PRICE DYNAMICS AND NATURAL RUBBER PRODUCTION IN MALAYSIA: EVIDENCE FROM AN EMPIRICAL ARDL ANALYSIS

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Abstract. This study aims to examine the factors influencing Malaysia's natural rubber production and the fluctuating prices of SMR20 from 1995 to 2024. It utilized the Autoregressive Distributed Lag (ARDL) model to analyze both short- and long-run relationships between natural rubber production and other macroeconomic variables. The results of natural rubber production revealed that smallholdings have consistently contributed more than 80 percent of national production but are highly responsive to price factors and structural constraints. In fact, production records peaked at over 1.3 million tonnes in the mid-2000s but plunged drastically to 347,900 tonnes in 2023. It slightly improved to 386,400 tonnes in 2024. The empirical results verify that price volatility is an important factor in the production of SMR20, as higher prices boost tapping activities while declining prices decrease production. Exchange rate depreciation has both positive and negative effects on the sustainability of smallholders, as it increases export competitiveness while raising the price of inputs. Increases in the price of crude oil improve the competitiveness of natural rubber relative to synthetic materials, while growth in GDP enhances industrial demand, especially in the automotive and medical industries. The results of the ARDL approach verify the cointegration relationships between the production of natural rubber and the macroeconomic factors, confirming the vulnerability of the natural rubber industry in Malaysia to external factors and structural decline.
Keywords: *natural rubber production, SMR20 prices, exchange rate, crude oil prices, GDP growth, ARDL*

Introduction

Natural rubber has been an important strategic crop for Malaysia's agricultural and industrial development, contributing considerably to Malaysia's export revenue, employment opportunities, and manufacturing activities. Natural rubber is obtained from Hevea brasiliensis, which is used to produce automobile tires, medical equipment and other industrial products because of its high elasticity and longevity. Southeast Asia is a major producer of natural rubber globally, contributing more than 99 percent of total world production, with Malaysia being a prominent producer of natural rubber in the region (Men et al., 2019; Bashier et al., 2022). The natural rubber industry has contributed to Malaysia's value-added manufacturing industry, especially in products such as medical gloves, which have helped to improve Malaysia's global competitiveness. The Malaysian natural rubber industry faces structural problems along with a decline in production levels. Major problems faced by this industry include ageing rubber plantations, labor shortage, increased cost of production and conversion of land used to more profitable crops such as palm oil. These problems have caused low levels of production capacity and sustainability in the industry (Naim and Hussain, 2022). Moreover, increased competition from synthetic rubber, along with volatility in global demand have further intensified the pressure on the Malaysian natural rubber industry.

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Beyond these structural challenges, the production of natural rubber is also impacted by various macroeconomic factors. In particular, the issue of price volatility of Standard Malaysian Rubber 20 (SMR20) becomes vital when it comes to the determination of production activities. The fluctuation of rubber prices impacts not only tapping intensively but also incomes of smallholders. As previous research has indicated, high prices become incentives for the production of rubber, while low prices tend to discourage tapping activities (Ramli et al., 2019; Fong et al., 2020). Apart from price volatility, exchange rates, crude oil prices and GDP become other significant demand for rubber based products. Although previous studies have examined several factors that affecting the production of natural rubber, the existing literature mainly focused on individual determinants such as rubber prices, export performance, exchange rate or market dynamics) (Fong et al., 2020; Khin et al., 2019; Ali et al., 2021). There is limited evidence that focusing on combined effects of SMR20 prices, exchange rates, crude oil prices, GDP and rubber acreage on natural rubber production in Malaysia (Bashier et al., 2022; Ali et al., 2021). Moreover, examining the relationships among all these variables in both short-run and long-run periods remain relatively scarce. As such, a thorough analysis required to determine the dynamic interaction between the macroeconomic elements and natural rubber production. To fill the gap, the use of the Autoregressive Distributed Lag (ARDL) methodology is applied in this study, which is useful to examine both short-term and long-term effects between economic variables based on the annual data ranging from 1995 to 2024.

Literature review

The factors that affect natural rubber production in Malaysia are both structural and macroeconomic. As per production theory, production is determined by physical inputs as well as economic incentives. For an open economy like Malaysia, an agricultural commodity reacts highly to international prices, exchange rates, industrial demand and global energy prices. Thus, this research has conceptualized natural rubber production as a dependent variable, whereas SMR20 price, exchange rates, crude oil prices, GDP and acreage of rubber are considered independent variables.

SMR20 price and natural rubber production

Price is a fundamental factor that influences agricultural supply. The supply theory states that when prices rise, smallholders respond by increasing supply because of anticipated higher profitability. For Malaysia, the benchmark price of natural rubber is indicated by SMR20. Ramli et al. (2019) highlight that price volatility of natural rubber has an impact on tapping intensity. For instance, when prices are high, tapping is activities will increase. On the other hand, when prices are low for an extended period, tapping will be discouraged. Moreover, Fong et al. (2020) assert that global price fluctuations affect Malaysia’s natural rubber supply because of its export-based economy. Bashier et al. (2022) support this argument that prices are fundamental factors that affect agricultural production. Hence, an increase in prices of natural rubber as indicated by SMR20 is leads to an increase natural rubber production.

Exchange rate and natural rubber production

The movements of exchange rates have an impact on export competitiveness and production costs. The depreciation of the Malaysian Ringgit would make Malaysia's

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natural rubber cheaper in the global market. This would increase demand for Malaysia's natural rubber exports (Bashier et al., 2022). On the other hand, depreciation would also increase the cost of imported materials such as fertilizers, machinery and chemicals (Fahmy-Abdullah et al., 2020). Exchange rate volatility has a significant impact on Malaysia's agricultural commodity industry. The two effects of exchange rates imply that its impact on natural rubber production could be influenced by external market factors.Thus, it is expected that exchange rate movements would have a significant impact on natural rubber production.

Crude oil price and natural rubber production

Furthermore, crude oil price is a significant factor to be considered due to its relationship with synthetic rubber production. As synthetic rubber is a petroleum product, an increase in the price of crude oil will lead to an increase in the production costs of synthetic rubber (Khin et al., 2019). Arunwarakorn et al. (2019) state that with a rise in the price of crude oil, natural rubber becomes more competitive, resulting in increased demand. This fact regarding the substitution between natural and synthetic rubber markets. Therefore, it can be concluded that a rise in the price of crude oil will lead to an increased demand for natural rubber, which in turn will lead to increased production.

Rubber acreage and natural rubber production

On the other hand, acreage refers to the structural capacity of production. Theoretically, in agricultural production, an increase in the planted area directly leads to a positive increase in potential production. Bashier et al. (2022) also proved that one of the most important factors affecting the level of agricultural production is the allocation of the land. Nevertheless, Naim and Hussain (2022) argue that the reduced acreage of rubber plantations, which were converted from oil palm plantations, has resulted in the structural decline of rubber production in Malaysia. Therefore, it is expected that the more the acreage of rubber plantations, the higher the natural rubber production.

Gross Domestic Product (GDP) and natural rubber production

Gross Domestic Products is an indicator of general economic performance and industrial demand. Economic growth would imply an increase in demand for products derived from the use of rubber. The demand would be higher, especially for industries such as automobiles and medicine (Fong et al., 2020). According to Ali et al. (2021), economic growth is likely to support industrial production and exports, which would imply an increase in demand for agricultural products. The demand for products derived from natural rubber is likely to be supported because of its close relationship with industrial demand. Thus, GDP growth is likely to support long-term stability and positively influence natural rubber production.

Materials and Methods

This study employs a quantitative research design to examine the macroeconomic determinants of natural rubber production in Malaysia. The objective is to investigate both the short-run and long-run relationships between natural rubber production and selected macroeconomic variables using time-series data. To achieve this, the study utilizes the Autoregressive Distributed Lag (ARDL) model, introduced by (Pesaran et al., 2001). The ARDL approach is suitable because it enables the estimation of both short-run dynamics and long-run equilibrium relationships within a single framework. It is also appropriate for small sample sizes and can be applied when variables are integrated at different orders, namely I(0) and I(1).

Data source and description

This research employed secondary data collected annually from 1995 to 2024. The dependent variable is natural rubber production (NRP). Meanwhile, the independent variables implemented are SMR20 price (LPSMR), exchange rate (EXC), crude oil price (LCOP), rubber acreage (LACR) and Gross Domestic Product (LGDP).

Table 1*. Sources of data.*

Variables	Abbreviation	Unit	Sources	References
Natural rubber production	TNRP	(000'tons)	Malaysian Rubber Board	Bashier et al. (2022)
Acreage of natural rubber plantations	ACR	('000 Hectares).	Malaysian Rubber Board	Phyoe (2020)
Price of natural rubber (SMR 20)	PSMR	Malaysian Ringgit (MYR)	Malaysian Rubber Board	Bashier et al. (2022)
Exchange rate	EXC	Ringgit (MYR) against the US Dollar (USD)	Bank Negara Malaysia	Arifin et al. (2022)
Crude oil prices	COP	(USD$/barrel)	Organization of the Petroleum Exporting Countries (OPEC)	Pramananda et al. (2022)

Model specification

The models and their determinants are shown as below:

$$TNRP_{t=} \beta_0 + \beta_1 TNRP_{t-1} + \beta_{2L} PSMR20_t + \beta_{3L} ACR_t + \beta_4 EXCt_t + \beta_{5L} COP_t + \beta_6 LGDP_t \, \varepsilon_t \qquad \text{Eq. (1)}$$

Where: TNRP = total natural rubber production, PSMR = price of natural rubber (Standard Malaysian Rubber 20), ACR = acreage of natural rubber, EXC = exchange rate, COP = Crude oil price, GDP = Gross domestic products β = coefficient and ε = error term.

Unit root test

A unit root test was conducted to determine whether the variables were stationary at level, I(0), or became stationary after first differencing, I(1), using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests.

Long-run cointegration relationship

The presence of cointegration is tested by comparing the calculated F-statistic with the critical values of the ARDL bounds test. Once cointegration is established, the long-run relationship can be estimated using the following model:

$$H_O = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 \text{ (no cointegration)}$$
$$H_1 \neq \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \text{ (cointegration exists)} \qquad \text{Eq. (2)}$$

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Long-run coefficients

If the results or tests show that there is a presence of a long-run cointegration relationship between the series, the estimation of the long-run cointegration model has to be examined. This means that the model that represents the long-run equilibrium relationship between the variables has to be specified. Typically, estimation will be in regard to appropriate functional form identification, including all relevant variables in the model. This helps to understand how the variables interact over the long term and make adjustments to maintain equilibrium after short-term disturbances.

$$\begin{aligned} TNPR_t &= \beta_0 + \sum_{i=1}^{k} \alpha_1 TNPR_{t-i} \\ &+ \sum_{j=0}^{l} \alpha_2 \Delta PSMR20_{t-j} \\ &+ \sum_{j=o}^{l} \alpha_3 \Delta ACR_{t-j} \\ &+ \sum_{j=0}^{l} \alpha_4 \Delta EXC_{t-j} \\ &+ \sum_{j=0}^{l} \alpha_5 \Delta COP_{t-j} \\ &+ \sum_{j=0}^{l} \alpha_5 \Delta GDP_{t-j} + \varepsilon_t \end{aligned} \quad \text{Eq. (3)}$$

Short-run coefficients

The Error Correction Model helps explain the short-run behavior of the model, ensuring that the long-run equilibrium position is regained after a disturbance. The inclusion of the error correction term helps in the explanation of how the variables return to the long-run equilibrium position.

$$\begin{aligned} \Delta TNPR_t = {} & \Upsilon_0 + \lambda\, ect_{t-1} + \beta_1 TNPR_{t-1} + \beta_2 PSMR20_{t-1} + \beta_3 ACR_{t-1} + \beta_4 EXC_{t-1} + \\ & \beta_5 COP_{t-1} + \textstyle\sum_{i=1}^{k} \alpha_1 TNPR_{t-i} + \sum_{j=0}^{l} \alpha_2 \Delta PSMR20_{t-j} + \sum_{j=0}^{l} \alpha_3 \Delta ACR_{t-j} + \\ & \textstyle\sum_{j=0}^{l} \alpha_4 \Delta EXC_{t-j} + \sum_{j=0}^{l} \alpha_5 \Delta COP_{t-j} + \sum_{j=0}^{l} \alpha_5 \Delta GDP_{t-j} + \varepsilon_t \end{aligned} \quad \text{Eq. (4)}$$

In this model,(k) and (1) represent the lag lengths determined based on the long-run equation. Besides, the 〖ect〗_(t-1) represents the error correction terms.

Diagnostic statistics

For the Diagnostic Test, serial correlation, normality, heteroscedasticity and the functional form. The CUSUM Square Test was also performed for the long-run stability test.

Results and Discussion

Unit root test

As shown by the ADF and PP test results, all the variables are non-stationary at the level but stationary after first differencing, conforming integration at I(1) and supporting the application of the ARDL methodology.

Table 2. *Statistical output for unit root test.*

Category	Level I(0)		First Difference I(1)		
	Augmented Dickey-Fuller	Phillips-Perron	Augmented Dickey-Fuller	Phillips-Perron	Order of Integration

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LNRP	-0.011611	0.088984	-5.419913*	-5.421394*	I(1)
LPSMR	-1.287074	-1.416717	-4.758842*	-4.758842*	I(1)
LCOP	-1.670390	-1.587193	-4.929240*	-4.993854*	I(1)
LACR	-2.476573	-2.463803	-4.513325*	-4.509019*	I(1)
LGDP	-0.626834	-0.961003	-6.044746*	-6.561990*	I(1)
EXC	-1.826363	-1.906526	-4.409265*	-4.416032*	I(1)

*Note: (Symbols of *p<.01, **p<.05, ***p<.10). All variables are in natural logarithms. All series are stationary at I(1).*

ARDL bounds test for cointegration

The bounds test is used to test for the existence of a long-run equilibrium relationship between the variables. The results from the bounds test in *Table 3* show that the F-statistic of 12.31214 is much higher than the corresponding critical values for all conventional significance levels. Since the F-statistic is higher than the upper bound of the test statistic at all significance levels, the null hypothesis of no long run relationship is rejected. This result shows strong evidence of cointegration between the natural rubber production variable and its determinants, which include SMR20 prices, exchange rate, crude oil prices, acreage and GDP.

***Table 3**. Statistical output for bound test.*

F-Statistics	Lag Length	Significance Level	Bound Critical Values (Unrestricted intercept and no trend)	
			I[0] (Lower Bound Value)	I[1] (Upper Bound Value)
12.31214	2	10%	2.75	3.79
		5%	3.12	4.25
		2.5%	3.49	4.67
		1%	3.93	5.23

*Note: Symbols of *p<.01, **p<.05, ***p<.10. Critical value bounds are computed by surface response procedure developed by Pesaran et al. (2001).*

ARDL long-run models

Long-run coefficients provide insight into the equilibrium relations between natural rubber production and its determinants. A positive coefficient represents facilitating factors, while a negative coefficient highlights inhibiting forces. The long-run ARDL estimates suggest that prices of SMR20 and exchange rate depreciation positively influence Malaysia’s natural rubber production, while crude oil prices, acreage and GDP have negative effects. The R^2 value of 0.8868 and high F-statistic value suggest that the model is significant, thereby confirming that these factors critically influence Malaysia’s natural rubber production.

***Table 4**. ARDL long-run models.*

Variable	Coefficient	T-Statistic	P-Value
LPSMR	3.330033**	2.3081	0.0396
EXC	2.846892***	2.127591	0.0548
LCOP	-1.88701***	-2.025675	0.0656
LACR	-6.3766**	-2.266871	0.0427
LGDP	-5.85983**	-2.655918	0.0209
Constant	185.2634**	2.715843	0.0188
R2		0.88685	
Adjusted R2		0.83028	
F-statistics		7.37341	

*Note: Symbols of *p<.01, **p<.05, ***p<.10. Standard Error are in parentheses.*

ARDL Short-Run Model

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The coefficients from the short-run results of the ARDL model provide detailed results concerning the response of natural rubber production in Malaysia to changes in its determinants. The short-run ARDL results in *Table 5* reveal that there are significant influences of acreage, GDP, SMR20 prices and exchange rates. A negative and significant coefficient of ECT indicates that the variables are converging to long-run equilibrium.

***Table 5**. Short-run models.*

Variable	Coefficient	Coefficient	T-Statistic
Δ (LACR(-1))	1.329533*	3.203879	0.0076
Δ (LGDP)	0.931560**	2.870012	0.0141
Δ (LGDP(-1))	0.952005**	2.629541	0.0220
Δ (LPSMR)	0.470017*	6.143156	0.0000
Δ (EXC)	0.271350*	4.450351	0.0008
Δ (LPSMR (-1))	-0.288068*	-3.599425	0.0036
Δ ((EXC(-1))	-0.415988*	-7.018262	0.0000
Δ (LNRP (-1))	-0.275050***	-2.119040	0.0556
Δ (LACR)	0.442613	1.319826	0.2115
ECTt-1	-0.241354*	-8.798908	0.0000
R2		0.88685	
Adjusted R2		0.83028	
F-statistics		7.37341	

*Note: Symbols of *p<.01, **p<.05, ***p<.10. Standard Error are in parentheses.*

Diagnostic statistics

Diagnostic tests are performed to determine the robustness of the ARDL model. The diagnostic test results further support the robustness and validity of the ARDL model. All diagnostic tests are statistically insignificant, thus indicating the absence of serial correlation, heteroscedasticity, non-normality, and model misspecification

***Table 6**. Results of diagnostic testing.*

Serial Correlation LM Test	Normality Test (Jarque Bera)	Breusch-Pagan Test	Ramsey RESET Test
3.485316	2.497315	0.471743	10.38638
(0.5144) (p-value)	(0.286890) (p-value)	(0.9147) (p-value)	(0.5791) (p-value)

*Note: Symbols of *p<.01, **p<.05, ***p<.10. P-values are in parentheses*

Stability test (CUSUM and CUSUMQ)

The stability tests using CUSUM and CUSUMQ tests are performed to determine the stability of the parameters of the model. In addition to the diagnostic tests, the stability of the model parameters is further established through the CUSUM and CUSUMQ graphs in *Figures 1* and *Figure 2*. Both plots remain within the 5% significance bounds for the entire observation period, which demonstrates that the estimated coefficients are stable over time and that the model is not subject to structural instability.

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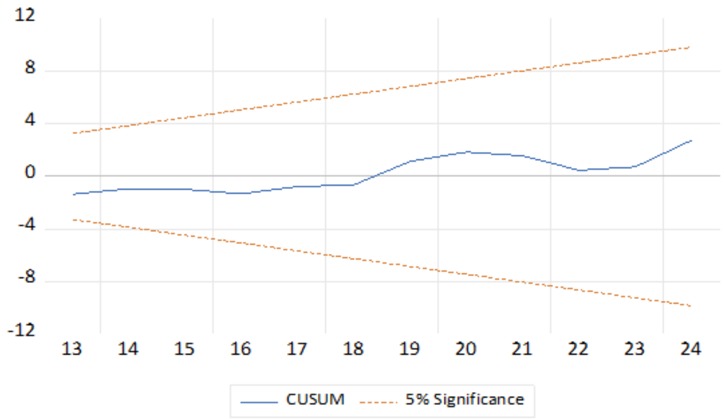

Figure 1. *Recursive least square of CUSUM test.*

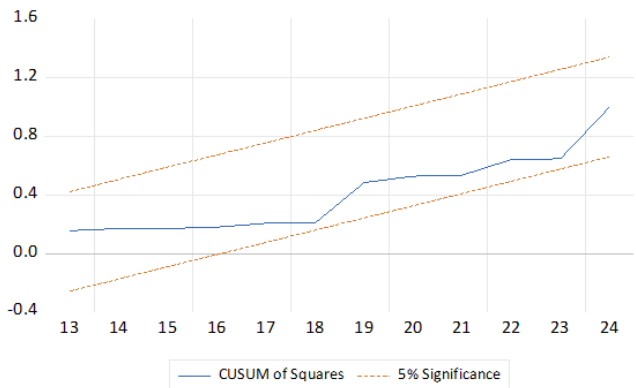

Figure 2. *Recursive least square of CUSUMQ test.*

Conclusion

This research shows that the natural rubber industry in Malaysia is affected by natural rubber prices, crude oil prices, acreage, GDP and exchange rates, confirmed by the bound test for a long-run relationship through cointegration. In the short run, there is volatility and adjustment, where the response of the variables to changes in natural rubber prices, acreage and exchange rates is unstable but tends towards a stable adjustment through the error correction model, where the adjustment corrects with a measurable speed. The diagnostic tests also confirm the robustness of the ARDL model, where there is no evidence of problems of serial correlation, heteroscedasticity and misspecification, with stable parameters throughout the data periods confirmed by the tests of parameter stability of the model. This research work gives empirical evidence of the significance of macroeconomic variables and commodity relationships to natural rubber industries, with relevant implications for stabilizing prices, improving acreages and managing currency fluctuations for effective and sustainable development of natural rubber industries.

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Conflict of interest

The authors confirm that there is no conflict of interest involved with any parties in this research study.

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