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Determinants of Tea Production in Indonesia, 1990–2023: An Error Correction Model (ECM) Approach

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Abstract

Indonesian tea production showed a declining and fluctuating trend during 1990–2023, while studies that simultaneously examine the effects of plantation area, tea prices, and tea exports on production in both the short and long run remain limited. This study aims to analyse the effects of plantation area, tea prices, and tea exports on Indonesian tea production. A quantitative approach with a time-series design was employed using 34 annual observations covering the study period. Secondary data were obtained from BPS-Statistics Indonesia, the Food and Agriculture Organization, the World Bank, and other official sources. The data were analysed using the Error Correction Model through stationarity testing, cointegration testing, multicollinearity assessment, and long- and short-run estimations. The results show that all variables were integrated at first difference and cointegrated in the long run. Plantation area, tea prices, and tea exports had positive and significant effects on tea production in the long run, whereas only tea exports had a significant effect in the short run. The negative and significant Error Correction Term indicates a rapid adjustment toward long-run equilibrium. These findings contribute to plantation economics by clarifying the temporal dynamics of production determinants in Indonesia's tea sector. The

study implies that land optimisation, stronger price incentives, and improved export competitiveness are essential to strengthening tea production performance and supporting the sustainability of the national plantation industry.

Keywords: Indonesian Tea Production; Plantation Area; Tea Prices; Tea Exports; Error Correction Model

INTRODUCTION

Tea is an economically important plantation commodity that supports employment, rural household income, agro-processing industries, and foreign exchange earnings in producing countries. Global demand for tea remains substantial as consumption continues to expand across both traditional and emerging markets. Tea production is largely concentrated in Asia and Africa, particularly in China, India, Kenya, Sri Lanka, Vietnam, and Indonesia. Competition among producing countries has also intensified, extending beyond production volume to product quality, certification, supply-chain efficiency, sustainability, and market diversification. These developments require tea-producing countries to improve productivity and competitiveness in order to maintain their position in the international market (Nations, 2024).

Indonesia remains one of the world's tea-producing and exporting countries. Nevertheless, the national tea industry has faced persistent structural challenges, particularly declining plantation area, production, and export volume. Data for the 1990–2023 period indicate that Indonesian tea production did not follow a consistent growth pattern. Production increased during the earlier years of the observation period but subsequently declined alongside the contraction of tea plantation areas and weakening export performance. This trend deserves attention because a continuing reduction in production capacity may affect the availability of raw materials for the processing industry, reduce plantation income, and weaken Indonesia's position in the global tea trade (Bank, 2024; Harahap et al., 2023; Nations, 2022).

Table 1. Trends in Indonesian Tea Production, Plantation Area, Tea Prices, and Tea Exports, 1990–2023

Year	Tea production (tons)	Plantation area (ha)	Tea price*	Tea exports (tons)
1990	155,919	129,080	5,560	110,963
1995	154,013	152,431	7,052	79,227

Year	Tea production (tons)	Plantation area (ha)	Tea price*	Tea exports (tons)
2000	162,587	153,675	27,946	105,582
2010	156,604	122,898	60,813	87,101
2015	132,615	114,891	64,200	61,915
2020	128,016	112,308	104,600	45,265
2023	122,680	99,757	104,600	35,971

Source: BPS-Statistics Indonesia (2024), FAOSTAT (2024), and World Development Indicators (2024), processed by the authors.

As presented in Table 1, Indonesian tea production reached 155,919 tons in 1990 and increased to 162,587 tons in 2000. It subsequently declined to 122,680 tons in 2023. Over the same period, the tea plantation area decreased from 129,080 hectares to 99,757 hectares. Tea exports also fell sharply, from 110,963 tons in 1990 to 35,971 tons in 2023, whereas tea prices generally moved upward. These contrasting movements suggest that higher prices have not automatically resulted in greater production. The decline in plantation area and export volume may reflect broader problems related to production capacity, land productivity, product quality, operational efficiency, and the ability of Indonesian producers to respond to international market demand. Previous studies have similarly reported that Indonesian tea faces increasing competitive pressure from other producing countries, although certain tea products continue to possess comparative advantages in selected markets (Cakra & Munandar, 2020; Muflihah et al., 2023; Nursodik et al., 2021).

The relationship between plantation area and tea production can be explained through production theory, which regards land as a fundamental input in agricultural activities. An expansion of productive land, assuming that technology and other inputs remain constant, is expected to increase potential output. Conversely, a reduction in plantation area may limit production capacity, particularly for perennial crops that require specific land conditions and relatively long cultivation periods. Mankiw (2021) and Alrehaili et al. (2024) and Herzberg et al. (2011) argue that changes in the quantity and quality of production inputs influence the amount of output that producers can generate. Empirical evidence from tea farming further indicates that land conditions, soil moisture, pruning cycles, input use, and technical efficiency are closely associated with tea yields (Tran et al., 2021; Wulansari et al., 2022). The continuing reduction in Indonesia's tea plantation area may therefore be an important factor behind the long-term decline in national tea production.

Price also plays an important role in production decisions because it signals the potential returns available to producers. According to supply theory, an increase in

commodity prices creates an incentive to raise output because producers expect higher revenues. The production response of tea growers, however, may not occur immediately. Tea is a perennial crop that requires time for planting, maintenance, pruning, plant recovery, and yield improvement. Producers may also need to undertake additional investment or rehabilitate existing plantations before output can be increased. The effect of price is therefore likely to be more visible over the long run than in the short run. Previous research on Indonesian tea trade has shown that domestic and international prices may produce different effects depending on the period of analysis, production costs, market destinations, exchange-rate movements, and exporters' ability to respond to changing market conditions(Ganeswara, 2025; Nahdudin et al., 2025; Tarigan et al., 2021).

Tea exports represent international market demand and provide a channel through which global market conditions influence domestic production. Stronger export demand may offer greater market certainty and encourage farmers, plantation companies, and processing firms to maintain or expand their production capacity. By contrast, declining exports may weaken production incentives, particularly when the domestic market cannot fully absorb existing output. Nursodik et al. (2021) found that national production was closely associated with the volume of Indonesian tea exports. Muflihah et al. (2023) also reported that Indonesian tea retained a comparative advantage, although its position remained below that of several major producing countries. Evidence from specific export markets suggests that tea export performance is influenced by prices, competitiveness, exchange rates, economic conditions in destination countries, and compliance with international product standards (Darmashanty & Kuncoro, 2024; Ganeswara, 2025; Tarigan et al., 2021; Wedari & Hendrati, 2024). These findings point to a close relationship between domestic production, international demand, and Indonesia's trade performance.

Earlier studies on the tea industry have generally developed along two lines of inquiry. The first has focused on agronomic conditions and production efficiency. Wulansari et al. (2022) examined the relationship between land slope, pruning year, soil water content, and tea yield. Tran et al. (2021) demonstrated that input use, farm characteristics, technical efficiency, and environmental conditions affected tea production. Rahmawati et al. (2025) found that seasonal differences and rainfall patterns influenced the yield components of seed-derived tea plants. The second line of research has concentrated on exports and competitiveness. Cakra & Munandar (2020); Muflihah et al. (2023); Nahdudin et al. (2025); Nursodik et al. (2021); Wedari & Hendrati (2024) investigated comparative advantage, export

performance, market position, and factors affecting the competitiveness of Indonesian tea. Although these studies provide important evidence, agronomic production factors have often been examined separately from price and international trade dynamics.

A clear research gap therefore remains. Few studies have treated Indonesian tea production as the main dependent variable while simultaneously examining plantation area, tea prices, and exports within a dynamic empirical model. Much of the existing literature has relied on competitiveness indices, panel-data regression, linear regression, or trade-performance measures, with export volume commonly used as the principal outcome. Ningrum & Agustini (2025), for example, applied an Error Correction Model to examine the determinants of Indonesian tea exports, but their analysis focused on export volume rather than national production. This distinction is important because agricultural and economic time-series variables often display long-term trends as well as short-term deviations that cannot be adequately captured by a static regression model. The Error Correction Model makes it possible to estimate long-run equilibrium relationships while also identifying short-run adjustments following changes in economic conditions (Wooldridge, 2020).

The novelty of this study lies in integrating a production-related factor, represented by plantation area, with economic factors, represented by tea prices and exports, to explain changes in Indonesian tea production over the 1990–2023 period. Rather than examining production conditions and trade performance separately, the study evaluates how these variables operate within a single dynamic framework. The model also distinguishes immediate responses from long-term effects and measures the speed at which production returns to equilibrium after short-run disturbances. This approach provides a more comprehensive account of the structural and market-related forces shaping the Indonesian tea industry.

Accordingly, this study examines the effects of plantation area, tea prices, and tea exports on Indonesian tea production from 1990 to 2023 using an Error Correction Model. The analysis is intended to identify long-run equilibrium relationships, estimate short-run effects, and determine the speed of adjustment toward equilibrium. The findings are expected to enrich empirical research in agricultural and plantation economics and to provide evidence for policies concerning plantation-land protection, price incentives, productivity improvement, and the strengthening of Indonesia's tea export markets.

METHODS

This study employed a quantitative approach using annual secondary time-series data covering the period from 1990 to 2023. The quantitative approach was selected because the study aimed to measure the direction and magnitude of the relationships among Indonesian tea production, tea plantation area, tea prices, and tea exports through statistical estimation. Quantitative research is appropriate for examining relationships among measurable variables using numerical data and statistical procedures (Creswell & Creswell, 2018). The study adopted an explanatory time-series design because it examined changes and dynamic relationships among variables over a specific period. The population consisted of all annual national data on Indonesian tea production, tea plantation area, tea prices, and tea exports from 1990 to 2023. All available data were included through a census or total sampling technique, resulting in 34 annual observations. The dependent variable was Indonesian tea production, while the independent variables were tea plantation area, tea prices, and tea exports.

The study used secondary data collected through documentation. The data were obtained from BPS-Statistics Indonesia, the Food and Agriculture Organization through FAOSTAT, the World Bank through the World Development Indicators, and other relevant official sources. Indonesian tea production and tea exports were measured in tons, tea plantation area was measured in hectares, and tea prices were measured in US dollars per kilogram. The data were compiled annually, arranged chronologically, and verified by comparing figures across official databases and publications. Because the study relied on secondary statistical data rather than questionnaires, interviews, or observational instruments, conventional validity and reliability tests were not required. Data quality was maintained through source verification, examination of data completeness, comparison of variable definitions, and consistency checks on measurement units. All variables were transformed into natural logarithms to reduce differences in scale, stabilise data variation, and enable the coefficients to be interpreted as elasticities.

Data analysis was conducted using Stata 17 and the Error Correction Model developed by Engle and Granger (1987). The analysis began with descriptive statistics, followed by the Augmented Dickey-Fuller test to examine the stationarity of each variable. The Engle-Granger cointegration test was subsequently applied to determine whether a long-run equilibrium relationship existed among the variables. Gujarati and Porter (2009) and

Wooldridge (2020) explain that the ECM is appropriate when time-series variables are non-stationary at level, stationary at the first difference, and cointegrated. The long-run model was formulated as follows:

$$LnPRODt = \beta 0 + \beta 1 LnAREAt + \beta 2 LnPRICEt + \beta 3 LnEXPORTt + \varepsilon t$$

LnPROD represents the logarithm of Indonesian tea production in tons, LnAREA represents the logarithm of tea plantation area in hectares, LnPRICE represents the logarithm of Indonesian tea prices in US$/kg, LnEXPORT represents the logarithm of Indonesian tea exports in tons, β_0 is the constant, β_1, β_2, and β_3 are the regression coefficients of the respective independent variables, and ε is the error term. The short-run relationship was estimated using the following Error Correction Model:

$$\Delta LnPRODt = \alpha 0 + \alpha 1 \Delta LnAREAt + \alpha 2 \Delta LnPRICEt + \alpha 3 \Delta LnEXPORTt + \lambda ECTt - 1 + \mu t$$

ΔLnPROD represents the change in the logarithm of Indonesian tea production, ΔLnAREA represents the change in the logarithm of tea plantation area, ΔLnPRICE represents the change in the logarithm of Indonesian tea prices, and ΔLnEXPORT represents the change in the logarithm of Indonesian tea exports. Furthermore, α_0 is the short-run constant, α_1, α_2, and α_3 are the short-run coefficients, ECT_{t-1} is the Error Correction Term from the previous period, λ is the error correction coefficient or speed of adjustment, and μ is the error term. Hypothesis testing was conducted using the t-test to assess the partial effect of each independent variable, the F-test to examine their simultaneous effect, and the coefficient of determination (R^2) to measure the model's ability to explain variations in Indonesian tea production. Statistical significance was evaluated at the 5% level.

RESULTS

1. Descriptive Statistics

Descriptive statistical analysis was conducted to provide an overview of the characteristics and distribution of the research variables during the 1990–2023 period. The variables consisted of Indonesian tea production, tea plantation area, tea prices, and tea export volume. The descriptive statistics include the number of observations, mean, standard deviation, minimum value, and maximum value, as presented in Table 2.

Table 2. Descriptive Statistics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Tea production	34	150,254.90	13,813.36	122,680	169,821
Plantation area	34	130,257.30	16,852.51	99,757	157,039
Tea price	34	45,928.35	32,341.42	5,560	104,600
Tea exports	34	80,312.29	25,056.87	35,971	127,926

Source: Authors' calculations using Stata 17.

Table 2 shows that the average Indonesian tea production during the study period was 150,254.90 tons. The lowest production level was 122,680 tons, while the highest was 169,821 tons. The standard deviation of 13,813.36 tons indicates that annual tea production varied considerably throughout the observation period.

The average tea plantation area was 130,257.30 hectares, with a minimum of 99,757 hectares and a maximum of 157,039 hectares. Its standard deviation of 16,852.51 hectares reflects substantial changes in the area allocated to tea cultivation. These variations are consistent with the long-term contraction of tea plantations observed in Indonesia.

Tea prices had an average value of 45,928.35, ranging from 5,560 to 104,600. The relatively high standard deviation of 32,341.42 indicates that tea prices fluctuated considerably during the 34-year period. Meanwhile, the average volume of tea exports was 80,312.29 tons, with a minimum of 35,971 tons and a maximum of 127,926 tons. The standard deviation of 25,056.87 tons indicates considerable variation in Indonesia's annual tea export performance. Overall, the descriptive results confirm that the Indonesian tea industry experienced notable changes in production, plantation area, prices, and exports between 1990 and 2023.

2. Stationarity Test

Before estimating the Error Correction Model, the stationarity properties of all variables were examined using the Augmented Dickey–Fuller test. The test was performed at both the level and first-difference forms. The null hypothesis of the ADF test states that a variable contains a unit root and is therefore non-stationary. The results are presented in Table 3.

Table 3. Augmented Dickey–Fuller Stationarity Test Results

Variable	Level probability	First-difference probability	Order of integration
Ln Tea Production	0.4352	0.0000	I(1)
Ln Plantation Area	0.9875	0.0000	I(1)
Ln Tea Price	0.5420	0.0034	I(1)
Ln Tea Exports	0.8561	0.0000	I(1)

Table 3. Augmented DickeyFuller Stationarity Test Results shows that, at the level form, the probability values of all variables exceeded the 5% significance threshold. The null hypothesis of a unit root could therefore not be rejected, indicating that tea production, plantation area, tea prices, and tea exports were non-stationary at level. Non-stationary variables may produce spurious regression results when they are estimated directly without further transformation.

After the variables were transformed into first differences, all probability values fell below the 5% significance level. The probability values were 0.0000 for tea production, 0.0000 for plantation area, 0.0034 for tea prices, and 0.0000 for tea exports. The null hypothesis of a unit root was therefore rejected for all variables at first difference. These findings indicate that all variables were integrated of order one, or I(1), and met the basic requirement for further cointegration testing.

3. Cointegration Test

The Engle–Granger residual-based cointegration test was conducted to determine whether the variables shared a stable long-run equilibrium relationship. In this procedure, the residual generated from the long-run regression was tested for stationarity using the Augmented Dickey–Fuller test. The results are reported in Table 4.

Table 4. Engle–Granger Cointegration Test Results

Indicator	Value
ADF residual statistic	-5.660
Probability	0.0000
Significance level	0.05
Conclusion	Cointegrated

Source: Authors' calculations using Stata 17.

Table 4. Engle Granger Cointegration Test Results shows that the residual ADF statistic was -5.660, with a probability value of 0.0000. Because the probability value was lower than the 5% significance level, the null hypothesis that the residual contained a unit root was rejected. The residual generated from the long-run equation was therefore stationary.

This result confirms the existence of a cointegrating relationship among Indonesian tea production, tea plantation area, tea prices, and tea exports. Although the individual variables were non-stationary at level, they moved together toward a stable equilibrium over

the long run. Consequently, the Error Correction Model could be estimated to distinguish between long-run effects and short-run adjustments.

4. Multicollinearity Test

A multicollinearity test was performed to determine whether strong linear relationships existed among the independent variables. Severe multicollinearity can increase the standard errors of estimated coefficients and reduce the precision of statistical inference. The Variance Inflation Factor was used to assess multicollinearity. A VIF value below 10 is commonly interpreted as indicating the absence of serious multicollinearity (Gujarati & Porter, 2009). The results are presented in Table 5.

Table 5. Variance Inflation Factor Results

Variable	VIF
Ln Plantation Area	3.19
Ln Tea Exports	2.82
Ln Tea Price	2.16
Mean VIF	2.72

Source: Authors' calculations using Stata 17.

Table 5. Variance Inflation Factor Results shows that the VIF values ranged from 2.16 to 3.19. Plantation area had the highest VIF value of 3.19, followed by tea exports at 2.82 and tea prices at 2.16. The mean VIF value was 2.72. Because all VIF values were below the threshold of 10, no serious multicollinearity was detected among the independent variables.

These results indicate that plantation area, tea prices, and tea exports did not exhibit excessively strong linear relationships. Each variable could therefore be retained in the model to estimate its separate association with Indonesian tea production.

5. Long-Run Estimation Results

The long-run model was estimated to examine the effects of tea plantation area, tea prices, and tea exports on Indonesian tea production. Because all variables were expressed in natural logarithms, the estimated coefficients can be interpreted as long-run elasticities. The results are shown in Table 6.

Table 6. Long-Run Estimation Results

Variable	Coefficient	Standard error	t-statistic	Probability
Ln Plantation Area	0.4693	0.1088	4.31	0.000
Ln Tea Price	0.0289	0.0118	2.45	0.020
Ln Tea Exports	0.1334	0.0394	3.39	0.002
Constant	4.5931	1.1498	3.99	0.000

Model statistic	Value
R-squared	0.7812
Adjusted R-squared	0.7593
Probability of F-statistic	0.0000
Number of observations	34

Source: Authors' calculations using Stata 17.

Based on Table 6. Long-Run Estimation Results, the long-run equation can be written as follow

$$LnPROD_t = 4.5931 + 0.4693LnAREA_t + 0.0289LnPRICE_t + 0.1334LnEXPORT_t + \varepsilon_t \quad (1)$$

The coefficient of plantation area was 0.4693, with a probability value of 0.000. This result indicates that plantation area had a positive and statistically significant effect on tea production in the long run. A 1% increase in tea plantation area was associated with a 0.4693% increase in Indonesian tea production, holding the other variables constant. Among the independent variables, plantation area had the largest coefficient, indicating that it had the strongest long-run association with tea production.

Tea price had a positive coefficient of 0.0289 and a probability value of 0.020. Because the probability value was below 0.05, tea price had a statistically significant long-run effect on production. A 1% increase in tea prices was associated with a 0.0289% increase in tea production, other factors remaining constant. Although statistically significant, the magnitude of the price elasticity was relatively small.

Tea exports also had a positive and statistically significant long-run coefficient. The estimated coefficient of 0.1334, with a probability value of 0.002, indicates that a 1% increase in tea exports was associated with a 0.1334% increase in domestic tea production. This result suggests that stronger export performance was related to greater production capacity over the long run.

The R-squared value of 0.7812 indicates that plantation area, tea prices, and tea exports jointly explained 78.12% of the variation in Indonesian tea production. The remaining 21.88% was attributable to other factors not included in the model, such as labour,

rainfall, plant productivity, technology, fertiliser use, investment, and plantation management. The adjusted R-squared value of 0.7593 remained relatively high after accounting for the number of explanatory variables.

The probability value of the F-statistic was 0.0000, which was below the 5% significance level. Therefore, plantation area, tea prices, and tea exports jointly had a statistically significant relationship with Indonesian tea production in the long run. The long-run model was consequently considered statistically meaningful.

1. Short-Run Error Correction Model Results

After cointegration had been established, the Error Correction Model was estimated to examine short-run changes in Indonesian tea production and the adjustment process toward long-run equilibrium. The short-run results are presented in Table 7.

Table 7. Short-Run Error Correction Model Estimation Results

Variable	Coefficient	Standard error	t-statistic	Probability
D(Ln Plantation Area)	0.3122	0.2572	1.21	0.235
D(Ln Tea Price)	-0.0004	0.0701	-0.01	0.995
D(Ln Tea Exports)	0.1717	0.0565	3.04	0.005
ECT(-1)	-0.9695	0.1852	-5.23	0.000
Constant	0.0014	0.0115	0.12	0.903

Model statistic	Value
R-squared	0.6104
Adjusted R-squared	0.5548
Probability of F-statistic	0.0000
Number of observations	33

Source: Authors' calculations using Stata 17.

Based on Table 7. Short-Run Error Correction Model Estimation Results, the estimated short-run equation can be written as follows:

$$\Delta LnPROD_t = 0.0014 + 0.3122\Delta LnAREA_t - 0.0004\Delta LnPRICE_t + 0.1717\Delta LnEXPORT_t - 0.9695ECT_{(t-1)} + \mu_t \quad (2)$$

The short-run coefficient of plantation area was 0.3122, with a probability value of 0.235. Although the coefficient was positive, the probability value exceeded the 5% significance level. Changes in plantation area therefore did not have a statistically significant immediate effect on changes in tea production. This result indicates that adjustments in

plantation area were not followed by an immediate change in production within the same period.

The short-run coefficient of tea price was -0.0004, with a probability value of 0.995. The coefficient was close to zero and statistically insignificant. Short-term changes in tea prices therefore did not produce a measurable immediate change in Indonesian tea production during the study period.

Tea exports had a coefficient of 0.1717 and a probability value of 0.005. This result indicates that exports had a positive and statistically significant short-run effect on tea production. A 1% increase in tea exports was associated with a 0.1717% increase in tea production in the short run, assuming that the other variables remained constant. Tea exports were therefore the only explanatory variable with a significant short-run coefficient.

The Error Correction Term had a coefficient of -0.9695 and a probability value of 0.000. Its negative and statistically significant coefficient confirms the validity of the error correction mechanism. The coefficient indicates that approximately 96.95% of the disequilibrium occurring in the previous period was corrected within one annual period. In practical terms, deviations of tea production from its long-run equilibrium were adjusted relatively quickly.

The R-squared value of 0.6104 indicates that short-run changes in plantation area, tea prices, tea exports, and the lagged disequilibrium term explained 61.04% of the variation in tea production. The adjusted R-squared value was 0.5548. The probability value of the F-statistic was 0.0000, indicating that the short-run explanatory variables and the error correction term were jointly significant.

Taken together, the results reveal different short-run and long-run patterns. Plantation area, tea prices, and tea exports were all positively and significantly associated with production in the long run. In the short run, however, only tea exports had a statistically significant effect. The significant negative ECT coefficient further demonstrates that short-run deviations were corrected rapidly, supporting the presence of a stable long-run relationship among the variables.

DISCUSSION

1. Effect of Tea Plantation Area on Indonesian Tea Production

The findings show that tea plantation area had a positive and statistically significant effect on Indonesian tea production in the long run, but its short-run effect was not significant. The long-run coefficient of 0.4693 indicates that a 1% increase in plantation area was associated with a 0.4693% increase in tea production. This result confirms that land availability remains a major determinant of national production capacity. Tea is a perennial crop that depends on the continuity of cultivated land, plant maintenance, and long production cycles. Consequently, changes in plantation area tend to influence production gradually rather than immediately.

The insignificant short-run effect can be explained by the biological characteristics of tea cultivation. An increase in cultivated area does not directly generate additional output because newly planted tea requires time to reach a productive stage. Likewise, the rehabilitation of existing plantations, replanting, pruning, and improvements in plantation management do not produce immediate changes in harvested output. The effect of land expansion or contraction is therefore more evident over a longer period.

This finding is consistent with production theory, which identifies land as a fundamental input that determines agricultural output. It also supports Rahmawati et al. (2025), who found that plant characteristics and seasonal conditions affected tea productivity, and Wulansari et al. (2022), who demonstrated that physical land conditions and plantation management were closely related to tea production. Tran et al. (2021) similarly showed that land use, farming practices, and technical efficiency played an important role in determining tea output.

From a theoretical perspective, this result strengthens the argument that production capacity in perennial agriculture depends not only on the quantity of land but also on its productive quality and continuity of use. From a practical perspective, the finding highlights the importance of preventing the conversion of productive tea plantations to non-agricultural uses. Policies aimed at rehabilitating unproductive plantations, improving soil quality, renewing ageing plants, and optimising existing land may be more realistic than relying solely on new plantation expansion. The results also suggest that land-related policies should be designed with a long-term orientation because their effects on production are unlikely to appear within a single year.

2. Effect of Tea Prices on Indonesian Tea Production

Tea prices had a positive and statistically significant effect on production in the long run, whereas their short-run effect was statistically insignificant. The long-run coefficient of 0.0289 indicates that a 1% increase in tea prices was associated with a 0.0289% increase in production. Although the magnitude of this coefficient was smaller than those of plantation area and exports, the result indicates that price remains an economic consideration in production decisions.

A higher price can improve expected revenue and encourage producers to maintain plantations, invest in plant maintenance, increase input use, or rehabilitate low-yielding areas. However, such adjustments require time. Tea producers cannot immediately increase output in response to higher prices because production is constrained by the maturity of the plants, harvesting cycles, climatic conditions, labour availability, and the condition of the plantation. These constraints help explain why the price effect emerged in the long run but not in the short run.

The result is consistent with supply theory, which states that producers tend to increase output when prices provide stronger economic incentives. Nevertheless, the weak elasticity suggests that Indonesian tea production is relatively unresponsive to price changes. This limited response may reflect rigidities in land availability, ageing plantations, high production costs, low productivity, and limited access to investment. The finding is also in line with Ganeswara (2025), who found that tea prices interacted with exchange rates, competitiveness, and export conditions in shaping the performance of the Indonesian tea industry.

Theoretically, the result shows that price incentives remain relevant, but their effect is moderated by structural and biological constraints. Practically, price support alone is unlikely to generate a substantial increase in production without improvements in productivity, plantation management, financing, and market certainty. Government intervention may therefore need to combine price stabilisation with access to credit, support for replanting, input assistance, and stronger bargaining positions for farmers. A stable and remunerative price may encourage producers to remain in the tea sector, but its effectiveness depends on whether producers have the capacity to respond.

3. Effect of Tea Exports on Indonesian Tea Production

Tea exports had a positive and statistically significant effect on Indonesian tea production in both the short and long run. The long-run coefficient of 0.1334 indicates that a 1% increase in exports was associated with a 0.1334% increase in production, while the short-run coefficient of 0.1717 indicates a stronger immediate response. Among the explanatory variables, exports were the only factor that significantly affected production in both time horizons.

This finding suggests that international demand provides a direct market signal to producers and processing companies. When export orders increase, firms may respond by raising the volume of harvested leaves, intensifying processing activities, drawing on existing stocks, or improving procurement from farmers. Such adjustments can occur relatively quickly because exporters and processors operate within established supply chains. Over the long run, sustained export growth may also encourage plantation investment, quality improvement, and capacity expansion.

The result supports Nursodik et al. (2021), who found a close relationship between national production and Indonesian tea export volume. It is also consistent with Muflihah et al. (2023), who reported that Indonesian tea retained comparative advantages in international markets, although its competitive position remained below that of several major producers. Darmashanty & Kuncoro (2024) , Wedari & Hendrati (2024) Nahdudin et al. (2025) also showed that export performance was shaped by market access, prices, competitiveness, exchange rates, and conditions in destination countries.

The positive effect of exports contributes to the literature by demonstrating that international demand is not merely an outcome of production but also a factor that can stimulate domestic output. This two-way relationship should, however, be interpreted cautiously because higher production may also create more exportable supply. From a policy perspective, the result underlines the importance of strengthening export competitiveness through quality improvement, certification, traceability, product differentiation, and market diversification. Dependence on a limited number of export markets may expose producers to external shocks. Expanding access to emerging markets and developing higher-value tea products may help sustain production and improve the resilience of the national tea industry.

4. Adjustment Mechanism toward Long-Run Equilibrium

The Error Correction Term coefficient was -0.9695 and statistically significant at the 1% level. The negative sign confirms that the model contains a valid error-correction mechanism, while the magnitude indicates that approximately 96.95% of the disequilibrium from the previous period was corrected within one year. This result suggests a rapid adjustment toward long-run equilibrium.

The relatively high adjustment coefficient indicates that Indonesian tea production responds strongly when short-run conditions deviate from the long-run relationship among plantation area, prices, and exports. Such deviations may arise from temporary shocks in market demand, prices, weather, input availability, or trade conditions. The model suggests that most of these imbalances are corrected in the following period as production, market conditions, and resource use move back toward their long-run path.

This finding is consistent with the theoretical function of the Error Correction Model, which links short-run fluctuations to a stable long-run equilibrium. It also confirms that the variables included in the model move together over time rather than independently. The rapid speed of adjustment implies that shocks affecting the tea industry may not persist indefinitely, provided that the structural relationship among production, plantation area, prices, and exports remains intact.

The practical implication is that temporary policy interventions may produce limited effects unless they are supported by long-term measures. Short-term export incentives, price interventions, or production support should therefore be integrated with structural policies concerning plantation rehabilitation, productivity, investment, and market development. The high adjustment rate also indicates that policies affecting exports and production conditions may be transmitted relatively quickly through the tea industry.

Several limitations should be considered when interpreting these findings. First, the study used 34 annual observations, which is relatively limited for time-series estimation. The small sample size may reduce the sensitivity of statistical tests and restrict the use of more complex dynamic models. Second, the model included only plantation area, tea prices, and exports. Other factors that may influence tea production, such as rainfall, temperature, labour, plant age, productivity, fertiliser use, technology, investment, exchange rates, and production costs, were not included because consistent annual data were not available for the entire study period.

Third, the use of national aggregate data may conceal differences among provinces, plantation ownership types, and production systems. State-owned plantations, private estates, and smallholder farms may respond differently to changes in prices and export demand. Fourth, the relationship between production and exports may involve simultaneity because production can affect export availability, while export demand can also stimulate production. The present ECM estimates dynamic associations but does not fully resolve this potential endogeneity.

Future research may address these limitations by using quarterly data, provincial panel data, or disaggregated data based on plantation ownership. Additional variables such as rainfall, productivity, labour, exchange rates, investment, and technological adoption may also be incorporated. Alternative methods, including the Autoregressive Distributed Lag model, Vector Error Correction Model, or instrumental-variable approaches, may provide further evidence on causality and dynamic interactions within the Indonesian tea industry.

CONCLUSION

This study concludes that tea plantation area, tea prices, and tea exports significantly influenced Indonesian tea production over the 1990–2023 period, although their effects differed between the long run and the short run. In the long run, all three variables had positive and statistically significant effects on tea production. Plantation area produced the largest long-run coefficient, indicating that land availability remained the most influential factor in determining national tea production capacity. Tea prices also had a positive effect, although the magnitude was relatively small, while tea exports contributed positively to production by reflecting stronger international market demand. In the short run, only tea exports had a positive and significant effect, whereas plantation area and tea prices did not show statistically significant immediate effects. These results indicate that changes in land use and price incentives require a longer adjustment period before they affect tea output.

The negative and significant Error Correction Term confirms the existence of a valid adjustment mechanism from short-run disequilibrium toward long-run equilibrium. Approximately 96.95% of the previous period's imbalance was corrected within one year, suggesting that Indonesian tea production adjusted relatively quickly to changes in plantation area, prices, and exports. These findings provide practical evidence that efforts to increase tea production should prioritise the protection and optimisation of plantation land, the

maintenance of favourable price incentives, and the strengthening of export competitiveness. Future research is recommended to include additional variables such as productivity, labour, rainfall, exchange rates, investment, production costs, and technological adoption, as well as to apply provincial or quarterly data to obtain more detailed and robust results.

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