.59 20.80 7.44 15.36 Std. Dev. 0.06 0.00 8.61 0.27 0.29 0.49 0.44 0.53
0.41 0.87 0.66 0.38 Slope 1.65 0.41 –0.58 –0.10 0.60 –0.69 1.15 –0.72 –0.42 –1.06 –0.99 –0.05 Curtosis
6.07 1.17 2.58 2.28 2.33 1.39 2.33 2.72 1.39 2.81 2.57 1.71

Jarque Bera 3.42 1.39
16.92 3.35 1.29 0.47 1.59 3.46 4.81 1.80 2.77 3.80

Probability 0.00 0.19 0.53 0.79 0.45 0.18 0.09 0.41 0.25 0.15 0.18 0.50
Number of Sq. Dev. 14.37 8.21 2.78
0.068 3.23E– 1409.6 1.41 1.63 4.55 3.75 5.32 3.28

Source: EViews Release (2023).

3.4. *Simultaneity Test*

The importance of using simultaneity testing is to ensure that in a concentration equation model, all components are arranged simultaneously. Possible simultaneity problems can be identified by examining the relationship between residual effects and endogenous effects.

Table 5 - Simultaneity Test

Variable Coefficient PMS errors. t-Statistics C 49.1577*** 7.7349 6.3553 EF
–48.8295*** 7.7476 –6.3025 RCAF –0.0046*** 0.0003 –13.0180 error
1.3125*** 0.0388 33.8503 C 49.1577*** 7.7349 6.3553 CR4F2 –48.8295***
7.7476 –6.3025 error –0.0046*** 0.0003 –13.0180 C 3085.95*** 4577.504
6.7403 CR4F –73.3592*** 9.2770 –7.9076 EF –3080.66*** 4576.612 –6.7302
error 1.5888*** 0.4318 3.6799

Note: *** represents statistical significance at 1 percent.
Source: EViews Output (2023).

Table 5 shows the importance of t-error tests for CR4, EF, and RCAF models. This signifies that (E) and (RCA) collectively affect the concentration variable (CR4). Model E produced noteworthy results, and the same was true for the endogenous variable CR4F. The interpretation shows a reciprocal influence, suggesting that the concentration variable (CR4) also together impacts the efficiency variable (E). The RCA model also produced significant results, covering all endogenous variables CR4F and EF, showing the co-influence of concentration (CR4) and efficiency (E) variables on competitiveness variables (RCA).

3.5. *Exogeneity Test*

The application of the Hausman test was used to evaluate whether the variables in the simultaneous equations of the CR4, E, and RCA models could be classified as exogenous or endogenous variables.

Table 6 - Exogeneity Test Results

Model	F-stats
Model 1 CR4F	7.9559***
Model 2 EF	4103.467***
Model 3 RCAF	10.6227***

Note: *** represents statistical significance at 1%.
Source: EViews Release (2023).

Based on the results of the exogeneity test of the CR4F model (Table 6), the F test was obtained at 7.9559 with a probability of 0.001, which is less than $\alpha = 0.05$. That is, rejecting the null hypothesis (Ho), EF and RCAF are variables that influence each other in the equation system simultaneously. In the EF model, the F test is 4103.467 with a probability of 0.0000 or less than $\alpha = 0.05$. This means rejecting the null hypothesis (Ho), CR4F is a mutually influencing variable in a system of simultaneous equations. Meanwhile, in the RCAF model, the F test value is 10.6227 with a probability of 0.0002, which is also smaller than $\alpha = 0.05$. This means that CR4F and EF are mutually influencing variables in a system of simultaneous equations.

3.6. *Classical Assumption Test*

3.6.1. Normality Test

The normality test was carried out to find out whether the residuals obtained in each model were normally distributed or not.

Table 7 - Normality Test

Type JB Probability Model 1 (CR4) 2.109756 0.348235 Model 2 (E) 3.333333 0.188876 Model 3 (RCA) 0.046455 0.977040

Source: Data processed (2023).

Based on the results of the analysis, the Probability Jarque Bera for model 1, model 2, and model 3 was 0.348235, 0.188876, 0.977040 > α (0.05), respectively, so that H_0 was not rejected (accepted). This means that the residuals follow the normal distribution and the assumption of normality is met.

3.6.2. Autocorrelation Test

The autocorrelation test aims to determine whether or not there is a correlation between the current observation time (t) and the previous observation time (t – 1) that affects each other. A method that can be used to test autocorrelation is the Breusch-Godfrey Serial Correlation LM test.

Table 8 - Breusch-Godfrey Test Serial Correlation LM (Autocorrelation)

Type Obs*R-squared Prob. Chi-Square Model 1 (CR4) 2.503542 0.2860 Model 2 (E) 3.600939 0.1652 Model 3 (RCA) 5.792471 0.0552

Source: Data processed, Eviews Output (2023).

The results of the autocorrelation test in Table 8 show the Prob value. The Chi-Square for model 1, model 2, and model 3 is 0.2860, 0.1652, and 0.0552 > α (0.05), respectively, so H_0 is not rejected (accepted). This means that there is no autocorrelation in each regression model.

3.6.3. Heteroscedasticity Test

The heteroscedasticity test aims to determine whether there is a variant inequality in the residual regression model. The method that can be used is the Breusch-Pagan-Godfrey test with the following hypothesis.

Table 9 - Breusch-Pagan-Godfrey Test (Heteroskedasticity)

Type F-Statistic Prob. F Model 1 (CR4) 0.640738 0.7156 Model 2 (E) 1.054218 0.4127 Model 3 (RCA) 1.107990 0.4173

Source: Data processed (2023).

The results of the heteroscedasticity test in the Table 9, show that the Prob F values for model 1, model 2, and model 3 are 0.7156, 0.4127, and 0.4173 > α (0.05), respectively, so that H_0 is not rejected (accepted). This means that there is no heteroscedasticity or variance in each regression model that is the same or fixed (homoscedasticity).

3.7. *Two-Stage Least Squared Result (2SLS)*

Table 10 - 2SLS Results

Pattern Variable Coefficient T Statistics Prob.

R2

F-stats

Model 1 (CR4)

C 55.1979* 2.0349 0.0000 0.9999 E

–54.8716* –2.0281
RCA 0.0026*** 75.2942
RSPO –0.0310*** –6.0350
PCPO 0.0345*** 9.6134
PCO 0.2070*** 11.4368
BD 0.0156 1.0209
XCPO –0.0880*** –145.569

Model 2 (E) C 0.9963*** 1230.364 0.0005 0.6713 CR4 –0.0010** –2.2104
LL 0.0004*** 5.4348
BD –0.0001*** –3.5937
PSOLI –0.0004*** –6.7099

Model 3 (RCA)
C –10233.6* –2.0727 0.0000 0.9952
CR4 29.3454** 2.2664
E 9953.339* 2.0245
PCPO –24.1508*** –6.5609
PSFO –10.7052** –2.3641
RSPO –5.0142** –2.8066
BD 7.6721*** 8.2121
EXM 24.5478*** 6.6190

Note: ***, **, and * represent statistical significance at 1%, 5%, and 10%, respectively.
Source: EViews Output (2023).

3.8. *F-Stats Test*

Table 11 - F-Stats Test

F-stats

Model 1 CR4 13058.6*** Model 2 E 9.2848*** Model 3 RCA 359.2859***

Note: *** represents statistical significance at 1%.
Source: EViews Release (2023).

Based on Table 11, exogenous variables together have a significant impact on equation model 1 (CR4), equation model 2 (E), and equation model 3 (RCA).

3.9. *Industrial Concentration Analysis (Model 1)*

The results show that technical efficiency is negatively and significantly correlated with CR4 in the palm oil industry (CPO) in Indonesia. High technical efficiency is associated with lower production costs and higher profits, thus allowing the company to dominate the market by reducing the number of competitors. This is in line with research conducted by Manjunatha *et al.* (2013); Hidayat *et al.* (2024). In addition, more efficient companies can sell their products at more competitive prices, which further strengthens their dominance in the market. A high CR4 indicates that the industry is dominated by a handful of large companies, reflecting the increasing market concentration. Further, these findings suggest that high competitiveness in the industry can increase market concentration, as large companies tend to leverage their efficiency to expand market share. However, this competitive advantage can also create a more exclusive market environment, where small businesses find it difficult to compete (Crouzet & Eberly, 2019).

Policies at RSPO lower the level of industrial concentration. This certification aims to improve sustainable practices in the CPO Industry. The implementation of such certification increases the costs incurred by the Company (Saswattecha *et al.*, 2015). This policy can be an obstacle for companies that want to enter this industry. The RSPO policy was officially implemented in 2008. Meanwhile, the Government of Indonesia supports the RPPO through the Indonesian Sustainable Palm Oil (ISPO) national certification scheme launched in 2011. When compared to other sustainability initiatives, such as the Forest Stewardship Council (FSC) for the forestry sector or the Rainforest Alliance certification for agriculture, RSPO and ISPO have unique characteristics (Rafael *et al.*, 2018; Munasinghe *et al.*, 2021). The RSPO is more targeted at the international market and is globally recognized as the gold standard for palm oil sustainability, while the ISPO is more focused on domestic legal compliance and strengthening the role of governments in industry supervision. However, several studies show that the main challenge of ISPO is the lack of recognition in the global market compared to RSPO, thus affecting the competitiveness of Indonesian palm oil products at the international level (Hidayat *et al.*, 2018). Along with the growth of the biodiesel industry, this policy is also closely related to efforts to reduce carbon emissions through sustainable fuels. The implementation

of sustainability standards, both under RSPO and ISPO, can help ensure that feedstocks for biodiesel are produced responsibly.

The European Union is likely to continue to introduce policies that prioritize environmental sustainability and deforestation reduction in the palm oil supply chain. Programs such as RED II (Renewable Energy Directive II) will further tighten the requirements for products imported into the EU, requiring palm oil producers from Indonesia and Malaysia to meet higher sustainability standards. In the future, the EU could impose stricter policies, forcing palm oil-producing countries to increase their production methods, as reflected in the increasing focus on deforestation and Carbon Emission Reduction (Ostfeld & Reiner, 2024). The EU will be very careful in paying close attention to collaborative projects with major palm oil producing countries, such as Indonesia and Malaysia, to support sustainability in the palm oil sector. Projects such as the USAID Palm Oil Smallholder Support Projects in Liberia can serve as a model for broader initiatives in other palm oil-producing countries, with the goal of increasing smallholder incomes while reducing deforestation (Mai, 2024). Through this cooperation, the EU can provide solutions such as green agricultural technology, access to credit, and training of farmers on more efficient and sustainable agricultural practices.

Palm oil is the most widely used vegetable oil for cooking, food processing, cosmetics, oleochemicals and fuels (Oosterveer, 2015). The EU's stricter policy on palm oil imports could affect the supply of raw materials for the food industry, causing an increase in raw material prices and affecting the production costs and selling prices of food products. Additionally, changing regulations and consumer preferences are opening up opportunities for the food industry to innovate by using more sustainable alternative raw materials, such as other environmentally friendly vegetable oils, or developing products with sustainability claims to appeal to specific market segments. Food practitioners need to monitor these changes to adjust their raw material procurement strategies and meet consumer demand that is increasingly concerned about sustainability and environmental impact.

In addition, the increase in CPO prices is able to increase industrial concentration. The increase in CPO prices has the potential to increase profitability and a more competitive position (Shahida *et al.*, 2018). The increase in CPO prices tends to encourage the improvement of the Company's operational efficiency by investing in more modern and sustainable technology. On the other hand, the influence of packaged oil prices has a positive and significant effect on the concentration of the CPO industry (Dey *et al.*, 2021). Biodiesel policy has a positive but insignificant effect on the concentration of the CPO industry, in line with research (Kumar *et al.*, 2013). The biodiesel policy has no effect because the implementation is still relatively new.

3.10. *Efficiency Analysis (Model 2)*

Based on the findings in model 2 (efficiency), the industrial concentration measured by CR4 has a negative and significant influence on technical efficiency. Large companies concentrated in the four dominant players in Indonesia's CPO industry have significant market power (Destiarni *et al.*, 2021). This concentration has a detrimental impact on technical efficiency because large companies tend to hinder healthy competition in the CPO industry market. In a market dominated by a few large companies, the limited number of potential competitors reduces the pressure to innovate and improve technical efficiency. This happens because large companies are more focused on maintaining market share than aggressively competing, which ultimately lowers the incentive for more efficient technological innovation. Instead, these companies often rely on existing and proven technologies, which lack the drive for efficiency in the production process.

This dynamic demonstrates the need for policies that can balance the market structure by encouraging healthy competition and innovation. For example, regulatory frameworks can mandate or encourage investment in research and development and facilitate technology sharing initiatives that can improve efficiency across industries.

In addition, the land area has a positive and significant influence on technical efficiency. The positive relationship between land area and industrial efficiency highlights the importance of this factor in improving the company's operational performance. Research by Uckert *et al.* (2015) supports these findings, where large land holdings directly increase production capacity and enable economies of scale to be achieved. Companies with large plots of land have greater opportunities to optimize their agricultural practices, such as the application of data-driven fertilization, proper irrigation, and more effective pest and disease management. These measures significantly increase the production of fresh fruit bunches (FFB) per hectare and overall efficiency.

To harness this potential, policies that support equitable land allocation and better access to advanced agricultural technology are needed. Programs that provide land management training and promote sustainable agricultural practices can help small businesses improve their production capacity and efficiency. The integration of these measures into broader sustainability frameworks, such as RSPO and ISPO certifications, can also align industry practices with national and global goals for sustainable palm oil production.

The biodiesel policy has a negative and significant impact on the technical efficiency of Indonesia's CPO industry. The B30 Mandatory Program will be implemented simultaneously throughout Indonesia starting January 1, 2020. Indonesia is also recorded as the first country to implement B30 in the world.

Biodiesel policies usually increase the demand for CPO as the main raw material for biodiesel production (Kinseng *et al.*, 2023). The biodiesel policy can cause fluctuations in CPO prices, as the market must meet the needs of food and energy consumption at the same time. In producing biodiesel from CPO, different processing technologies are needed compared to CPO processing for food products. This means forcing companies to invest in new technologies and infrastructure specifically for biodiesel production. The comparison with other countries' policies also highlights Indonesia's position as a pioneer in the implementation of 30% biodiesel-based blend-based fuels. Brazil, for example, despite being known for its successful biodiesel program, has not implemented a blending level as high as Indonesia. The Brazilian biodiesel market faces different periods, from an initial non-mandatory blend of 2% to an actual blend of 13% in diesel (Rodrigues, 2021). However, Brazil takes a different approach by utilizing more varied raw materials such as soybeans and sugar, which reduces pressure on one particular commodity. Meanwhile, in Thailand, Crude Palm Oil (CPO) is produced from FFB (Fresh Fruit) which is then processed into pure biodiesel (B100). The mixing rate of biodiesel is called B2, B3, B5, and B7, when mixed with fossil diesel by 2%, 3%, 5%, and 7%, respectively (Nupueng *et al.*, 2018).

The price of diesel has a negative and significant effect on the technical efficiency of the CPO industry. The transportation of FFB from plantations to processing plants is highly dependent on vehicles that use diesel. The increase in diesel prices increases transportation costs. The use of mechanical equipment such as tractors, excavators, and harvesting machines also relies heavily on diesel. In CPO plants, diesel is widely used to drive generators and machines needed for the palm oil extraction process. When the price of diesel rises, energy costs increase so that it has a direct impact on technical efficiency because the cost per unit of production increases (Procházka & Hönig, 2018). Companies can't quickly switch to more efficient energy sources, so they continue to incur higher energy costs.

3.11. *Competitiveness Analysis (Model 3)*

In the third model of simultaneous equations that analyze the factors affecting competitiveness, the results show that industrial concentration has a positive and significant influence on competitiveness. These findings are in line with research Maier (2013) which shows that industrial concentration allows large companies to achieve production efficiency, enjoy economies of scale, as well as invest in innovation. These advantages ultimately increase the profitability and quality of the CPO products produced. Concentrated firms are also able to stabilize prices and reduce unwanted price volatility,

both for producers and consumers. The four largest companies that dominate the industry have greater bargaining power and strong influence in regulating market conditions, especially in market pricing. This strong bargaining position also applies in negotiations with suppliers and buyers, providing an additional competitive advantage. Thus, these advantages strengthen the position of the Indonesian CPO industry in international trade, emphasizing the important role of industry concentration in driving market efficiency and competitiveness.

Furthermore, technical efficiency has a positive and significant relationship in influencing the competitiveness of the Indonesian CPO industry. More technically efficient companies can produce more CPO by using fewer resources, such as labor and raw materials. This efficiency contributes to a decrease in production costs, allowing the company to offer more competitive selling prices of CPO in the international market. These lower prices attract buyers from major export markets, such as China, India, and Europe, thus strengthening Indonesia's position in global trade. These findings are consistent with research Islamiya *et al.* (2022) and Kadarusman and Herabadi (2018). An efficient production process not only lowers costs but also improves product consistency and quality through better resource management and quality control. High-quality and reliable products help improve the reputation of the Indonesian CPO industry in the global market, creating a sustainable competitive cycle driven by efficiency and quality.

CPO prices have a positive and significant influence on the competitiveness of Indonesia's CPO industry. These results are supported by the findings Rifin *et al.* (2020); Anyamvu *et al.* (2005); Yanita *et al.* (2020); and Setyadewanta *et al.* (2016). When CPO prices rise, companies in the CPO industry can earn large revenues making it possible to invest more in technology development, productivity improvement, and product quality improvement. Higher prices will increase profits from exports. Higher CPO prices provide incentives for companies to invest in the development of downstream products from CPO, such as cooking oil, biodiesel, and other derivative products.

Lower sunflower oil prices can increase the competitiveness of the palm oil (CPO) industry globally. Sunflower oil and palm oil are two vegetable oils that are often used as substitutes for each other. When the price of sunflower oil falls, consumers and producers tend to choose sunflower oil as a more economical alternative. In addition, low sunflower oil prices will encourage countries such as India, the European Union, and China to increase palm oil consumption. This can affect the dynamics of the global vegetable oil market, including the supply and demand for palm oil. For food industry practitioners, fluctuations in sunflower oil prices can affect production costs and raw material procurement strategies. The increase in the price of sunflower oil could encourage food producers to turn to palm oil as a more affordable

alternative, while the decline in the price of sunflower oil could increase the price competition between the two vegetable oils. Therefore, monitoring vegetable oil price trends and adjusting raw material procurement strategies are important for food industry practitioners to maintain cost efficiency and competitiveness of their products in the market. In addition, changes in the price of sunflower oil can affect consumer preferences for food products. Consumers who are increasingly concerned about sustainability and environmental impact may prefer products that use vegetable oils with a lower carbon footprint. Therefore, food industry practitioners need to consider sustainability aspects in the selection of raw materials to meet the demand of increasingly environmentally conscious consumers.

The implementation of the RSPO has a negative and significant effect.

Certification requires a large cost for CPO producers. These costs include audits, environmental monitoring and operational adjustments in accordance with RSPO sustainability standards. Small and medium-sized producers who do not have access to large capital often struggle to bear these costs. As a result, manufacturers who are unable to compete due to high costs are able to reduce competitiveness and efficiency. Although RSPO is supported by markets in developed countries such as Europe and North America, global demand for RSPO-certified palm oil is still limited. In many countries, especially Asia and Africa, consumers and food producers do not always care whether or not certified palm oil is sustainable, and this policy is ambiguous, especially in Indonesia. The implementation of RSPO is complicated and time-consuming. This is supported by the Indonesian Palm Oil Entrepreneurs Association (GAPKI) which is influential in urging the government to use ISPO so that there is no global condemnation and increased demand for CPO in Indonesia as well as maintaining diplomatic relations with the European Union (Choiruzzad *et al.*, 2021), However, GAPKI also mentioned that the implementation of this sustainability certification is quite high in terms of cost (Supriyono, 2016).

The biodiesel policy has a positive and significant influence on the competitiveness of the CPO industry. These results are also highlighted by the research Kharina *et al.* (2018). The implementation of the biodiesel mandate (for example, B30 in Indonesia, where the biodiesel blend contains 30 percent palm oil), increases the demand for CPO as the main raw material in biodiesel production. This increase in biodiesel mandate increases the volume of palm oil needed to meet the needs of biofuel production. The CPO industry is gaining new market share in the energy sector as renewable energy. With the increasing production of biodiesel from palm oil, countries implementing this policy can reduce their dependence on fossil fuel imports.

Malaysia's CPO exports have a positive and significant effect on the competitiveness of the CPO industry in Indonesia, supported by a study Lim

et al., (2015). Malaysia as Indonesia's main competitor encourages strong competition. Along with the increase in Malaysian CPO exports, especially to countries with stricter environmental standards, Indonesia will indirectly be encouraged to increase its production standards in order to compete in the same market. In addition, there is a close relationship in the regionalization of ASEAN, making the possibility of knowledge and technology transfer higher. Not only competitors, Indonesia and Malaysia also often collaborate on palm oil trade policies, especially in the face of strict international regulatory barriers from the European Union and other developed countries.

Conclusion

This study examines the simultaneous impact on three research models, namely industrial concentration, technical efficiency, and competitiveness of the Indonesian CPO industry. Model 1 shows that competitiveness, technical efficiency, global CPO prices, RSPO, cooking oil prices, and CPO exports have a significant effect on the concentration of the CPO industry. Model 2 shows that exogenous factors such as industrial concentration, oil palm land area, biodiesel policy, and RSPO have a significant influence on technical efficiency. In addition, on Model 3, exogenous factors such as industrial concentration, technical efficiency, CPO prices, sunflower oil prices, RSPO policies, biodiesel, and Malaysian CPO exports have a significant influence on competitiveness. In addition, the study highlights that the CPO industry in Indonesia shows a high level of concentration, with several large companies dominating the CPO market. Indonesian CPO companies also demonstrate a high level of technical efficiency, which contributes to global competitiveness. Malaysia as a competitor country of Indonesia, shows that the high export of competitors has a positive impact on the Indonesian CPO industry.

In sustainable goals, there are several policies that can be obstacles in the process of increasing the competitiveness of the CPO industry. As in Indonesia, the implementation of ISPO is still very minimal and still ambiguous. The government needs to ensure that regulations related to certification are in accordance with the principles that support the improvement of the SDGs. In addition, by optimizing the implementation of certification, Indonesia will not be criticized by the European Union. The government can provide subsidies or financial assistance schemes to support small companies in obtaining ISPO certification. The government also needs to consider the evaluation of this policy dynamically, following technological developments and market changes. Indonesia and Malaysia must also unite against negative rumors related to the anti-palm oil campaign. As the two main producers of palm oil, the two countries have the same economic

interest in CPO commodities. Therefore, Indonesia and Malaysia must work together against discriminatory measures from Europe that focus on reducing the use of palm oil in their industries. Governments and industry associations should encourage the adoption of green technologies and efficient production processes through fiscal incentives, such as tax breaks for companies that invest in green technologies.

This study has some limitations, such as the use of a simultaneous model to provide an overview of the relationship between variables, but it has not fully captured the complexity of the European Union's discriminatory discrimination against CPO. The results of this study are mainly applicable to the CPO industry in Indonesia and may not be fully relevant to other CPO producing countries with different market structures. Further research may include social variables, such as smallholder well-being or the environmental impact of RSPO policies. Additionally, a comparative analysis of policies in a competitor country like Malaysia can provide additional insights. In addition, researchers can use panel data with longer time coverage and policy impact more accurately.

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Publisher

FrancoAngeli.it

— Early View

Published aprile 3, 2025

Issue description

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