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TECHNICAL EFFICIENCY OF NATURAL RUBBER PRODUCTION IN HAINAN STATE-OWNED RUBBER ENTERPRISE

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Abstract: This paper examines the Technical Efficiency (TE) of natural rubber production in the Hainan state-owned rubber enterprise and the factors influencing inefficiency. In particular, Stochastic Frontier Analysis (SFA) is employed to quantitatively analyse the study, aiming to understand possible issues and ongoing developments in the production process. Accordingly, the results indicate a continuous TE decline in the Hainan state-owned rubber enterprise, with an average efficiency level measured at 90.4% since 1986. Factors such as workers' education and rubber trees per area significantly contribute to the technical inefficiency. At the same time, the study reveals that an increase in tree density increases TE and thus increases rubber production. Moreover, the study unexpectedly reports that increasing workers' education could increase technical inefficiency, highlighting that higher education is often associated with increased knowledge, skills, and critical thinking abilities. However, it does not guarantee better job performance in all cases. Therefore, the Hainan state-owned rubber enterprise should provide the workers with enough on-the-job training.

Keywords: Natural rubber, technical efficiency, technical inefficiency, stochastic frontier analysis, state-owned rubber enterprise.

Introduction

China's natural rubber is in short supply, posing hidden dangers to economic and national security. Therefore, it has become a top priority in the country. In 2022, the domestic natural rubber production was 818,400 tonnes and the consumption reached 5.79 million tonnes (China Rubber Industry Association, 2022). Notably, the dependence on natural rubber imports has reached 86% (China Rubber Industry Association, 2022), indicating that China's natural rubber production currently struggles to meet the demands of high-speed economic development. The significance of this 86% dependence on imports for economic and national security is a matter of concern. Specifically, natural rubber is a crucial national strategic substance, integral to national security, and a fundamental component of economic development. With economic growth, the domestic demand for natural rubber is increasing, a trend reflected in Figure 1, illustrating the widening gap between production and consumption.

It is challenging to obtain rapid growth of rubber output solely through continuous investment. From a production point of view, the production phase of natural rubber production, which involves increasing the area of land, labour, and capital to increase output has ended. From the output curve in Figure 1, it can be observed that natural rubber has been stabilised. Due to the limitation of natural resources and production laws, production will take the form of a logical curve. After production reaches a certain level, the rate of increase in output tends to slow and the phase of relying solely on the input of production factors to obtain output comes to an end. Currently, the increased output can only be achieved by modifying the technical system, recombining existing production factors, and optimising the mix of these factors.

To contextualise China's position within the global natural rubber market, it is imperative to compare its productivity with that of neighbouring countries such as Thailand and

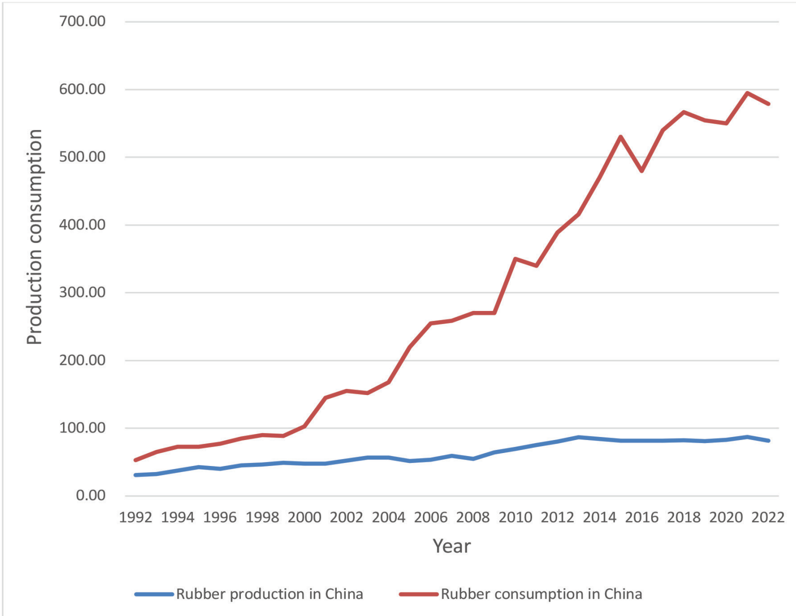

Figure 1: The trends map of China's natural rubber supply and consumption
Source: China Rubber Statistics (1992 to 2022)

Indonesia. As elucidated in Figure 2, natural rubber productivity in China exhibited a notable increase from 0.76 tonnes per hectare (t/ha) in 1992 to 1.26 t/ha in 2013. However, a subsequent decline ensued, with productivity reaching 1.08 t/ha by 2022. A similar trend can be observed in Indonesia, where natural rubber productivity increased from 0.71 t/ha in 1992 to 1.01 t/ha in 2017, prior to declining to 0.82 t/ha by 2022. This pattern is also evident in Thailand, where natural rubber productivity rose from 1.20 t/ha in 1992 to 1.79 t/ha in 2003, then, decreased to 1.38 t/ha by 2022. Concurrently, the notably lower productivity of China's natural rubber than Thailand's may stem from underlying issues of inefficiency and lower productivity levels.

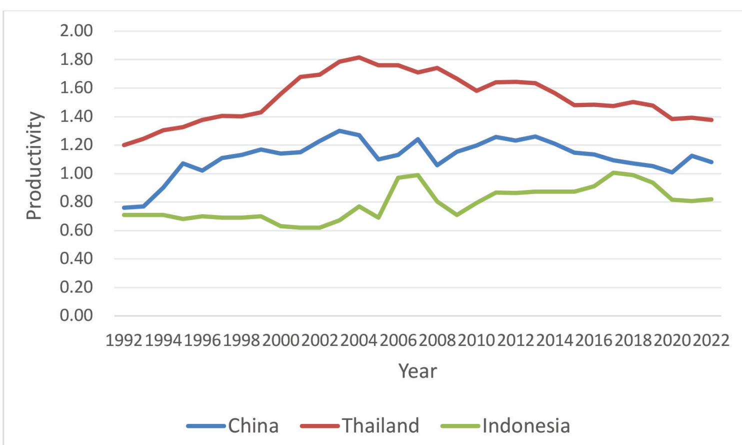

Figure 2: Natural rubber productivity in China, Thailand, and Indonesia
Source: FAOSTAT (1992 to 2022)

China's natural rubber industry is mainly composed of state-owned rubber enterprises and private rubber enterprises. The state-owned rubber enterprises mainly include the Hainan state-owned rubber enterprise, the Yunnan state-owned rubber enterprise, and the Guangdong state-owned rubber enterprise.

From the rubber tapping area perspective, Figure 3 and Figure 4 depict that the rubber tapping area of state-owned rubber enterprises in China accounts for 45% of the total amount of rubber tapping in China. Conversely, in the rubber tapping area distribution of state-owned rubber enterprises in China, Hainan state-owned rubber enterprise accounts for 56%, making it the largest state-owned rubber enterprise in the rubber tapping area in China.

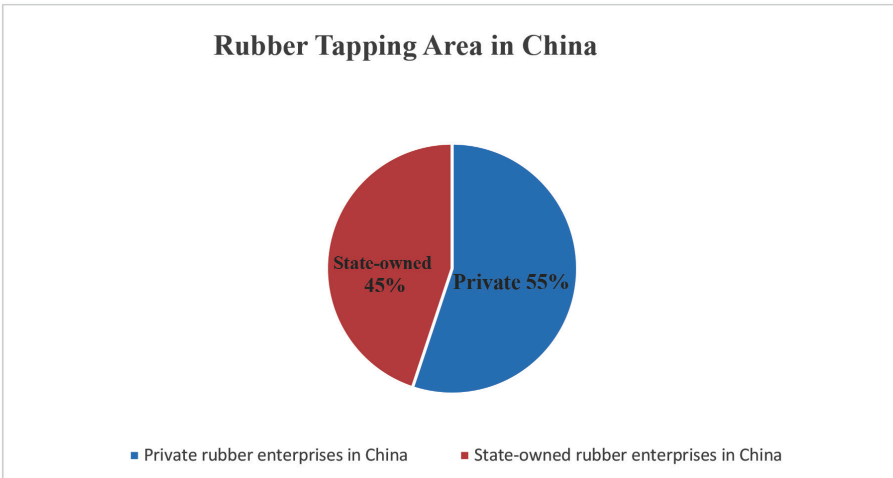

Figure 3: Rubber tapping area in China
Source: China Rubber Statistics (2022)

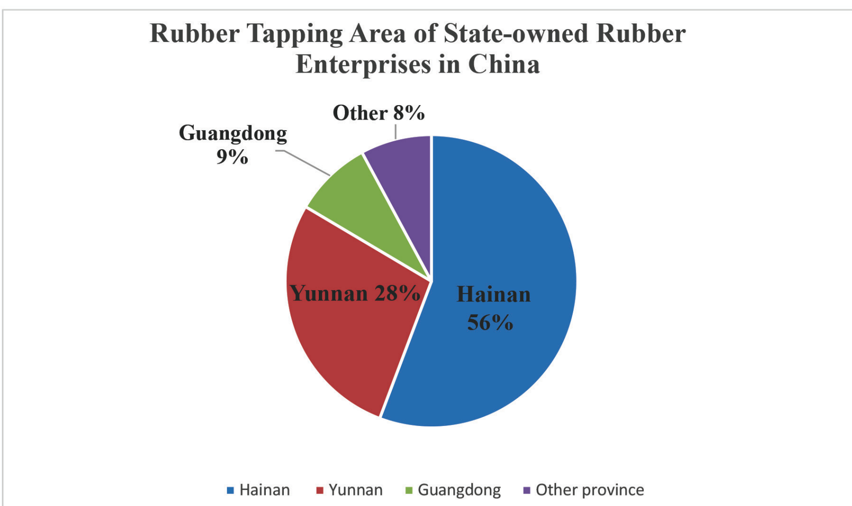

Figure 4: Rubber tapping area of state-owned rubber enterprises in China
Source: China Rubber Statistics (2022)

In 2022, China's overall natural rubber production reached 814,000 tonnes, with a rubber tapping area spanning 782,000 hectares (China Rubber Industry Association, 2022). Remarkably, state-owned rubber enterprises contributed 322,000 tonnes to the total production, covering 355,000 hectares, representing 40% and 45% of the national figures, respectively (China Rubber Industry Association, 2022). Among these, Hainan, the largest of China's three state-owned natural rubber production bases, accounted for 116,000 tonnes of rubber in 2022, encompassing 198,000 hectares (China Rubber Industry Association, 2022). This constitutes 14.3% and 25.3% of the country's total, respectively. This suggests that Hainan state-owned rubber enterprise natural rubber production accounted for the main part of the total production of natural rubber. Thus, the Hainan state-owned rubber enterprise's natural rubber research is of great significance.

In addition to the overall data on natural rubber production and tapping area, it is imperative to analyse the productivity of state-owned natural rubber enterprises across various provinces, with a particular emphasis on Hainan. As depicted in Figure 5, Hainan's state-owned rubber enterprises generally exhibited higher productivity than Guangdong, yet, it is lower than Yunnan from 1992 to 2022. However, between 2018 and 2022, Hainan's state-owned enterprises experienced a marked decline in productivity, ultimately becoming the lowest among the three provinces. Specifically, Hainan's productivity was 0.57 t/ha in 2018 and marginally improved to 0.59 t/ha by 2022. During this period, Hainan's productivity fell below that of Guangdong, which reported a productivity of 0.84 t/ha in 2022. This trend highlights a significant shift, indicating that Hainan's state-owned natural rubber enterprises, which previously demonstrated relatively higher productivity, now confront challenges. Moreover, in 2022, the productivity of Hainan's state-owned rubber enterprises was 0.59 t/ha, significantly lower than the national average of 1.05 t/ha (China Rubber Industry Association, 2022). This discrepancy underscores the inefficiency in Hainan's state-owned rubber production, making it crucial to investigate the factors contributing to this lower productivity.

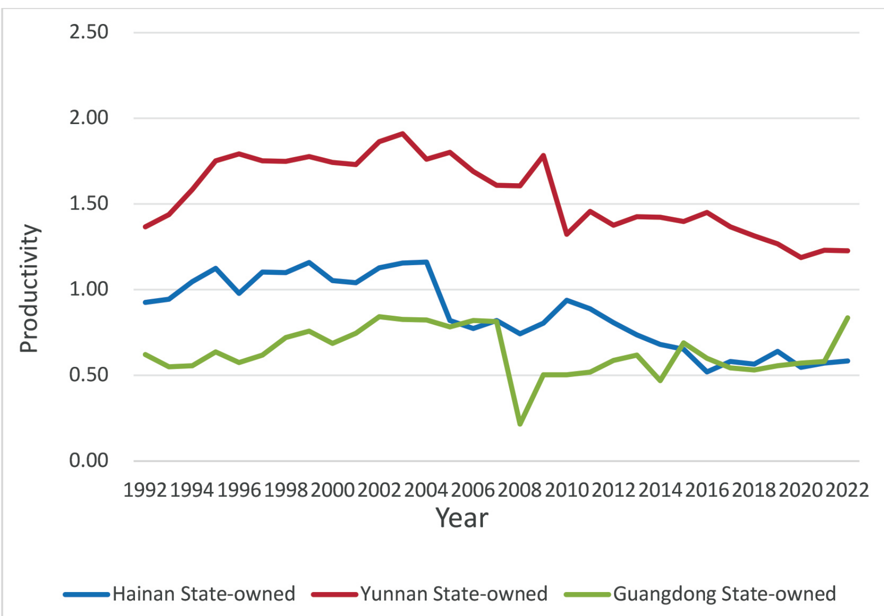

Figure 5: Natural rubber productivity of state-owned rubber enterprises in China
Source: China Rubber Statistics (1992 to 2022)

This research aims to examine the Technical Efficiency (TE) and identify the factors contributing to rubber production inefficiency at Hainan state-owned rubber enterprises. Previous studies such as those by Zheng and Chang (2018) analysed the TE of Hainan state-owned rubber farms, focusing on specific operational modes and using limited variables like rubber tapping area and labour input. However, their study was restricted to data from a single year (2018) and did not account for long-term trends in TE. Similarly, Chen *et al*. (2023) explored the green production efficiency of Hainan's natural rubber farmers.

Nonetheless, their research was focused on small-scale farmers and neglected the unique challenges faced by state-owned enterprises over an extended period. These studies, while valuable, do not sufficiently address the long-term efficiency dynamics and inefficiency factors in state-owned rubber enterprises. Therefore, this study leverages 37 years of data to fill this gap, providing a comprehensive multi-decade analysis of TE. Specifically, this study employs the Stochastic Frontier Analysis (SFA) model, an established method for measuring efficiency and identifying factors contributing to inefficiency. By analysing these factors using SFA, this research offers recommendations for optimising production factors and improving TE in Hainan's state-owned rubber enterprises.

Literature Review

Theoretical Background

To study the contribution of technological progress to economic growth, Solow (1957) assumed that all the input elements in economic growth were fully utilised. However, this assumption did not conform to the economic growth law of the real world. To solve this paradox, Farrell (1957) innovatively proposed the concepts of production efficiency and configuration efficiency (allocative efficiency) to analyse and study the impact of technological progress on economic growth. Meanwhile, Fried *et al*. (1993) defined production efficiency as the ratio of minimum input to actual input under a given output level or the ratio of actual output to maximum output under a given level of input factors. As such, allocation efficiency is defined as achieving the optimal combination of inputs (outputs) given a given factor price. Since the actual economy does not always meet the conditions of perfect competition assumed in theoretical research, it is not easy to accurately obtain and measure the prices of various factors of economic growth. Considering that production efficiency is easier to measure than allocation efficiency, in real life, production efficiency is often used as an indicator to measure the impact of technological progress on economic growth.

The theory of TE was founded by Farrel *et al*. in the 1950s. Farrel (1957) proposed decomposing economic efficiency into TE and allocation efficiency and provided a clear conceptual definition of TE. Accordingly, TE refers to the premise that the output scale and price level remain unchanged. At the same time, the input factors change according to the established ratio, the ratio between the minimum amount of factor input that can be achieved and the actual amount of factor input. In other words, from the investment perspective, the ratio between the minimum cost and the actual cost that the production activity can ultimately achieve is TE.

Empirical Review

This research is based on the actual development of natural rubber in the Hainan state-owned rubber enterprise. It examines the TE of natural rubber production in the Hainan state-owned rubber enterprise and the factors influencing inefficiency.

Many previous studies have measured TE, focusing on the agricultural sector, notably the rubber manufacturing industry. In a study conducted in Malaysia, the efficiency levels were evaluated and the factors contributing to inefficiencies in the rubber manufacturing sector were identified (Abdullah *et al*., 2020). Their findings revealed an average TE level of 92%, with factors such as capital-labour ratios, wage rates, and firm size playing significant roles in minimising inefficiencies. Another Malaysian study discovered a positive correlation between the number of households, extension agent visits, knowledge of improved technology, and the productivity and TE of smallholders (Aliyu *et al*., 2017). Furthermore, Aliyu *et al*. (2018) conducted a parametric efficiency analysis of rubber production in Malaysia, reporting TE scores of 0.70, 0.77, and 0.72 for all-age, matured-age, and old-age crop categories, respectively. The study concluded that rubber latex productivity peaked during the matured-age category and declined in the old-age category. In addition, Radam *et al*. (2012) conducted a study measuring TE levels in the Malaysian rubber industry, reporting an average efficiency of 70.33%. Therefore, this suggests that the sampled rubber industry in Malaysia operated at 70.33% of its potential output, as defined by the best-performing entities in the industry.

In addition to its application in the rubber industry, TE is employed in diverse areas. For instance, Izon *et al*. (2018) conducted a study on the healthcare system in the USA while Feng *et al*. (2007) investigated efficiencies within the transport sectors. According to the findings of Gayosa *et al*. (2014), the average TE score for selected manufacturing industries over an extended period was 82.63%. This implies that to reach peak efficiency, these industries could lower their input consumption such as raw materials, capital, and operational costs, by 17.37% without reducing their current output. Hamdan *et al*. (2019) reported an average TE score of 0.89 for enterprises. Collectively, the study's results highlight the significant determinants of technical inefficiency, primarily linked to employee wage rates.

Education was identified as a factor positively influencing inefficiency, as indicated by Radulovic and Dragutinovic (2015). However, this does not necessarily imply that educated workers are inherently more efficient than their less-educated counterparts. Li (2022) revealed a negative impact of farmers' years of education on their green productivity, suggesting that higher levels of education may not necessarily translate to significant benefits for agricultural workers. Hence, it is imperative to enhance non-academic education for farmers, focusing on skills training, to effectively enhance their vocational capabilities.

Meanwhile, Latifah *et al*. (2021) concluded that enhancing skills training for farmers, particularly when they are well-versed in technological changes can increase agricultural yield. Conversely, Tun and Kang (2015) noted that farm operators with lower education levels tended to have lower efficiency scores. This implies that increased investment in private and public education could contribute to notable improvements in the agricultural sector. A study conducted by Aboaba (2020) revealed a positive impact of farmers' level of education on their productivity. The farmers are encouraged to strengthen the existing association structures and organise new farmers' associations for the common benefit.

The density of rubber trees per area was determined to negatively impact technical inefficiency, suggesting that increasing the number of natural rubber trees planted per area can enhance TE (Mustapha, 2011). The study focused on assessing the performance of rubber smallholders supervised by RISDA personnel in the Besut District, Malaysia. This top-down supervision aims to enhance smallholder productivity, efficiency, and prospects for commercialisation. Moreover, the study presents TE scores for Cobb-Douglas and Translog stochastic frontier estimates of the rubber smallholders' estate in Besut. In particular, the average TE score for the entire estate is 0.832 (Cobb-Douglas). For those achieving higher levels of TE, the observed change may have contributed to increased income levels and improvements in family needs, health, productivity, expenditures, and consumption patterns, ultimately enhancing their overall quality of life.

The study on the TE of the rubber manufacturing industry is limited in China. One study by Li (2014) investigated the production efficiency of Guangdong state-owned rubber enterprise natural rubber. From 1992 to 2012, the average TE of Guangdong state-owned rubber enterprise natural rubber production was 0.9303, demonstrating a downward trend year by year. The main reason is that from 1992 to 2012, Guangdong had an inefficiency of scale, which was an unreasonable allocation of resource investment. Thus, it is essential to allocate resources more effectively to enhance the TE of natural rubber production. Specifically, increasing investment in areas that demonstrate increasing returns to scale while reducing investment in areas with decreasing returns to scale can lead to significant improvements in TE.

Methodology

This study utilises 37 years of annual data to examine the TE of natural rubber production in the Hainan state-owned rubber enterprises and the factors influencing inefficiency. The data is the input and output data of the Hainan state-owned rubber enterprise natural rubber, which can be obtained from the Compilation of Statistics of the Hainan Annual Report.

This study utilises the SFA approach to assess the TE of natural rubber production in Hainan's state-owned rubber enterprises. Over the past two decades, the SFA method has been extensively used to analyse TE. In this study, the models developed by Battese and Coelli (1995) are employed, which build upon the foundational work of Aigner *et al*. (1977). Correspondingly, the SFA model assesses inefficiencies in production and accounts for random fluctuations beyond the producer's control that may influence output. Moreover, this method is adaptable to environmental factors, making it highly flexible for different type of analyses (Fahmy-Abdullah *et al*., 2017). The SFA approach also assists in identifying data inconsistencies during the analysis process. Additionally, it can detect unpredictable external factors that impact production outside the manufacturer's direct control (Fahmy-Abdullah *et al*., 2017).

The original SFA formulation was initially designed for production models that focused on cross-sectional data. This specification accounts for errors as a combination of two distinct components: One capturing random effects (v) and the other representing technical inefficiencies (u). This foundational approach can be traced back to in-depth studies such as those by Forsund *et al*. (1980), Schmidt (1985), Bauer (1990), and Greene (2008). Kumbhakar (1990) and Battese and Coelli (1995) later developed a simplified model for estimating inefficiencies. Specifically, Battese and Coelli (1995) introduced an SFA model that incorporates the assumption that inefficiency effects follow a truncated normal distribution. This model proposed by Battese and Coelli (1995) can be expressed as follows:

$$Y_i = X_i + (V_i - U_i) \tag{1}$$

where Y_i is the logarithm for the production of the i-th firm (i = 1,2,…, N) and X_i is the (k x 1) vector that reflects the transformation of input quantities for the i-th firm. Meanwhile, β is the (k x 1) vector of unknown parameters. U_i is a non-negative random variable, representing the technical inefficiency, which is assumed to be independently distributed as truncations at zero of the N (μ, σ_u^2) distribution. Moreover, V_i is a random error assumed to be iid N (0, σ_u^2), where $\mu = Z_i\ \delta$ and variance σ_u^2. Z_i is the (1 × p) vector containing explanatory variables related to technical inefficiency in the rubber manufacturing sector over time, where δ is a (p × 1) vector of unknown parameters.

Equation (1) specifies the stochastic frontier production function in terms of the original production values. However, the technical inefficiency effect, U_i is assumed to be a function of a set of explanatory variables, Z_i, and an unknown vector of unknown parameters. The coefficient of the frontier and inefficiency effect model in Equation (1) can be measured using the Maximum Likelihood Method (MLE). Battese and Broca (1997) replaced parameters σ_v^2 and σ_u^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2 = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ (Coelli & Battese, 1996), which has a value between 0 and 1. If $H_0 = 0$ is rejected, it indicates that deviations from the frontier are due to technical inefficiency and the null hypothesis of no inefficiency is rejected. To evaluate the null hypothesis, the Likelihood Ratio (LR) test (generalised LR) L is applied with the following test statistic:

$$\lambda=-2\{\ln[L(H0)]-\ln[L(H1)]\}. \quad (1)$$

The likelihood functions $L(H_0)$ and $L(H_1)$ correspond to the null hypothesis and the alternative hypothesis, respectively. If the LR test rejects the null hypothesis H_0 (where H_0: $\delta = 0$), the model without a time factor will be applied, as outlined in the Battese and Coelli (1988) model. These two model specifications have been extensively applied in previous research to estimate TE values collectively. The TE for the i-th firm is calculated as the ratio of its actual output to its potential maximum output, expressed as follows:

$$TEi=E[\exp(-U_i)] \quad (3)$$

Since U_i is a non-negative variable, the efficiency lies between zero value and one. A firm is technically efficient if the TE value is equal to one (i.e., the firm has an ineffective effect equal to zero). In this study, the Transcendental Logarithmic (Translog) approach is utilised as outlined by Coelli *et al*. (2005). The hypothesis test is performed to identify the most suitable model by selecting the optimal MLE. The SFA model, based on the Translog function, is expressed as follows:

$$\ln Y_i=\beta_{0+}\sum_{j}^{n}{}_{=1}\beta_j \ln X_{ij+}\frac{1}{2}\sum_{j}^{n}\sum_{j}^{n}\beta_{ji}\ln Xij+(V_i-U_i) \quad (4)$$

where Y_i is the log of the observed output of the i-th establishment, X variables are the log of inputs, while subscripted j and i dictate the inputs. In Equation (4), Y_i is the output and the three inputs are the values of capital (K_i), labour (L_i), and land (D_i).

The first objective of this study is to measure the level of TE of natural rubber production in Hainan state-owned enterprises. The R language program developed by Battese and Coelli (1995) analyses the data. Meanwhile, the second objective is to determine the technical inefficiency of natural rubber production in Hainan state-owned enterprises. The variables involved in the technical inefficiency of the SFA model are as follows:

$$U_i=\delta_0+\delta_1 Ed+\delta_2 Ex+\delta_3 Rt \quad (5)$$

where Ui represents technical inefficiency.

Ed: Denotes the level of education of a worker, measured in years of schooling. Education is a variable since previous studies such as those by Radulovic and Dragutinovic (2015), have indicated its complex relationship with efficiency. Note that higher education can enhance knowledge and skills. However, it does not always correlate with increased productivity in agricultural contexts (Li, 2022).

Ex: Reflects the experience of workers, quantified by the number of years spent in the rubber industry. This variable is included based on the premise that experience can influence TE, as indicated in existing literature (Aliyu *et al*., 2017). Hence, understanding the role of experience is crucial for identifying inefficiency in production.

Rt: Represents the number of rubber trees per hectare of the tapping area. Research has suggested that higher tree density can enhance TE (Mustapha, 2011), indicating that increasing the number of rubber trees per area is associated with improved productivity and overall efficiency in rubber production (Hainan State-owned Rubber Annual Report, 1986-2022).

Results and Discussion

The average output of natural rubber for Hainan state-owned rubber enterprise is 158,300 tonnes, which are presented in Table 1. At the same time, capital is the main expenditure of manufacturing, with an average expenditure of RMB246.2 million (US$34.3 million). In addition, the average number of tapping workers is 73,200 people. At the same time, the average tapping area of rubber land is 182,684 hectares. In addition, the average years of education for workers is 7.84 years and the average working experience of workers is 9.39 years. Finally, regarding rubber tree planting, the average number of rubber trees per tapping area is 313.58.

The generalised LR test indicates that the first null hypothesis is rejected in favour of the Translog production model, as summarised in Table 2. After determining the appropriate production model, the Translog model was utilised to conduct another generalised LR test regarding the second hypothesis: "no inefficiency effect". This hypothesis was assessed to confirm the significance of the inefficiency effect in analysing TE and the second null hypothesis was also rejected.

Prior to conducting the generalised LR tests, the following hypotheses were formulated:

Hypothesis 1: Regarding the choice between the Cobb-Douglas and Translog production models.

H_0: The Cobb-Douglas production model is preferred.

H_1: The Translog production model is preferred.

Hypothesis 2: Regarding the presence of inefficiency in the TE analysis.

H_0: There is no inefficiency effect.

H_1: There is an inefficiency effect.

Using the Translog production model, SFA was conducted to measure TE. Table 3 indicates that the average level of TE is as much as 0.904. This indicates that approximately 9.6% of output is lost due to the Hainan state-owned rubber enterprise's inability to optimally combine available inputs. Moreover, it suggests there is potential for about a 9.6% improvement in TE through better utilisation of existing technology.

This study further discussed the result of SFA using the Translog production model. The Translog production model was estimated by maximum likelihood. A gamma value of 0.999 indicates that technical inefficiency was 99.9% affected by this set of factors (Table 3). This proved that technical inefficiency significantly impacts the production of natural rubber at the same level as the change in the Hainan state-owned rubber enterprise.

Table 1: Summary statistics of selected variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Output	15.83	3.98	9.50	23.32
Land	18.27	1.98	13.06	20.95
Labour	7.32	2.46	5.13	12.29
Capital	24.62	13.32	6.90	57.60
Education	7.84	0.88	6.20	8.80
Experience	9.39	2.50	3.80	11.60
Rubber trees per area	313.58	10.00	296.52	335.19

Table 2: Generalised LR test of hypothesis for the stochastic production model

Test of the Null Hypothesis	Log Likelihood of H0	Log Likelihood of H1	Test Statistic, Λ	DF	Critical Value at 10%	Decision
Cobb Douglas is preferred	76.07	88.25	24.36	6	10.645	Reject H0
No inefficiency effect	56.24	88.25	64.00	5	8.574	Reject H0

The findings regarding the factors contributing to technical inefficiency are summarised in Table 3. A negative coefficient derived from the analysis indicates that an increase in the corresponding factor leads to a decrease in inefficiency within the Hainan state-owned rubber enterprise. In contrast, a positive coefficient suggests an increase in the inefficiency of natural rubber production.

The coefficient for education is estimated to be positive and highly significant, with statistical significance at the 1% level, highlighting that higher education is often associated with increased knowledge, skills, and critical thinking abilities. However, it does not guarantee better job performance in all cases. This finding was consistent with previous findings (Radulovic & Dragutinovic, 2015; Li, 2022). Note that this situation may arise from a potential mismatch between the educational levels of workers in state-owned rubber enterprises and their production efficiency. In this context, moderation refers to the harmonious relationship between education levels and economic and social development. Such a well-aligned relationship is advantageous for enhancing workers' production efficiency, ecological consciousness, and the implementation of eco-friendly practices. Despite improvements in the agricultural production environment with the economic and social development of rural China, the departure of highly educated farmers has resulted in a generally low level of education among workers remaining in state-owned rubber enterprises.

Table 3: Estimated translog production and inefficiency model

Variable	Coefficient	Standard Error	t-statistic
Constant	-3.328	0.668	0.000***
Ln(land)	2.546	0.498	0.000***
Ln(labour)	4.070	0.302	0.000***
Ln(capital)	0.750	0.404	0.063*
Ln(land)2	-0.835	0.538	0.120
Ln(labour)2	-1.788	0.128	0.000***
Ln(capital)2	-0.240	0.1366	0.079*
Ln(land)*Ln(labour)	0.350	0.282	0.215
Ln(land)*Ln(capital)	0.692	0.312	0.027*
Ln(labour)*Ln(capital)	-1.360	0.315	0.000***
Inefficiency Model:			
Education	0.274	0.034	0.000***
Experience	-0.029	0.019	0.012
Rubber trees per area	-0.006	0.001	0.000***
Sigma-squared	0.002	0.034	0.001***
Gamma	0.999	0.001	0.000***
Log Likelihood	88.25		
Mean Efficiency	0.904		

*Statistically significant at 0.1 level
**Statistically significant at 0.05 level
***Statistically significant at 0.01 level

Moreover, the educational level of the workforce does not align with the current level of economic and social development. Consequently, pursuing higher education does not necessarily translate into increased production efficiency or a shift in the agricultural mode of production. Instead, it emphasises the significance of an education level commensurate with the ongoing economic development, which serves as the foundation for efficiency growth (Li, 2022).

Meanwhile, the presence of externalities introduces a discrepancy between private and social returns on education, potentially hindering the role of education in promoting economic development. While research indicates that education can enhance the efficiency of natural rubber production, it is essential to recognise that natural rubber production encompasses not only anticipated outcomes but also unforeseen consequences. Workers in state-owned rubber enterprises employing novel agricultural techniques to boost natural rubber production may overlook the unintended outputs of the production process.

For instance, developing and applying pesticides can significantly combat agricultural pests, increasing natural rubber production. However, the prolonged use of pesticides can lead to environmental pollution, generating substantial non-economic external effects. Guided by the assumption of the rational economic individual, workers may prioritise output expansion without considering the environmental pollution stemming from agricultural production. Consequently, in certain instances, elevated levels of education may empower state-owned rubber enterprise workers to adopt new technologies and enhance natural rubber production. Although it benefits rubber enterprises, it can also have adverse consequences for society (Li, 2022).

The coefficient for the experience of workers is negative but not statistically significant, indicating that, within the context of this study, years of experience in the rubber industry do not substantially impact technical inefficiency. These results contradict the previous findings that experience significantly affects technical inefficiency (Aliyu *et al*., 2017).

The coefficient of rubber trees per area is negative and statistically significant at a 1% significance level. Notably, the negative sign of rubber trees per area representing an increase in the intensity of trees will decrease technical inefficiency. Therefore, the Hainan state-owned rubber enterprise should increase the intensity of planting rubber trees by reducing the technical inefficiency to increase natural rubber production, and the finding was consistent with the finding (Mustapha, 2011). When the number of natural rubber planting trees per area increases, the growth height of rubber trees will increase, and more effective rubber trees per area can be preserved, increasing TE.

Conclusions

This research examines the TE level and analyses the factors determining the technical inefficiency of Hainan state-owned rubber enterprise rubber production. The results reveal that the average TE of Hainan state-owned rubber enterprise natural rubber production is 90.4%. Subsequent results suggest that technical inefficiency factors, including education and rubber trees per area play an essential role in inefficiency.

At present, the core of measuring the development of natural rubber on state-owned rubber enterprises in Hainan is still the increase of output, which depends on the increase of natural rubber productivity. Thus, to increase the production rate of the state-owned rubber enterprise in Hainan, some areas to be focused on are as follows.

First, to stimulate and improve efficiency and productivity, the Hainan state-owned rubber enterprise should prioritise providing workers with skills training that aligns with economic development rather than focusing solely on improving educational attainment (Latifah *et al*., 2021; Li, 2022). Note that pursuing higher education does not guarantee increased productivity or a transformation in the agricultural mode of production. For instance, offering training and education in operational skills is crucial, as workers who are unfamiliar with operational processes possess inadequate skills or use improper methods may result in subpar work quality in the rubber industry. Additionally, this lack of proficiency may also contribute to a deficient safety culture. In response, rubber production enterprises have established educational facilities that regularly educate workers on technical knowledge and provide training in safety operation skills. This approach ensures that workers are well-versed in the operation of new equipment, technologies, and materials, enabling them to effectively learn and master the required skills for formal operations.

For the rubber industry, the number of trees per area is worth further study. In this study, an increase in tree density will increase TE. Therefore, the Hainan state-owned rubber enterprise should increase the intensity of planting rubber trees by increasing TE to increase rubber production. Nevertheless, further studies are required to investigate whether the current planting strategy should be revised by increasing the number of trees per area and the optimal number of plants. From the perspective of production inputs, further research on how the production material input indicators of organic fertilisers, ethylene, and sulfur powder impact the TE of Hainan rubber production is worthy.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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