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Article

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GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

The relationship between technical efficiency, firm growth and market structure in the Indonesian palm oil industry

Berliana Anggun Septiani^{1*} and Maman Setiawan¹

Abstract: This research investigates the relationship between efficiency and firm growth as well as the relationship between firm growth and market structure (CR4) to evaluate whether the quiet-life (QL) and/or efficient structure (ES) hypothesis applies in the Indonesian palm oil industry. This study uses large and medium industry survey data sourced from the Indonesian Bureau of Central Statistics (BPS) for the period from 1990 to 2017. The efficiency score is calculated using data envelopment analysis (DEA) using a bootstrapping approach. The two-step generalized method of moments (GMM) and panel vector auto regression (PVAR) are used to test the two hypotheses. The results show that technical efficiency can increase a firm's market share, market concentration, and market power. These results support the ES hypothesis. This research also finds that market structure (CR4) has an impact on firm efficiency, providing evidence supporting the QL hypothesis. These results indicate that the ES and QL hypotheses apply in Indonesia during a business cycle that needs to be considered by policymakers.



Berliana Anggun Septiani

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PUBLIC INTEREST STATEMENT

This study examines the causal relationship between market structure and technical efficiency in the palm oil industry in Indonesia in the period 1990–2017 to determine whether the quiet period hypothesis (QL) and/or efficient structure hypothesis (ES) apply to the industry. According to the results, the finding suggests that technical efficiency can increase a firm's market share, market concentration, and market power. These findings are in line with the ES hypothesis. Moreover, market structure has an impact on a firm's efficiency, according to this study's findings, which lend support to the QL hypothesis. These results indicate that the ES and QL hypotheses apply in the Indonesian palm oil industry. The policy implication proposed based on research findings is that policymakers need to set and evaluate the balance between competition and firm concentration levels because the implications of the ES hypothesis contrast with those of the QL hypothesis.

Subjects: industrial organization; efficiency; productivity; microeconomics; manufacturing industry; food and beverage industry; palm oil processing

Keywords: technical efficiency; industry concentration; the efficient structure hypothesis; the quiet-life hypothesis; palm oil industry

1. Introduction

The Indonesian palm oil industry is important to the Indonesian economy. Indonesia has surpassed other countries as the world's largest palm oil producer since 2006, with palm oil production of 49,710,345 tons per year. In addition, the palm oil industry contributes 3.5 percent to Indonesia's gross domestic product (GDP). The Indonesian palm oil industry absorbed 4,500,520 employments in 2022. Additionally, according to annual data from the Ministry of Industry of the Republic of Indonesia (2021), palm oil, with a market value of USD 18.44 billion, is the largest source of foreign exchange for the manufacturing sector.

Based on the significant contribution to the Indonesian economy, an investigation into the performance of the Indonesian palm oil industry is important. The performance of the palm oil industry will affect consumer welfare and the profitability of Indonesian firms. Related to the industry's performance, the Indonesian palm oil industry had low technical efficiency during the period 1990–2017; technical efficiency fluctuated and tended to decline. This is supported by previous research in Indonesia, such as Rifin (2017), which found that the crude palm oil (CPO) industry code International Standard Industrial Classification (ISIC) 10432 (crude palm kernel oil industry) had low performance. This research concluded that the average efficiency of the CPO industry was only 0.253 in 2013. Therefore, it is important to look at the efficiency performance of the Indonesian palm oil industry because low performance can affect product quality and prices for consumers (Setiawan et al., 2012; Setiawan, 2019b).

In relation to the performance of the palm oil industry, a number of earlier studies have correlated market structures such as industry concentration with the industry's low efficiency. For example, Muslim et al. (2008) showed that the ISIC code 10,437 (palm cooking oil industry), a CPO industry, had a high industrial concentration, scattered fluctuations, and was categorized as an oligopoly. High industrial concentration can cause inefficiencies that eventually harm consumers' welfare (see Sexton & Zhang, 2001; Setiawan et al., 2012; Brookes et al., 2017; Setiawan & Effendi 2016; Setiawan et al., 2016; Effendi et al., 2018).

Related to the relationship between market structure and efficiency, this relationship can be explained by two opposite theories. The first theory is the quiet life (QL) hypothesis, and the second theory is the efficient structure (ES) hypothesis. The QL hypothesis, proposed by Hicks (1935), suggests that industry concentration reduces competition between firms, which in turn decreases incentives for firms to maximize efficiency. Firms with market power tend to operate inefficiently because there is no pressure from competitors. Conversely, the ES hypothesis states that efficient firms can create higher industrial concentrations. Efficient firms can conserve physical resources and produce a large part of a sector's output, but at the same time, they increase industrial concentration.

In relation to research on the QL and ES hypotheses, many approaches have been used, but these approaches are conventional. In spite of this, conventional approaches for evaluating the ES hypothesis are not convincing (Khan et al., 2017). The original hypothesis proposed by Demsetz (1973) was a combined hypothesis that predicted the stages of a causal relationship from firm efficiency to firm growth, then to market structure, and finally to market performance. However, in each stage, causality may or may not hold, and there may be alternative hypotheses that better explain the data. For example, although a small number of efficient firms may eventually dominate a market, the market may temporarily become less concentrated if for example, large

inefficient firms lose market share. Thus, testing the reduced-form relationship between efficiency and market performance is too rough to validate or invalidate the ES hypothesis as a whole (Homma et al., 2014).

There is another, more moderate approach, such as that carried out by Homma et al. (2014), which examined the relationship between efficiency and firm growth. Homma et al. (2014) expanded the ES hypothesis by suggesting that efficient firms outperform the competition and grow. Then Khan et al. (2017) expanded the methodology of Homma et al. (2014) by examining the relationship between cost efficiency and bank growth and then between bank growth and market concentration. The advantages of the moderate ES method are that it is more direct and can evaluate the QL hypothesis at the same time. Thus, the moderate ES method is better to use. However, this approach is still applied in the banking industry, and it is still difficult to find this approach being applied to the palm oil industry. It has also never been implemented in Indonesia. Therefore, research related to testing the QL and ES hypotheses in the palm oil industry in Indonesia using more moderate approach is relevant.

This paper aims to investigate the relationship between industry concentration, growth, and technical efficiency in the palm oil industry in Indonesia. This paper is organized as follows: Section 1 discusses the conceptual framework of the relationship between technical efficiency, growth, and market structure. This is followed by the modeling approach in Section 2 and a description of the data in Section 3. Results are presented and discussed in Section 4. The final section presents the conclusions and policy implications.

2. Literature review

Two opposite theories, namely the QL hypothesis and the ES hypothesis, posit an opposite causal relationship between efficiency and market structure. The QL hypothesis proposed by Hicks (1935) states that firms with market power tend to operate more inefficiently; one of the reasons is inadequate management, where managers increase some expenses, especially to maintain the firm's market power (Berger & Hannan, 1998). An empirical study of the QL hypothesis uses industry concentration as a measure of market power. For example, Setiawan et al. (2012), Setiawan et al. (2013), Setiawan and Oude Lansink (2018) and Setiawan (2019a) examined the relationship between industrial concentration and technical efficiency in the Indonesian food and beverage industry. Also, Doyran and Roman Santamaria (2019) and Haghnejad et al. (2020) examined the relationship between efficiency and industry concentration in the banking industry in Costa Rica and Iran, respectively. Then Alshammari et al. (2019) specifically examined industry efficiency and concentration in the insurance and takaful sectors. The study found a negative relationship between industry concentration and efficiency, supporting the QL hypothesis.

On the other hand, the ES hypothesis predicts a positive effect of efficiency on market structure because profitable firms can improve market performance, thereby expanding market share and producing a concentrated market (Demsetz, 1973). Furthermore, the ES hypothesis testing method was developed by Homma et al. (2014), and the hypothesis states that firms that operate efficiently can beat the competition and grow. However, this research does not examine the causal relationship between firm growth and market structure. Then, Khan et al. (2017) refined it into a more complete test method, which tests the causal relationship from efficiency to growth and then from growth to market structure. Several empirical studies have been conducted using either conventional or moderate testing methods. For example, Aguirre et al. (2008), Samad (2008), Williams (2012) and Ab-Rahim and Nie Chiang (2016) investigated the relationship between market structure and efficiency in the banking industry. Then Sahile et al. (2015) examined market share and market concentration in the Kenyan banking industry using the Smirlock model (1985), Molyneux et al. (1994), and Mackinnon et al. (1995). Also, Outreville (2015) specifically investigated industry efficiency and concentration in the Canadian wine industry. Some of these studies used conventional testing methods and found a positive relationship between efficiency and industrial concentration, supporting the ES hypothesis. Meanwhile, studies using moderate testing methods

have been conducted by Homma et al. (2014) and Khan et al. (2017). The study found that the ES and QL hypotheses apply to large banks in Japan and to the banking industry in the Association of South East Asian Nations (ASEAN), respectively. Also, Le et al. (2021) and Khan and Kutan (2021) found that the ES hypothesis dominates the Vietnamese and ASEAN banking industries.

By using the moderate approach, this step is feasible because the moderate ES method can be used to test whether there is a mediating variable between efficiency and market structure, while the conventional method can only test the direct relationship between efficiency and market structure. In spite of this, the moderate method is never applied in the manufacturing industry, particularly in Indonesia. Applying the methodology from Khan et al. (2017) to investigate the ES and QL hypotheses in the palm oil industry will give useful insight. The estimation can contribute to the literature in the manufacturing industry, especially in the palm oil industry.

3. Modeling approach

This research uses the moderate ES testing method. The test method is to identify an indirect relationship from technical efficiency to market structure through firm growth. The choice of this method was made because it is more direct and can simultaneously evaluate the QL hypothesis, which states that in a concentrated market, firms do not minimize costs or do not achieve potential output.

3.1 Empirical models

If technical efficiency causes the firm to grow and the resulting growth then causes the firm's market power to increase, then technical efficiency, growth, and market structure must be linked into one system (Baron & David, 1986). In other words, the relationship can be translated into the following: (1) technical efficiency can affect firm growth, (2) firm growth affects market structure, (3) technical efficiency affects market structure without growth, and (4) efficiency effect on market structure diminishes when growth variables are added to the model. To test some of these relationships, Equations (1)–(2) are used, as follows (Khan et al., 2017):

$$Growth_{i,t} = \omega_0 + \omega_1 Growth_{i,t-1} + \omega_2 Efficiency_{i,t-1} + \sum_{m=3}^4 \omega_m X_{i,t} + \sum_{m=5}^5 \omega_m Z_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$MS_{i,t} = \alpha_0 + \alpha_1 MS_{i,t-1} + \alpha_2 Efficiency_{i,t-1} + \sum_{m=3}^4 \alpha_m X_{i,t} + \sum_{m=5}^5 \alpha_m Z_{i,t} + e_{i,t} \quad (2)$$

where $Growth_i$ is the output growth of the firm i , $Efficiency_{i,t-1}$ is the technical efficiency of the firm i at time $t - 1$, $t - 1$ shows that it is assumed that efficiency affects the firm's growth and market structure with a one-year time lag, using context such as the Arellano—Bond models, where in a dynamic panel-data model, lagged values of the dependent variable are included as regressors. X is a control variable at the firm level, which is represented by the capital output ratio (COR) and the number of firms per year (NF), Z is a vector of regulatory control variables, which is represented by the Dispo variable (regulations for managing palm oil (dummy of the Indonesian Sustainable Palm Oil (ISPO))), MS is the market structure of the industry subsector, of which the four-firm concentration ratio (CR_4) is its representative and ε is a random error term.

The next stage of this research examines whether *Efficiency* affects the coefficients of the variables based on the results of Equations (1)–(2) above. This research takes the logit transformation of CR_4 and technical efficiency since both CR_4 and technical efficiency are restricted in the unit interval. Logistics transformation is necessary to ensure that the estimated technical efficiency will be maintained between 0 and 1 as the market structure increased (Setiawan et al., 2012).¹

Equations (1) and (2) are estimated using the two-step system GMM with Windmeijer (2005) corrected standard errors. This study carried out two postestimation procedures to obtain

consistent and efficient estimation results. First, the Sargan test is used to ensure the validity of the instrument used (H0: the instrument used is valid); when the Sargan value is not significant, it means that the instrument used is valid. GMM allows the use of instrument variables, which produce more precise and accurate estimators. The instrument must be relevant and valid, which means it must correlate with endogenous regression rather than error. The second post-estimation procedure is the Arellano-Bond (AR) test to test the null hypothesis that there is no first and second-order serial correlation caused by differences in the estimators under the GMM system. When the AR value is not significant, it means that the error terms in the regression are not correlated.

After the diagnostic tests show that GMM has no identification problems, the next step is to examine whether there is an indirect (mediated) relationship between technical efficiency and market structure. The test uses the calculation method by Goodman (1960), Sobel (1982), Mackinnon and Dwyer (1993), and Mackinnon et al. (1995), as follows:

$$\text{Sobel Statistics} = z = \alpha * \beta / \text{SQRT}(\beta^2 * SE_{\alpha}^2 + \alpha^2 * SE_{\beta}^2) \quad (3)$$

$$\text{Aroian Statistics} = z = \alpha * \beta / \text{SQRT}(\beta^2 * SE_{\alpha}^2 + \alpha^2 * SE_{\beta}^2 + SE_{\alpha}^2 * SE_{\beta}^2) \quad (4)$$

$$\text{Godman Statistics} = z = \alpha * \beta / \text{SQRT}(\beta^2 * SE_{\alpha}^2 + \alpha^2 * SE_{\beta}^2 - SE_{\alpha}^2 * SE_{\beta}^2) \quad (5)$$

where α is the coefficient on the independent variable (IV) when the mediating variable (MV) is regressed on IV. SE_{α} is the standard error of α , β is the coefficient on MV when the dependent variable (DV) is regressed on IV and MV. Then SE_{β} is the standard error of β .

Technical efficiency and growth coefficients are used to calculate the z statistic for the mediation analysis based on the Sobel, Aroian, and Goodman tests. The null hypothesis underlying the test is that the indirect relationship between efficiency and concentration or market power is not different from zero. Thus, the rejection of the null hypothesis implies that there is an indirect relationship between efficiency variables and market structure.

In addition, to test whether the quiet-life (QL) and/or efficient structure (ES) hypotheses apply to the palm oil industry in Indonesia, this study also examines the relationship between technical efficiency, firm growth, and market structure using the panel vector autoregressive (PVAR) model within the scope of the Generalized Method of Moments (GMM) (Setiawan et al., 2012) as follows:

$$\text{Growth}_{it} = \gamma_i + \sum_{k=1}^K \vartheta_k \text{Growth}_{i,t-k} + \sum_{k=1}^K \sigma_k \text{Efficiency}_{i,t-k} + \sum_{k=1}^K \mu_k \text{MS}_{i,t-k} + v_{j,t} \quad (6)$$

$$\text{MS}_{i,t} = \eta_i + \sum_{k=1}^K \lambda_k \text{MS}_{i,t-k} + \sum_{k=1}^K \theta_k \text{Growth}_{i,t-k} + \sum_{k=1}^K \delta_k \text{Efficiency}_{i,t-k} + \varepsilon_{i,t} \quad (7)$$

$$\text{Efficiency}_{i,t} = \varphi_i + \sum_{k=1}^K \tau_k \text{Efficiency}_{i,t-k} + \sum_{k=1}^K \alpha_k \text{MS}_{i,t-k} + \sum_{k=1}^K \pi_k \text{Growth}_{i,t-k} + u_{i,t} \quad (8)$$

Equations (6)-(8) show that each variable, namely firm growth, market structure, and technical efficiency, is represented as a function of its own lag and the lag of other variables.

The Wald test is used to determine whether the ES and/or QL hypotheses apply to the Indonesian palm oil industry. The choice of lag is based on the Akaike Information Criteria (AIC) value, which has the smallest value. The variables in Equations (6) through (8) are tested for unit roots using the Phillips-Perron unit root test. This approach is taken to check the stationarity of the time series variables. If the null hypothesis of non-stationary data is rejected at the 5% critical level, it can be concluded that the data series is stationary. Which indicates that data at the level form can be used to estimate the model.

The Wald statistic has an asymptotically chi-squared distribution with q degrees of freedom, where q is the number of restrictions under the null hypothesis if the variables in the VAR system are stationary. OLS estimators and Wald statistics are valid if the variables in the VAR process are stationary. However, Wald statistics based on OLS estimation of the level VAR model have non-standard asymptotic distributions that may incorporate obtrusive parameters if variables contain unit roots (Sims et al., 1990), as a result, the Granger causality test is invalid for variables that are non-stationary.

3.2 Estimation of technical efficiency

Scores of technical efficiency are used in this study as measures of firm performance.

Technical efficiency is the capacity of the DMU to maximize output above a certain input level. In Farrell (1957)'s classic paper on efficiency measurement, he proposed measuring efficiency by comparing optimal and actual output. The production frontier predicts the optimal (or efficient) output value, and there is an observed value of its output for each DMU. Farrell (1957) argued that measuring technical efficiency is important because it allows for determining whether output can be increased simply by increasing efficiency without necessarily increasing the amount of input. In addition, Lovell (1993) stated that measuring efficiency makes it possible to rank and evaluate the DMUs analyzed, thereby enabling the design of incentive mechanisms to reward the best DMUs and policies to increase efficiency.

Technical efficiency scores have the advantage of comparing the performance of individual firms and the best or most efficient practices in comparison to other accounting and productivity measures (Mok et al., 2007). There are two types of technical efficiency. First, output-oriented technical efficiency refers to the ability (usually of the firm) to obtain potential output from a certain set of inputs. Second, input-oriented technical efficiency, namely the ability to use minimum input levels in producing output (Farrell, 1957). There are two well-known methods for estimating technical efficiency, namely stochastic frontier analysis (SFA) and data envelopment analysis (DEA). SFA was developed by Aigner et al. (1977) and Meeusen and van Den Broeck (1977). SFA is a parametric technique that requires assumptions about the functional form of the production function and the error term distribution. In the stochastic method, efficiency measures are estimated under the Cobb-Douglas production limit specifications. While DEA is a non-parametric technique that was first introduced by Charnes et al. (1978), DEA measures the efficiency of each decision-making unit (DMU), where multiple inputs and outputs are reduced to a single virtual input and a single virtual output with optimal weights. Then the efficiency measure is a multiplier function of the virtual input-output combination; the ratio for each DMU must be less than or equal to one. In DEA, efficiency is estimated under the specification of constant and variable returns to scale.

In this research, the technical efficiency score will be calculated using DEA for several reasons. First, in contrast to SFA, DEA allows the use of multiple inputs and multiple outputs in one measure of efficiency. Second, technical estimation with varying time is needed because one of the goals is to determine the direction of causality between efficiency and market structure. This estimate can be obtained by using DEA independently for each year of observed data and in each industry subsector. Third, DEA avoids placing a uniform structure on input-to-output conversion technologies across sub-sectors by assuming a uniform functional form for production boundaries. Fourth,

the calculation of the transformation process that converts inputs (in the form of capital, materials, and labor) into more valuable outputs (in the form of goods and/or services) requires the right metrics to measure and evaluate efficiency, and DEA can be the right method to provide those metrics. DEA results can be used effectively to configure the allocation of resources.

The firm's technical efficiency score is calculated using the method used by Coelli et al. (2005):

$$\begin{aligned} \min_{\theta, \lambda} \quad & \theta, \\ \text{st} \quad & -y_i + Y\lambda \geq 0, \\ & \theta x_i - X\lambda \geq 0, \\ & N1'\lambda = 1 \\ & \lambda \geq 0, \end{aligned} \tag{9}$$

where θ is the i -th scalar and efficiency score (from 0 to 1). λ is the constant vector $N \times 1$, and y is the output vector for the i -th DMU. The y output matrix consists of data for all N firms. x_i is the input vector of the i -th DMU. $N1'\lambda = 1$ denotes that sum of lambdas for all firms are one (convexity constraint). The convexity constraint implies that firms are inefficient compared to firms of the same size. The convexity boundary is used in the estimation technique with DEA using variable return to scale (VRS). If the technical efficiency score of a particular firm is calculated without the convexity constraint $N1' = 1$, then the DEA estimation technique is under the assumption of constant returns to scale (CRS).

This research uses the input-oriented DEA model with variable returns to scale (VRS). VRS ensures that inefficient firms will only be compared with firms of the same scale. This study uses large and medium industries; the VRS method can compare large firms with other large firms and medium firms with other medium firms. The VRS assumption is also relevant because the CRS is too strong an assumption for the Indonesian palm oil industry, which is characterized by many distortions (Setiawan et al., 2012). Input-oriented DEA is used in this study to identify technical efficiency as reduced input with a fixed level of output. This assumption can be relevant in the Indonesian palm oil industry because reducing inputs is easier to do.

This research uses the Simar and Wilson (1998) bootstrapping method to obtain a reliable estimate of the efficiency score as also applied by Effendi et al. (2018), Setiawan (2019a), Setiawan (2019b), Setiawan et al. (2019) and Setiawan and Tisnawati Sule (2020), which may be used for the first time in the Indonesian palm oil industry. This method is also expected to reduce the problem of serial correlation in the efficiency score of the firm. The bootstrap method involves iteratively simulating the data generation process, applying the original estimator to the simulated sample, and then comparing the results to the sampling distribution of the original estimator (Simar & Wilson, 1998; Effendi et al. (2018); Setiawan (2019a); Setiawan (2019b); Setiawan et al. (2019); Setiawan and Tisnawati Sule (2020). As a final result, this research only presents a biased-corrected efficiency score, which can be calculated using the following formula:

$$\hat{\delta}(x, y) = \hat{\delta}(x, y) - \text{bias}_B[\hat{\delta}(x, y)] = 2\hat{\delta}(x, y) - B^{-1} \sum_{b=1}^B \hat{\delta}_b^*(x, y) \tag{10}$$

with the condition of the sample variance:

$$\hat{\delta}_b^*(x, y) < \frac{1}{3} \left(\widehat{\text{bias}}_B[\hat{\delta}(x, y)] \right)^2 \tag{11}$$

In the last two relationships, $\hat{\delta}(x,y)$ dan $\hat{\delta}^*(x,y)$ are the original and biased-corrected efficiency scores, respectively and $\hat{\delta}_b^*(x,y)$ is the bootstrap estimate of the efficiency score in b th from bootstrap repetitions. Effendi et al. (2018), Setiawan (2019a), Setiawan (2019b), Setiawan et al. (2019) and Setiawan and Tisnawati Sule (2020), all used the DEA with a bootstrapped approach in diverse industries. In comparison to the original DEA estimates, they claimed that the DEA with bootstrapped approach was more credible, accurate and effective at estimating the efficiency score.

3.3 Calculation of industrial concentration

Market structure is related to firm performance, so it is important to assess the market structure, as explained in the QL hypothesis. One method for determining market structure is by mapping the order of firm size from the largest to the smallest in order to calculate the total output concentrated in several firms, which is commonly called market concentration (Waldman & Jensen, 2016). Market concentration is an indicator of firm competition, efficiency, and market power in an industry. A measure of industrial concentration calculated by Pepall et al. (2014), Setiawan et al. (2012), Setiawan et al. (2013) and Setiawan et al. (2022) based on the firm's market share. The distribution of the firm's market share in the market can be represented by the four-firm concentration ratio (CR4). CR4 is the total market share of the four largest firms in the industry. CR4 is the most commonly used measure of market concentration. Therefore, it is important to use CR4 to represent market structure.²Therefore, this study uses CR4 as a measurement of market structure. The CR4 calculation is shown in the following equation (Waldman & Jensen, 2016):

$$CR_4 = \sum_{i=1}^4 S_i \quad (12)$$

where S_i is the market share. The CR4 value ranges from 0 to 1, when the CR4 value gets closer to 0, it is classified as a perfectly competitive market, whereas when the CR4 value gets closer to 1, it is classified as a monopoly.

Related to the interpretation of the CR4 calculation results, an increase in value indicates a decrease in competition and an increase in market power, while a decrease in value of CR4 indicates the opposite (Hernandez & Torero, 2013).

4. Data

This research uses establishment-level data from the Annual Manufacturing Survey provided by the Indonesian Bureau of Central Statistics (BPS) to estimate efficiency and CR4 value for the Indonesian palm oil industry. The dataset covers the period from 1990 to 2017. This study uses this period because using a longer sample period is not possible due to the difficulty of identifying the same firm data over a longer period of time. This industry uses the 5-digit International Standard Industrial Classification (ISIC). There are seven ISIC sub-sectors in the Indonesian palm oil industry. This study makes use of data from ISIC 10,431 (crude palm oil industry), ISIC 10,432 (crude palm kernel oil industry), ISIC 10,437 (palm cooking oil industry), and ISIC 10,438, which is a merger of ISIC 10,433 (industry of separation or fractionation of palm oil and palm core crude oil), ISIC 10,434 (refining industry for crude palm oil and crude palm kernel oil), ISIC 10,435 (pure palm oil separation or fractionation industry) and ISIC 10,436 (pure palm kernel oil separation or fractionation industry). The merger of the four sub-sectors was carried out because they contained fewer than four firms in each period.

The Indonesian palm oil industry uses raw materials, labor, and capital such as machinery and equipment to produce output. Output is measured as the value of the gross output generated by the firm each year. This research defines the growth variable as the firm's market share growth.

Table 1 shows the descriptive statistics of the variables used in the study. The relatively high coefficient of variation for all variables indicates the heterogeneous condition of each firm. Furthermore, Table 1 shows that the sectors in the palm oil industry are relatively inefficient in the estimation period. During the period 1990–2017, the average value of technical efficiency was 0.260, meaning that firms in the palm oil industry utilized an average of 26% of their production potential. Based on these data, the sub-sector (10438), which is an amalgamation of the sub-sector “crude palm oil and crude palm kernel oil separation and fractionation industry” (10433), “crude palm oil refining industry and palm kernel crude oil industry” (10434), “crude palm oil separation and fractionation industry” (10435), and “palm kernel crude oil separation and fractionation industry” (10436), has the highest technical efficiency, while the sub-sector “crude palm oil industry” (10431) has the lowest. The market share represented by CR4 varied during the period from 1990 to 2017; the average is 0.728 and the volatility reflects the dynamics of competition between firms in the palm oil industry sub-sector. According to Shepherd (1999), the industry concentration value classifies the industry as a tight oligopoly.

Table 2 shows measures of industry concentration, firm growth, and bias-corrected average technical efficiency scores for the time periods covered by the data. The findings indicate that efficiency levels, firm growth, and industry concentration are relatively varied over the period of estimation, and there is no specific pattern in the relationship between the variables.

During the research period, there were an average of 401 firms in the market. In 1990, the number of Indonesian palm oil firms was 129, increasing significantly to 773 in 2017. The number of firms fluctuated and tended to rise between 1990 and 2017, which could explain the decline in industrial concentration.

5. Results

Table 3 shows the pairwise correlation between the research variables. The pairwise correlation test results have two significant implications. First, the correlation between the main research

Table 1. Descriptive statistics of the variables from 1990 to 2017

Variable	Mean	Standard deviation	Coefficient of variation	Minimum	Maximum
CR4	0.467	0.188	0.403	0.235	0.999
Material (in million rupiah)	2.55×10^8	3.91×10^9	15.333	13.788	2.95×10^{11}
Labour (person index)	273.908	589.954	2.154	7.000	14996.000
Capital (in million rupiah)	1.07×10^7	2.75×10^8	25.701	8.467	2.19×10^{10}
Output (in million rupiah)	6.40×10^7	9.91×10^8	15.484	397.000	4.48×10^{10}
Efficiency	0.260	0.233	0.897	0.001	1.000
Growth (in percent)	0.251	0.929	3.704	−1.000	10.000
COR	3.061	55.011	17.973	0.000	5295.402
NF	401.007	229.035	0.571	5.000	850.000
Dispo	0.373	0.484	1.296	0.000	1.000

Source: Indonesian Bureau of Central Statistics (BPS) and author's calculations.

Notes: CR4, the four-firm concentration ratio; Growth, the firm's market share growth; COR, capital output ratio; NF, number of firms per year; Dispo, dummy of the Indonesian sustainable palm oil (ISPO).

Table 2. Technical efficiency score, growth and industrial concentration

Period	Efficiency	Growth (%)	CR4
1990–1993	0.608	34.489	0.867
1994–1997	0.676	30.514	0.817
1998–2001	0.650	31.821	0.81
2002–2005	0.491	31.818	0.735
2006–2009	0.431	42.296	0.581
2010–2013	0.412	34.578	0.618
2014–2017	0.356	37.794	0.667

Source: Authors' calculation.

Note: CR4, the four-firm concentration ratio; Growth data for the period 1990–1993 uses data for 1991–1993.

Table 3. Pairwise correlations

	Efficiency	CR4	Growth
Efficiency	1.000		
CR4	0.386***	1.000	
Growth	0.066***	0.030***	1.000

Source: Author's calculations

Note: This table shows the pairwise correlations among the research's important variables. The subscripts ***, **, * indicate significance at the 1%, 5%, and 10% levels.

variables, namely efficiency, growth, and market structure (CR4), is important. The correlation of the three variables is positive. Second, the correlation between the independent variables is not too high to cause multicollinearity problems.

5.1 Testing firm efficiency, growth, and market structure with the two-step Generalized Method of Moments (GMM) test

This research uses a two-step system GMM in Equations (1) and (2) separately to estimate the relationship between technical efficiency, firm growth, and market structure (CR4), as has been done by Khan et al. (2017).

We take into account the possibility of endogeneity for several variables by using the instrument variables in Equations (1) and (2). Applying instrumental variables such as exogenous variables, exogenous lag variables, endogenous lag variables, and lagged differences can be used to overcome the endogeneity problem (Bond, 2002; Petrick & Zier, 2012; Sharma, Gounder, & Xiang, 2013). This study uses different instrumental variables for each equation. The instrumental variable in the first equation is the lag variable of technical efficiency and the number of firms per year. While the instrument variable in the second equation uses the number of firms per year. The selection of the instrument variables is applied as suggested by Homma et al. (2014). The GMM model will provide consistent and reliable results as a control for endogeneity, compared to the ordinary least square (OLS) model. GMM can control for endogeneity, heterogeneity, and autocorrelation (Ullah et al., 2018). Therefore, GMM can be used without diagnostic tests because basically GMM is designed to solve endogeneity, autocorrelation, and heteroscedasticity problems (Yitayaw et al., 2023).

Table 4 shows that technical efficiency has a positive effect on firm growth. The diagnostic test on Equation (1) shows that the GMM is determined correctly and there are no identification problems; the insignificant AR value indicates that the error terms in the regression are not correlated; and the insignificant Sargan value indicates that the instrument used is valid, utilizing the Sargan test for fulfilling the orthogonality condition. At the 5% critical level, the test does not reject the null hypothesis of the orthogonality condition.

Table 4. The relationship between technical efficiency and firm growth

Firm Growth	
Growth (t-1)	-0.179*** (0.013)
Efficiency (t-1)	8.372** (3.097)
COR	1.373 (1.090)
NF	0.025 (0.030)
Dispo	-19.108 (19.247)
AR(1)	0.000
AR(2)	0.621
Sargan	0.858
Number of samples	11,238

Source: Author's calculations

Note: Corrected standard errors are reported in brackets. The subscripts ***, **, and * indicate the significance of the relationship at the 1%, 5%, and 10% levels, respectively.

Based on the estimation of Equation 1, Table 4 shows that the coefficient of the efficiency variable is significant, implying that the technical efficiency is significant in affecting firm growth. Then, the lag variable of efficiency has a coefficient of 8.372 on firm growth, which means that every 1 unit increase in efficiency will increase the firm's growth rate by 8.372 percent.

Furthermore, Table 5 presents the estimation results when the market structure (CR4) variable is regressed on technical efficiency and firm growth. The dependent variable is the market structure, represented by CR4.

Based on Table 5, there are two important findings from the estimation results. First, the coefficient on the growth variable is negative and significant. This finding is different from Homma et al. (2014) and Khan et al. (2017). However, the result of this study can be explained by the market growth-concentration decline hypothesis, which states that high market growth means high firm growth and will lead to reduced industry concentration (Nelson, 1960). High-growth firms may face strong competition that relies on technological breakthroughs and labor-intensive production processes for their competitive advantage. When firms with high growth are unable to compete, it will decrease their industrial concentration (Acquaah & Chi, 2007).

Then, the second finding is that the coefficient of technical efficiency is positive and significant, which means technical efficiency causes an increase in firm concentration. The lag of efficiency affects the market structure (CR4) with a coefficient of 1.032. The coefficient value explains that for every 1 unit increase in efficiency, it will increase the market structure by 0.1. These results provide empirical evidence of the relationship between technical efficiency and market structure (CR4).

The results of the tests of Equations (1) and (2) in Tables 4 and 5 show that there is no violation of identification problems; the AR (2) value, which is not significant, indicates that there is no autocorrelation; and the Sargan coefficients, which are not significant, indicate that the instrument used is valid. Then, these results are in accordance with the criteria for the ES hypothesis, as

Table 5. Technical efficiency, growth and market structure of the firm

CR4	
CR4 (t-1)	0.866*** (0.139)
Efficiency (t-1)	1.032*** (0.184)
Growth	-0.022*** (0.004)
COR	-0.048* (0.029)
NF	0.002*** (0.001)
Dispo	-0.577** (0.229)
AR(1)	0.085
AR(2)	0.762
Sargan	0.02
Number of samples	11,238

Source: Author's calculations

Note: Corrected standard errors are reported in brackets. The subscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

described in Section 2. The estimation results show three important findings. First, technical efficiency influences the firm's growth positively and significantly. Second, firm growth is proven to negatively and significantly affect market structure (CR4). Third, technical efficiency increases market concentration. These findings provide sufficient support for the ES hypothesis.

This result is in line with previous research from Esquivias and Kharis Harianto (2020), which found that the ES hypothesis applies to the Indonesian manufacturing sector. The results showed that more efficient firms gained market share as a result of dynamic competition. This is supported by the results of Outreville (2015), who found that performance is the result of firm-specific advantages, so firms with greater efficiency can gain market share and become more profitable.

However, the results of this study are different from previous research by Setiawan et al. (2012) and Maman and Oude Lansink (2018), who found that higher industry concentration causes inefficiencies in the food and beverage industry. Their findings implied that firms in highly closed industries choose anti-competitive practices rather than optimizing efficiency. Then, the results of Setiawan et al. (2019b)'s research found that higher industry concentration is associated with lower performance. The results of this study implied that firms operating in industries with high concentration tend to operate less efficiently.

5.2 Testing the mediation hypothesis

To verify the indirect relationship between technical efficiency and market structure (CR4), we follow the procedures introduced by Goodman (1960), Sobel (1982), Mackinnon and Dwyer (1993) and Mackinnon et al. (1995). Table 6 shows the technical efficiency coefficient in the first row and the growth variable in the second row, which are used to calculate the Sobel, Aroian, and Goodman z test statistics that are reported in the last three rows.

The test uses the calculation method according to the formula presented in Equations (3), (4), and (5) in Section 3.1, using some variables such as efficiency as an independent variable (IV),

Table 6. Sobel, Aroian, and Goodman test

Indirect relationship from technical efficiency to market structure through firm growth

The coefficient on the efficiency variable is based on Equation (1) (Table 4).	8.372**
	(3.097)
The coefficient on the growth variable is based on Equation (3) (Table 5)	−0.022***
	(0.004)
Sobel test	−2.426**
	(0.076)
Aroian test	−2.394**
	(0.077)
Goodman test	−2.459**
	(0.075)

Source: Author's calculations.

Note: Standard errors are reported in the parenthesis; the subscripts ***, **, * indicate significance at 1%, 5% and 10%.

growth as a mediating variable (MV), and market structure as a dependent variable (DV). Furthermore, α is the coefficient on the efficiency variable is based on Equation (1) which is the coefficient on IV when MV is regressed on IV. SE_{α} is the standard error of the efficiency variable based on Equation (1). β is the coefficient on the growth variable based on Equation (3) which is the coefficient on MV when DV is regressed on IV and MV. Then SE_{β} is the standard error of β . The estimation results of the calculation method by Goodman (1960), Sobel (1982), Mackinnon and Dwyer (1993), and Mackinnon et al. (1995) are shown in Table 6.

Based on the test results, the z-test statistics of the Sobel, Aroian, and Goodman tests are significant at the 5% critical level. It can be concluded that the null hypothesis is rejected. It is possible to draw the conclusion that there is an indirect relationship between technical efficiency and market structure (CR4). In other words, the technical efficiency variable affects the market structure (CR4) through the firm growth variable. These results are consistent with the results of the Equations (1) and (2) tests in Tables 4 and 5. This finding is one of the main contributions of this research.

5.3 Testing firm efficiency, growth, and market structure with Panel Vector Auto Regressive (PVAR)

To investigate whether the QL and/or ES hypotheses apply to the Indonesian palm oil industry, this study uses the Wald test in vector autoregression models using the Arellano-Bond estimation approach. The Granger causality Wald test is applied to determine the causal relationship between the variables in the model. The Granger causality test is based on the null hypothesis in the VAR framework, which is defined as zero restrictions on the coefficients of the lags of a subset of the variables. For examining zero restrictions on the VAR process coefficients, the Wald test is a common method.

The null hypothesis of this test is that the excluded variable does not contribute to the Granger-cause equation in the model. In other words, the Granger causality test's null hypothesis proves that no causality exists. The zero restriction on GMM estimates imposing correlation is calculated by the Granger causality test using the Wald statistic (Balcilar et al., 2021).

The Arellano-Bond (1991) estimator is used to calculate the Granger causality model in Equations (6)-(8). Which applies the generalized method of moments to deal with the endogeneity problem arising from the lagged endogenous variables in the model. The Arellano-Bond approach uses a number of instruments, or lags of the instrumental variables that vary with t, to take advantage of the additional moment conditions and produce unbiased estimates of the model parameters.

The endogeneity problem is overcome by applying the instrumental variables approach. This research uses the first four lags of the endogenous variables as instruments in Equations 6 and 7. Then it uses the first three lags of the endogenous variables as instruments in Equation 8, because it minimizes the value of the Akaike Information Criteria (AIC) by Andrews and Lu (2001). AIC shows that this equation has the best model for the third lag in Equations 6 and 7. Meanwhile, Equation 8 has the best model for the second lag. Wald's P-values in Table 7 show the probability of significance under Granger causality. By using the Phillips-Perron stationarity test, this research found that all variables in Equations (6) to (8) were significant at the 5% critical level, so the Granger causality test is based on the variable-level form.

Table 7 presents the estimation results of the Wald test from Equations (6)-(8). Table 7 shows some of the important results. First, technical efficiency affects growth (Model 1). Second, technical efficiency influences market structure (CR4) (Model 2). Third, there is causality from market structure (CR4) to firm growth (Model 1). Fourth, there is evidence of causality from market structure (CR4) to technical efficiency (Model 3). Fifth, there is causality from the firm's growth to market structure (CR4) (model 2). Finally, there is no causality from firm growth to technical efficiency (Model 3).

Based on these results, it can be concluded that there is a two-way relationship between industrial concentration and technical efficiency, where technical efficiency affects industrial concentration and industrial concentration affects technical efficiency. This is shown by the chi-square CR4 statistic, in which each variable is significant at the 1% critical level. The results show that the ES and QL hypotheses apply to the Indonesian palm oil industry.

According to the overall regression findings from Equations (1) to (8), technical efficiency increases market share through firm growth. Efficiency allows firms to be more concentrated and gain more market power; this finding supports the ES hypothesis. However, besides supporting the ES hypothesis, the findings in this research also support the QL hypothesis. From an economic point of view, our findings are interesting: the results for the ES hypothesis suggest that efficient firms become more concentrated, whereas the results for the QL hypothesis suggest that concentrated firms lose efficiency. They lose the market power they had previously obtained when they become inefficient (ES hypothesis). Because of the way market structure (CR4) and efficiency interact, these findings tend to imply that there are interesting cyclical dynamics present in firms. This finding is another major contribution of this study.

The findings of this research are the same as those that have occurred in the Japanese banking industry, which was investigated by Homma et al. (2014). It is also the same as the research results of Khan et al. (2017), who found that the ES and QL hypotheses existed in the banking industry in ASEAN during the 1999–2014 period. According to them, this cycle could occur because banks grew rapidly when they became more efficient, but market concentration caused them to lose efficiency.

Table 7. Panel Vector Auto Regression (PVAR)

Independent Variable	Dependent Variable		
	Model 1	Model 2	Model 3
	Growth	CR4	Efficiency
	Chi-square	Chi-square	Chi-square
Efficiency	17.762***	25.346***	-
CR4	15.615***	-	12.005***
Growth	-	31.054***	0.697

Source: Authors' calculation.

Note: The subscripts ***, **, * indicate significance at 1%, 5% and 10%.

In contrast, according to earlier studies by Setiawan et al. (2012), Setiawan et al. (2013), Setiawan (2019a), Setiawan (2019b) and Setiawan et al. (2022), the ES hypothesis did not apply to the Indonesian food and beverage industry. The findings point to a one-way causal relationship, with industrial concentration having a negative impact on technical efficiency. Setiawan et al. (2012) and Setiawan et al. (2013) found that firms operating in highly concentrated industries are less efficient. These findings support the quiet-life hypothesis, as they show that there is no incentive for firms in a highly concentrated market to be more efficient. The finding of Setiawan (2019a), who found that industrial concentration had a positive impact on dynamic technical inefficiency, is consistent with this. A negative effect of industrial concentration on technical efficiency is also found in Setiawan (2019b) and Setiawan et al. (2022). Different results may exist because Setiawan et al. (2012), Setiawan et al. (2013), Setiawan (2019a), Setiawan (2019b) and Setiawan et al. (2022) used the calculation from food and beverage manufacturing industry data, which is more broad. On the other hand, this study is based on more specific data from the palm oil industry, which is characterized by high economies of scale.

6. Conclusions and policy implications

This research provides empirical evidence to validate the existence of the quiet life (QL) and efficient structure (ES) hypotheses in the Indonesian palm oil industry in the 1990–2017 period through an analysis of the relationship between efficiency and growth and then an analysis of the relationship between growth and market structure (CR4). Based on the tests using the two-step systems GMM and PVAR on firm panel data, this research found that efficient firms increase market concentration through growth as a mediating variable. The empirical evidence is in accordance with the ES hypothesis. Besides supporting the ES hypothesis, the estimation results also support the QL hypothesis. This implies that there are cyclical dynamics in this industry. The implication of the ES hypothesis is that concentrated markets are dominated by efficient firms; therefore, anti-concentration policies can cause distortions in the market. The implications of the ES hypothesis are in stark contrast to the QL hypothesis. Thus, this study suggests that policy-makers need to find a balance between the level of competition and firm concentration.

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Notes

1. The logit transformation maps CR4 and technical efficiency from the unit interval to the real line by using the inverse of the logistic function as $CR4 = \ln\left(\frac{CR4}{1-CR4}\right)$ and $technical\ efficiency = \ln\left(\frac{technical\ efficiency}{1-technical\ efficiency}\right)$ to keep the predicted CR4 and technical efficiency score in the interval between 0 and 1.

2. Beside CR4, HHI is also often used to represent market structure, but this research only uses CR4 because CR4 is better both to determine whether there is market dominance and to determine the market structure of the four largest firms.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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