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EXPLORING THE DRIVERS OF COFFEE PRODUCTION IN MALAYSIA: A SHORT AND LONG-TERM ANALYSIS

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ABSTRACT

Coffee demand in Malaysia has shown an increasing trend; however, domestic production remains relatively low and unstable. This study examines the short-term and long-term effects of selected macroeconomic variables on coffee production in Malaysia using secondary data from 1982 to 2023 and the Autoregressive Distributed Lag (ARDL) approach. The results indicate that, in the long run, climate conditions (proxied by rainfall) and population growth are the main positive drivers of coffee production, reflecting the importance of favourable weather and growing domestic demand. In contrast, cultivated land area and cocoa prices are negatively associated with coffee production, suggesting land-use constraints and crop substitution effects. In the short run, government expenditure and rainfall exert positive influences on output, highlighting the role of policy support and climatic conditions during early adjustment periods. Lagged effects of past production, land use, cocoa prices, and government expenditure also contribute positively, indicating that historical decisions and investments continue to shape current production outcomes. However, adverse weather conditions in previous periods negatively affect yields, underscoring the vulnerability of coffee production to climatic extremes. Overall, the findings suggest that while targeted policy support can facilitate short-term production responses, the long-term sustainability and growth of Malaysia's coffee sector depend primarily on climate resilience, efficient land use, and demand-driven factors. Strengthening adaptive capacity, improving productivity, and enhancing value-chain efficiency are therefore essential to improve competitiveness and support sustainable development of the coffee industry.

Keywords: ARDL, coffee, long run, production response, short run.

INTRODUCTION

Coffee is a type of drink made from roasted and finely ground coffee beans. The word “coffee” itself comes from the Arabic term “qahwa”, which refers to a caffeinated drink. History records indicate that coffee was first discovered in the Ethiopian region before being introduced to the Arab world around the 15th century. Since then, coffee has developed into a global beverage that is not only drunk for its taste, but also for its cultural and economic value (Infopertanian, 2025). Coffee is one of the most widely consumed beverages globally, ranking just behind water and tea in popularity. Beyond being a daily refreshment, it has evolved into a cultural and lifestyle symbol, particularly among the younger generation. This transformation has been significantly influenced by technological advancements in coffee preparation, which have introduced a variety of sophisticated brewing techniques and machines capable of producing diverse beverage options, such as espresso, vanilla latte, and caramel macchiato (Astro Awani, 2023, October 1).

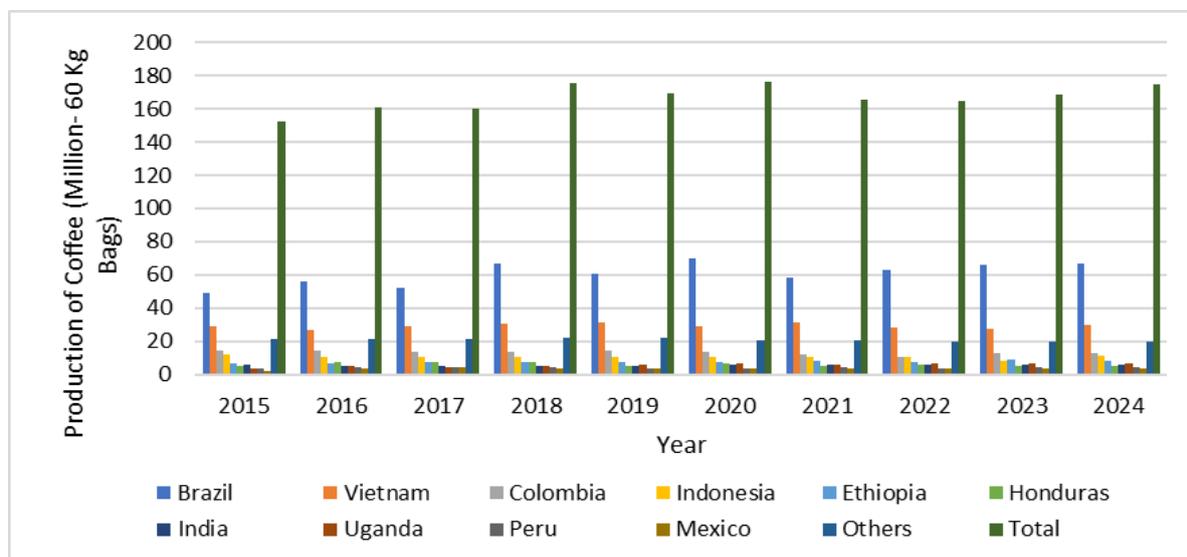
There are four primary species of coffee cultivated and traded commercially: *Coffea arabica* (Arabica), *Coffea canephora* (Robusta), *Coffea liberica* (Liberica), and *Coffea excelsa* (Excelsa). Among these, Arabica and Robusta dominate the global market, accounting for approximately 70 percent and 28 percent of production, respectively, while Liberica and Excelsa make up the remaining share (Barlow, 2023, May 22). Arabica is particularly prized for its smooth flavour, aromatic profile, and lower caffeine content compared to the more bitter and robust-tasting Robusta. The taste and quality of coffee are greatly influenced by the species, geographical origin, cultivation practices, and processing methods. High-quality beans, nurtured under optimal conditions, are capable of producing premium coffee that garners global appreciation. Notably, exclusive varieties, such as *Kopi Luwak* from Indonesia, processed through the digestive system of the civet cat have gained international acclaim for their rarity and distinctive flavour profile (Astro Awani, 2023, October 1).

Today, coffee plays a pivotal role not only as a morning stimulant but also as a social beverage and a driver of economic activity in many producing nations. Whether in the form of traditional brewed coffee or instant preparations, it has become an indispensable part of daily routines worldwide (The Editors of Encyclopaedia Britannica, 2025, June 11). About 70 countries are currently involved in commercial coffee cultivation, with a major focus on Southeast Asian countries, the Americas, India, and Africa. The coffee industry not only contributes to the economy but also forms part of the culture and lifestyle of today’s global society. World coffee production is led by three major countries, namely Brazil, Vietnam, and Colombia (United States Department of Agriculture, Foreign Agricultural Service, 2025). Figure 1 shows world coffee production for the period from 2015 to 2024. In general, world coffee production during that period fluctuated between 150 million to 175 million bags (60-kg bags).

Coffee production in Malaysia is relatively small compared to the global market. In Malaysia, the Arabica coffee plant was first introduced around 1779, originating from the African continent. However, due to local weather conditions that were not very suitable, the Liberica variety was introduced in 1875 by Leonard Wray and planted in Malaysia because it is more resistant to hot weather and drought (Mohd Nawati, 2025, Harian Metro February 12). The three main types of coffee grown in Malaysia are Arabica, Liberica, and Robusta. Coffee is categorized as an industrial crop along with other crops, such as coconut, nipah, areca nut, roselle, tea, and mushrooms (Department of Agriculture, 2016).

Figure 1

World Production of Coffee (million-60-kg bags): 2015 – 2024



Source: Tradeimex (2025, February 12).

Coffee crops have become one of the agricultural commodities given attention in the National Agricultural Policy 3 (NAP 3). However, coffee crops in Malaysia are still unsatisfactory in terms of production due to unstable coffee bean prices. This has caused coffee enterprises to be operated non-commercially and only on a small scale. During the period from 1986 to 2023, the area under cultivation continued to decrease and recorded the lowest area in 2018, which was 1,930 hectares. However, it increased marginally and reached 3,025.40 hectares in 2023. The same situation occurred with production. During that period, the highest production was recorded in 2003 and 2005, at 40,000 metric tons. The lowest production was recorded in 2018, at 3,369.2 metric tons, after which it began to increase in 2019 and recorded 6,804.67 metric tons in 2023. Malaysia's coffee production performance is shown in Figure 2 (Department of Agriculture, 2023).

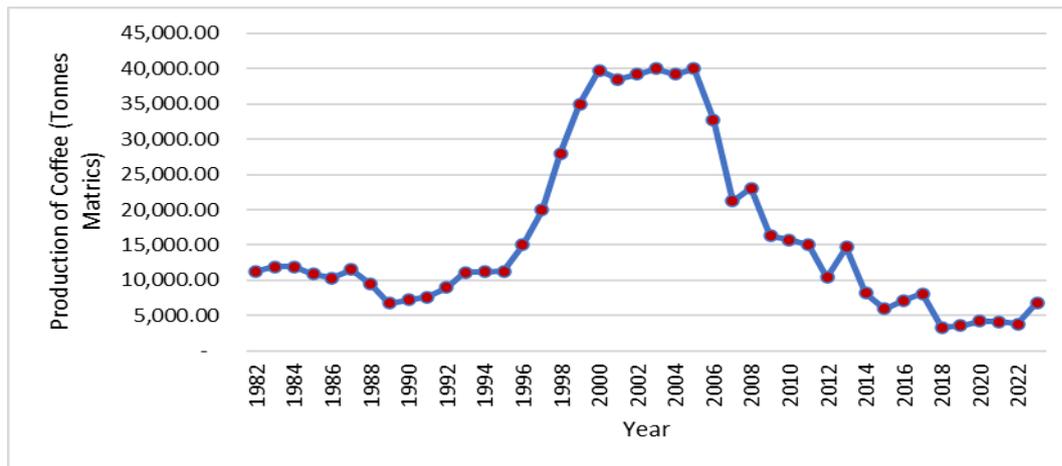
This encouraging situation is driven by the government's initiative to boost coffee cultivation. During the Eleventh Malaysia Plan (11th MP) period, incentives given to target groups through replanting and rehabilitation projects for existing coffee plantations included infrastructure development, area clearance, and agricultural inputs, such as coffee seedlings, fertilizers and pesticides. Throughout 2020, a total of 74 projects covering an area of 384.48 hectares with 299 participants were developed. The coffee varieties grown in Malaysia are Arabica coffee, mostly grown in Sabah and Sarawak, Robusta coffee, mostly grown in Kedah and Sabah, and Liberica coffee, grown in Johor, Perak, Selangor, Melaka, and Pahang (Jabatan Pertanian, 2020).

As the coffee industry in Malaysia continues to grow, various initiatives and financial assistance have been implemented by the government to support entrepreneurs in this sector. For example, the Ministry of Agriculture and Food Security (MAFS) through the Department of Agriculture provides comprehensive assistance to individuals interested in becoming coffee entrepreneurs, including aspects related to planting, irrigation systems, and coffee processing. In 2021, the government approved an allocation of RM4.5 million under the Twelfth Malaysia Plan (12MP) for the Coffee

Plantation Industry Development Project. The allocation was designated for the provision of infrastructure and post-harvest handling facilities, the supply of agricultural inputs, the procurement of pest control materials and equipment, and technology transfer. In 2021, there were 2,000 players in the coffee planting industry nationwide (Utusan Malaysia, October 1, 2021).

Figure 2

Malaysia's Coffee Production (Tonnes Metric): 1982 - 2023



Source: Department of Agriculture, various series (2016- 2023); Department of Statistics (DOSM), (2021).

Meanwhile, at the state level, the Selangor government through the ‘*Kita Ke Kampung #produkkampung4u*’ programme has helped local coffee entrepreneurs expand their markets. For example, a coffee entrepreneur from Kampung Kundang managed to increase his monthly sales from RM20,000 to RM30,000 after participating in the programme, which provides guidance and product promotion. In addition, in Sabah, the Ministry of Agriculture and Food Security (MAFS) has allocated RM3.37 million to develop the coffee industry in the interior, including the construction of a ‘Coffee House’ and ‘Café Coffeelive’ at the Sepulut Agricultural Station and the upgrading of the coffee collection centre in Nabawan (Infopertanian, 2025).

Furthermore, coffee consumption increased by 73 percent, from 344,783 bags of coffee beans in 2020 to 597,064 in 2021. This means that Malaysians have consumed an additional 252,281 bags of coffee beans, with each bag weighing 60 kg. This surge made Malaysia rank third among 58 countries in the region with the highest coffee consumption growth in 2021 (Bernama, 2025, January 20). Domestic coffee demand is also increasing due to the ‘coffee cafe’ culture. In 2022, the coffee industry recorded an output value of RM4.2 billion with an average annual growth of 4.1 percent. Meanwhile, the number of coffee industry players reached 5,021, with value added increasing by 5.5 percent to RM1.9 billion. The coffee shop industry recorded the highest output value in Kuala Lumpur, at RM1.6 billion, while Selangor ranked second with RM1 billion (Mahanum, Berita Harian 2024, July 29).

Overall, production has increased, but demand for coffee remains strong, both for home and restaurant consumption. The growing popularity of cafés, as well as the increasing demand for premium specialty coffees, may provide lucrative opportunities for businesses in Malaysia. In addition, according to the Department of Statistics Malaysia (DOSM), the country imports most of its coffee

beans from Vietnam, Indonesia, and Brazil, with the average Malaysian consuming 2.2 kilograms of coffee in 2022, an increase of 5.2 percent from 2017 (Bernama 2025, January 5). Therefore, to meet demand and reduce imports, domestic production needs to be increased. Hence, this study aims to analyse the factors affecting coffee production in Malaysia.

LITERATURE REVIEW

Supply response theory provides a basic explanation of how agricultural producers adjust output in response to economic incentives. Biological and institutional constraints cause farmers to base their production decisions on expected prices rather than actual prices. This results in slow adjustments in output over time (Nerlove, 1958). In addition to price expectations, production responses are influenced by input costs, macroeconomic conditions, and policy interventions that affect profits and resource allocation (Askari & Cummings, 1977; Mundlak, 2001). For perennial crops such as coffee, this adjustment process is often delayed, as planting and expanding output require longer planning horizons. As a result, changes in macroeconomic conditions may affect coffee production differently in the short and long run.

Previous studies on agricultural supply have used numerous econometric procedures such as Ordinary Least Squares (OLS), Vector Autoregression (VAR) and panel data models to delve into production dynamics (MacKay et al., 1998; Dawuda & Appiah, 2023). These approaches afford valuable insights, as they regularly assume that all variables are integrated in the same order and focus on either short-run or long-run effects, which may ignore important dynamic relationships. Small sample size limitations can also lead to biased estimates (Gujarati & Porter, 2009). Therefore, the Autoregressive Distributed Lag (ARDL) method addresses this issue by allowing for variables with mixed orders of integration (I(0) and I(1)) and by estimating both short-run and long-run effects within a single framework. As such, ARDL is particularly appropriate for studying how macroeconomic factors affect coffee production over time (Pesaran et al., 2001).

The relationship between agricultural production and its various determinants has long been a subject of empirical investigation. Price remains one of the most influential factors. Cleaver (1985) demonstrated that a 1 percent rise in the real price of cocoa resulted in a 0.39 percent increase in production in the short term and 0.77 percent in the long term. Conversely, low prices prompted farmers to reduce output by reallocating resources toward more profitable crops. Similarly, Pitt and Rosenzweig (1986) found that a 10 percent increase in agricultural output prices raised productivity by just over 1 percent. Aipi (2012) found that changes in international coffee prices had no significant impact on Papua New Guinea's coffee output, although long-term income growth in major importing countries positively influenced production and exports. Salifou et al. (2019) offered a nuanced view by showing that while cocoa yields responded positively to price increases (0.07%), coffee yields declined (0.085%) in response to the same, suggesting a potential crop substitution effect under price fluctuations. More recently, Thambi (2023) found that in Cameroon, a 1 FRS increase in coffee price per 100 kg bag was associated with a 0.411 kg increase in coffee production.

Land area and farm size are also critical in explaining variations in output. Abu Hassan Asari et al. (2011) found that a 1 percent increase in the total planted area resulted in a 0.7 percent decrease in palm oil production. Anigbogu et al. (2015) reported a 23.3 kg increase in output for every additional hectare of land in Nigeria. Kakar et al. (2016) found that a 1 percent increase in cultivated land area led to a 9 percent rise in agricultural production. Wickramarachchi and Weerahewa (2018) also observed that a one-acre increase in land size boosted productivity by 75 kg per acre. Yan et al.

(2019), however, suggested a U-shaped relationship between land size and technical efficiency in China, identifying the optimal efficiency range between 10 and 40 mu. Thambi (2023) found a positive coefficient for farm size (3.319), affirming that an increase in cultivable land area significantly enhanced output in the Melong subdivision. More recently, Widyawati et al. (2024) noted that in Indonesia, a one hectare expansion resulted in a 6,549-ton increase in coffee production, with notable regional disparities attributed to land availability.

Government spending has also been shown to significantly affect agricultural productivity. Diakosavvas (1990), in a cross-regional study, established that a 10 percent increase in government agricultural spending boosted production by 3.53 percent in Africa, 3.35 percent in Asia and the Near East, and 1 percent in Latin America. Iganiga and Unemhilin (2011) noted a 4.34 percent productivity gain from increased investment in Nigeria. Akintunde et al. (2013) demonstrated that a 10 percent increase in public spending on agriculture resulted in a 2 percent rise in output. Ojiya et al. (2017) reported a negative relationship between Nigerian agricultural productivity and government spending between 1990 and 2016, suggesting inefficiencies or misallocations in expenditure. Phiri (2018) reported that a 1 percent rise in public agricultural investment led to a 0.15 percent increase in productivity in Uganda, supporting the case for targeted and efficient public funding. Osuagwu (2020) found that a 1 percent increase in government investment correlated with a 0.695 percent increase in output, whereas Zhi and Wong (2020) identified a nonlinear relationship, with productivity gains occurring only up to a spending threshold (RM3,057 million), beyond which additional expenditures caused declines.

Climatic and environmental factors are increasingly influencing agricultural performance. Msuya (2013) noted that in Tanzania, coffee production and rainfall showed a decreasing trend, but the relationship was insignificant. However, coffee production was more influenced by other factors, such as the lack of agricultural inputs, including fertilizers and pesticides, which affected coffee production in the study area. Hakorimana and Akcaoz (2019) reported that about 74 percent of the variation in coffee yields in Rwanda over 17 years could be explained by climate variables, including temperature and rainfall patterns. Meanwhile, Salim et al. (2020) showed that in Bangladesh, a 1 percent increase in rainfall reduced agricultural productivity by 0.0037 percent due to frequent flooding. These findings highlight the complex and often adverse effects of climatic changes on crop yield. Wagner et al. (2021) documented that in the Mount Kilimanjaro region, increased annual precipitation did not improve water availability due to a delayed rainy season and irregular rainfall distribution, which disrupted key crop development stages.

Other institutional and demographic factors have also been considered. Josephson et al. (2014) observed that a ten-person population increase in Nigeria was associated with a 7.7 kg per hectare maize yield rise, likely due to enhanced market access and information flow, although this effect was not observed for teff. Niazi and Farooq (2018), using ARDL models, reported a positive relationship between Basmati rice prices and production, and a negative relationship with fertilizer prices. In Ethiopia, Tenaye (2020) found that both price and non-price factors (including education, land quality, fertilizer use, and precipitation) significantly influenced the supply of major cereals. Meanwhile, Xie et al. (2020) found that land consolidation area positively influenced production (0.0549%), investment in land consolidation had a negative impact (-0.549%), highlighting inefficiencies in capital utilization. Hegena and Teshome (2022) emphasized that larger land allocation for vegetables led to increased sales volumes, reinforcing the importance of land access and allocation in production outcomes.

While Bashir and Yuliana (2019) indicated that the wetlands and production of rice is positive, a one-hectare increase in the rice field area would promote a 0.237 percent annual improvement in rice output. The results also showed that urban population and rice production are negatively related, with a coefficient value of -0.670. Using the ARDL method Onwusiribe et al. (2022) found that coffee production in Nigeria has declined. In the short term, coffee production is significantly influenced by land and fertilizer use. In the long term, fertilizer use negatively affects coffee farmers' output. Climate change and producer prices also have negative impacts in the short and long term. Government funding has not resulted in an increase in coffee production either in the short and long term.

Overall, coffee production studies have concentrated in countries outside Malaysia, such as Tanzania, Nigeria, and Papua New Guinea. Therefore, this study aims to fill this gap by integrating macroeconomic factors into the coffee production model in Malaysia.

METHODOLOGY AND MODEL

Data Sources

This study uses annual time series data from 1982 to 2023. The categories and sources of variables used in this study are shown in Table 1.

Table 1

Variable Definition and Source

Variable Category	Variable Code	Variable Name	Measurement Unit	Description	Source
Dependent	PCFE	Coffee Production	Metric Tons	The total volume of coffee produced annually.	Department of Statistics Malaysia, the Department of Agriculture (DOA)
Independent	PRCO	Price of Cocoa	US\$/Kg	Average market price for cocoa	World Bank
Independent	LAR	Planting Area	Hectares	Total land area dedicated to coffee cultivation.	Department of Agriculture (DOA)
Independent	GEXP	Government Expenditure on agriculture sector	RM Million	Total annual government spending on the agricultural sector.	Department of Statistics Malaysia (DOSM)

Variable Category	Variable Code	Variable Name	Measurement Unit	Description	Source
Independent	POPG	Population Growth	Annual %	The annual percentage change in the total population of Malaysia.	Department of Statistics Malaysia (DOSM)
Independent	RF	Rainfall	Millimeter (mm)	Proxy for climate change; average rainfall.	World Bank

The properties of time series data are analysed using Ordinary Least Square (OLS). However, in many cases, time series data involve unit root problems, which cause spurious regressions. Thus, to overcome this problem, this study used the ARDL method to analyse the data. The ARDL method developed by Pesaran et al. (1996, 2001) is used to determine the cointegration features of the estimated equation. ARDL is utilized in this study because of its superiority. First, it allows variables to be integrated at either I(0) or I(1), including combinations of I(0) and I(1), as well as an unknown order of integration (Egwuma et al., 2016). Second, it can be used for small sample sizes. Third, it circumvents the numerous requirements outlined in conventional cointegration testing. Unlike typical cointegration tests, the ARDL technique allows for the possibility of having variables with different optimal lag lengths. Consequently, this model can be adapted to fit small sample sizes.

In selecting the best model, Hendry's general-to-specific method was used. Therefore, in the final model, only six variables were included, namely coffee production (PCFE), area (LAR), cocoa price (PRCO), government expenditure (GEXP), population growth (POPG). and climate change (RF). Thus, the ARDL estimated equation for this study is derived as follows (Equation 1):

$$\begin{aligned} \Delta PCFE_t = & \alpha_0 + \sum_{h=1}^k \beta_{1h} \Delta LAR_{t-h} + \sum_{i=1}^l \beta_{2i} \Delta PRCO_{t-i} + \sum_{j=1}^m \beta_{3j} \Delta GEXP_{t-j} \\ & + \sum_{k=1}^n \beta_{4k} \Delta POPG_{t-k} + \sum_{l=1}^o \beta_{5l} \Delta RF_{t-l} + \gamma_1 PCFE_{t-1} + \gamma_2 LAR_{t-1} \\ & + \gamma_3 PRCO_{t-1} + \gamma_4 GEXP_{t-1} + \gamma_5 POPG_{t-1} + \gamma_6 RF_{t-1} + \varepsilon_t \end{aligned}$$

Where;

α, β and γ = Estimated parameter

$PCFE_t$ = Malaysia coffee production (tonnes)

LAR_t = Land size (Hectare)

$PRCO_t$ = Coffee price (US\$/Kg)

$GEXP_t$ = Government expenditure in agriculture sector (RM million)

$POPG_t$ = Population growth (percentage)

RF_t = Climate change (rain fall (mililiter (ml))

ε_t = Error term

Meanwhile, to determine the existence of a long-run relationship between the variables in this study, the bounds cointegration test (Bounds test – F-statistic) was applied. This test was based on comparing the F-statistic with the upper and lower critical values (Pesaran et al., 2001). If the F-statistic exceeds the upper critical value, then there is a long-run relationship (the null hypothesis is rejected). Conversely, there is no long-run relationship if the F-statistic value is below the lower critical value. In addition, the Breusch–Godfrey Lagrange Multiplier (LM) diagnostic test was conducted estimated

to ensure the efficiency and reliability of the estimated model. This test confirms whether there is no evidence of serial correlation in the residuals of the estimated model. Meanwhile, the Jarque–Bera (JB) test was applied to test the normality of the residuals. In addition, the cumulative sum test (CUSUM) was used to test the stability of the estimated parameters in the estimated model. The stability of the parameters and the absence of structural instability are based on the 5 percent critical plot limit over the sample period (Brown et al., 1975; Pesaran et al., 1996; Pesaran et al., 2001).

RESULTS

Stationarity Testing of Variables

To determine the integration properties of the data, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were employed for each variable. The results, presented in Table 2, showed that the variables exhibited mixed orders of integration, where some were stationary at level (I(0)) and others were stationary after first differencing (I(1)). Importantly, none of the variables were integrated of order two (I(2)), confirming the data’s suitability for the subsequent ARDL bounds testing approach.

In Table 2, the variables in their level form were non-stationary, indicating that their variance, mean, and covariance were not constant over time.

Table 2

Unit Root Test ADF and PP

Augmented Dickey-Fuller (ADF)									
Level			First Different						
	Intercept		Trend and Intercept		Intercept		Trend and Intercept		
	t-Statistic	Prob.*	t-Statistic	Prob.*	t-Statistic	Prob.*	t-Statistic	Prob.*	
PCFE	-2.363412	0.1585	-1.040564	0.9267	-4.455776	0.0010	-4.407937	0.0059	I(1)
LAR	-1.838772	0.3571	-2.457342	0.3465	-6.810940	0.0000	-6.234661	0.0001	I(1)
PRCO	-1.105629	0.7046	-2.858240	0.1863	-4.907606	0.0003	-5.071743	0.0010	I(1)
GEXP	-2.020677	0.2772	-2.844262	0.1906	-6.117372	0.0000	-6.036754	0.0001	I(1)
POPG	0.231308	0.9714	-3.928781	0.0201	-4.564944	0.0007	-4.502417	0.0046	I(1)
RF	-4.533383	0.0007	-5.092254	0.0009	-7.367951	0.0000	-7.272363	0.0000	I(0) and I(1)

Phillips-Perron (PP) tests									
Level			First Different						
	Intercept		Trend and Intercept		Intercept		Trend and Intercept		
	t-Statistic	Prob.*	t-Statistic	Prob.*	t-Statistic	Prob.*	t-Statistic	Prob.*	
PCFE	-1.427235	0.5597	-1.434103	0.8356	-4.682400	0.0005	-4.645648	0.0032	I(1)
LAR	-2.793467	0.0680	-2.014596	0.5762	-7.074004	0.0000	-11.11605	0.0000	I(1)
PRCO	-1.128390	0.6955	-1.733619	0.7180	-3.820315	0.0057	-4.785902	0.0022	I(1)
GEXP	-2.104096	0.2442	-2.977703	0.1506	-6.562843	0.0000	-6.436329	0.0000	I(1)
POPG	0.231308	0.9714	-2.580819	0.2906	-4.538454	0.0008	-4.480342	0.0049	I(1)
RF	-4.502072	0.0008	-5.088887	0.0009	-16.85427	0.0000	-16.70858	0.0000	I(0) and I(1)

However, after applying the first-difference transformation, all variables, such as Malaysia’s coffee production (PCFE), land size (LAR), coffee price (PRCO), government expenditure in the agricultural sector (GEXP), Malaysia’s population growth (POPG) and rainfall (RF) became stationary. This is

evidenced by p-values below the 5 percent significance level, allowing the rejection of the null hypothesis of non-stationarity and acceptance of the alternative hypothesis (H_1).

Hence, the findings suggest that all variables are integrated of order one. These results align with the assertion by Phillips and Perron (1988), who highlighted that the presence of unit roots in time series data can influence the reliability of long-term analysis. Based on the unit root results, the ARDL approach was applied in this study. This choice was made due to the ARDL model's suitability for time series data comprising a mixture of $I(0)$ and $I(1)$ variables (provided no variable is $I(2)$). Consequently, a subsequent bounds testing procedure was conducted to formally test for a long-run relationship among the variables.

Short Run Error Correction Models

An Error Correction Model (ECM) is a powerful econometric tool used to model the relationship between non-stationary time series variables that are cointegrated. Cointegration implies that while individual time series may be non-stationary, a linear combination of them is stationary, indicating a long-run equilibrium relationship. ECMs are particularly useful for capturing both short-term dynamics and long-term equilibrium adjustments between variables. The results of the short-run analysis using the ECM model are presented in Table 3. Granger's Representation Theorem states that a valid error-correcting representation exists when there is a long-term link between variables, and vice versa (Engle and Granger, 1987).

The study revealed that the lagged error correction term (ECT) is -0.6633, indicating that approximately 66.33 percent of the deviation from the long-run equilibrium was corrected in each period following a shock. This suggested a relatively slow adjustment process. According to Wong and Mohammad Yusof (2017), such a rate implies that the market takes a considerable amount of time to return to equilibrium; approximately 1.5 years (calculated as $1/0.6633$) to fully adjust.

Table 3

Error Correction Represented for the Selected ARDL Model ARDL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-49300.6	5819.519	-8.4716	0.0000
D(PCFE(-1))	-0.0817	0.1124	-0.7272	0.4838
D(PCFE(-2))	0.8740	0.1351	6.4684	0.0001
D(PCFE(-3))	0.9078	0.1418	6.4003	0.0001
D(LAR)	-0.0107	0.1793	-0.0597	0.9536
D(LAR(-1))	0.9044	0.2008	4.5035	0.0011
D(LAR(-2))	0.9519	0.2006	4.7451	0.0008
D(LAR(-3))	0.5585	0.1968	2.8372	0.0176
D(PRCO)	1415.128	1414.082	1.0007	0.3406
D(PRCO(-1))	6957.754	1520.078	4.5772	0.0010
D(PRCO(-2))	6506.381	1354.144	4.8048	0.0007
D(PRCO(-3))	17689.93	2556.107	6.9207	0.0000
D(GEXP)	3.4189	0.8173	4.1833	0.0019
D(GEXP(-1))	3.6925	0.7629	4.8395	0.0007

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GEXP(-2))	1.6069	0.6917	2.3233	0.0425
D(GEXP(-3))	0.8311	0.6657	1.2485	0.2403
D(POPG)	-20231.3	6621.176	-3.0555	0.0121
D(POPG(-1))	11503.97	5100.481	2.2555	0.0477
D(RF)	3.0323	1.3266	2.2858	0.0453
D(RF(-1))	-15.579	2.0695	-7.5279	0.0000
D(RF(-2))	-8.5336	1.7663	-4.8314	0.0007
D(RF(-3))	-2.4169	1.5358	-1.5737	0.1466
CointEq(-1)*	-0.6633	0.0783	-8.4748	0.0000
R-squared	0.9116	Mean dependent var		-31.2808
Adjusted R-squared	0.7820	S.D. dependent var		3967.54
S.E. of regression	1852.421	Akaike info criterion		18.1674
Sum squared resid	51471949	Schwarz criterion		19.1585
Log likelihood	-322.18	Hannan-Quinn criter.		18.5200
F-statistic	7.0333	Durbin-Watson stat		2.306
Prob(F-statistic)	0.000164			

Notes:* p-value incompatible with t-Bounds distribution.

The results also indicated that the second (D(PRCE(-2))) and third (D(PRCE(-3))) lagged production terms had positive signs and significant. The coefficient values were 0.87 and 0.91, respectively. This explained that current coffee production was positively influenced by previous production. Coffee production typically takes approximately three years to produce crops.

Land under cultivation (LAR) also showed significant positive effects at lags one to three. The results suggested that expansion in agricultural area contributed positively to output but with a time lag, possibly due to the time required for land preparation and crop maturity. A two-year delay had a higher coefficient value than a one- and three-year delay. The coefficient value was 0.95, suggesting that for a one-unit increase in production delayed by two years, current production increased by 0.95 unit.

World cocoa prices (PRCO) exhibited strong positive effects from lag one to lag three, all highly significant. This implied that international market trends and export prices had a delayed but substantial influence on the domestic sector, likely through revenue and investment channels. The coefficient value were 6957.75, 6506.38 and 17689.93, respectively. The delayed cocoa price had a positive effect on the increase in coffee production. This can also be explained by the fact that an increase in cocoa prices raises the price of downstream cocoa products. As a substitute, coffee producers tend to increase their production to meet the demand for substitutes for coffee.

Government expenditure (GEXP) was significant at the 1 percent significance level, with a coefficient value of 3.42. This meant that for a one-unit increase in government expenditure, production increased by 3.42 units. Time lags 1 and 2 were also significant. This illustrated the important role of the government in driving coffee production, especially in the short term.

Population growth (POPG) presented mixed effects—current growth negatively impacted the dependent variable, while the lagged effect was positive. This could reflect short-term resource pressure due to rising population, followed by medium-term benefits, such as labour availability or

market expansion. In the short run, the population growth rate (D(POPG)) had a significant negative effect on coffee production, with a t-statistic of -3.06 and a p-value of 0.0121. This indicated that as the population grew, coffee production declined. One potential explanation is that population growth may lead to more land being used for urbanization or food crop cultivation, reducing the area available for coffee farming.

Additionally, population growth may divert labour away from coffee farming as people seek employment in other sectors. While a larger population may increase domestic demand for coffee in the long run, the immediate effect of population growth appears to strain resources and reduce coffee output in the short run. In addition, in the short run Rainfall (RF) was highly significant at 1 percent level, with an elasticity value of 0.5441. This meant that a 1 percent increase in rainfall increased yield by 0.54 percent. However, the excessive rainfall in previous periods (lags one and two) negatively affected the dependent variable. This may be due to flooding or adverse growing conditions. Meanwhile, the R-squared value was 0.9116, indicating that 91.16 percent of the variation in coffee production in Malaysia was explained by the variables D(LAR), D(PRCO), D(GEXP), D(POPG), and D(RF).

ARDL Bound Testing

Next, ARDL bounds tests for cointegration were performed to test the existence of a long-run relationship between the variables in this study. Referring to Equation 1, the ARDL bounds tests for cointegration were estimated. The test statistic was calculated by comparing the F-statistic with the critical F-value. The results are tabulated in Table 4. The F-statistic value was 7.9802, exceeding the critical value of the upper boundary at 1 percent significance level. According to the guidelines for hypothesis testing, if the calculated test statistic value is greater than the critical value, then the null hypothesis of no cointegration between variables is rejected among PCFE, LAR, PRCO, GEXP, POPG and RF variables. Since the F-statistic is greater than both the lower and upper bound values at 1 percent, this confirmed the existence of a long-term relationship among the variables.

Table 4

ARDL Bound Test of Cointegration

Test Statistic	Value	Significant	Lower bound (I (0))	Upper bound (I(1))
F-statistic	7.9802	10%	2.26	3.35
k	5	5%	2.62	3.79
		2.5%	2.96	4.18
		1%	3.41	4.68

Long Run Estimation

The findings of the study in the long run were shown in Table 5. Based on the regression results, rainfall (RF) was the most statistically significant variable in the model, with a positive coefficient of 25.06 at 1 percent significance level. This indicated that rainfall played a crucial role in influencing the production of coffee (most likely related to agricultural productivity), where a one-unit increase in rainfall led to an estimated increase of 25.06 units in output. The elasticity value was 4.50,

meaning that if the rain falls increased by 1 percent, the production increases by 4.49 percent. This result was consistent with the expectation that adequate rainfall is essential for crop growth and agricultural performance. This finding was similar to Hakorimana and Akcaoz (2019) but contradicted Salim et al. (2020).

The second most significant variable was population growth (POPG), which also showed a positive and statistically significant relationship with the dependent variable (coefficient = 25,303.13; $p = 0.0136$). This suggested that an increase in population growth contributed to higher output, possibly due to rising domestic demand or labour availability, which can stimulate production and economic activity in the relevant sector. The elasticity value was 3.56, indicating that 1 percent increase in population growth was associated with a 3.56 percent increase in coffee production. This finding may also be attributed to modern lifestyles with a variety of coffee drinks. This result was consistent with Josephson et al. (2014) but differed from Bashir and Yuliana (2019).

Table 5
Estimated Long run Coefficient Using ARDL Approach

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Elasticity
LAR	-1.9397	0.7082	-2.7388***	0.0209	-1.30
PRCO	-7133.852	3640.863	-1.9594**	0.0785	-0.87
GEXP	-2.3491	3.9836	-0.5897	0.5685	-0.30
POPG	25303.13	8460.933	2.9906***	0.0136	3.56
RF	25.0638	8.2687	3.0312***	0.0127	4.50

Note: *** Significant at 1 percent; ** Significant at 5 percent

Next, land area (LAR) had a negative and statistically significant coefficient of -1.9397 ($p = 0.0209$), significant at 1 percent level. The elasticity was -1.30, meaning that a 1 percent increase in the area planted reduced total coffee production by 1.30 percent. This also implied that increasing the land area used did not necessarily enhance output; in fact, it was associated with a decline. This counterintuitive result may be due to inefficiencies in land use, the inclusion of less fertile or marginal land, or diseconomies of scale in production expansion. The result was aligned with Abu Hassan Asari et al. (2011) but differed from Widyawati et al. (2024) and Hegena and Teshome (2022).

The price of cocoa (PRCO) had a negative coefficient of -7133.85, making it statistically significant at the 10 percent level. While the elasticity value was -0.87, implying that 1 percent increase in cocoa price led to a decrease in coffee production by 0.87 percent. The negative relationship suggested that as cocoa prices rose, the output of the coffee production declined. This situation could potentially be caused by resource redistribution or competition between crops. Producers tend to shift resources toward higher-priced crops to increase income and profits.

Finally, government expenditure (GEXP) had no statistically significant impact on the dependent variable, with a coefficient of -2.35. This indicated that government spending, as captured in this model, did not have a direct or measurable influence on output, possibly due to inefficiencies, misalignment with sectoral needs, or delayed effects that were not captured within the current data. This result was similar to Ojiya et al. (2017) but differed from Akintunde (2013).

Next, the serial correlation and normality diagnostic tests of the estimated ARDL model were conducted. This study confirmed that there was no serial correlation problem. This situation was assessed by using the LM Breusch-Godfrey (BG) test. Table 6 presents the findings. At the 95 percent

confidence level, the chi square value was 0.2305, with a probability value of 0.7250. This result was higher than the 0.05 significance, indicating the absence of serial correlation.

Table 6

Breusch-Godfrey Serial Correlation LM Test

Test	Statistics (F)	Obs*R-squared	Probability	Prob. Chi-Square (2)
Breusch-Godfrey (BG) LM	0.334801	2.934955	0.7250	0.2305

Meanwhile, the Jarque-Bera normality test was used to confirm that the regression was unbiased and stable, with a test statistic value of 0.4448 and a probability value of 0.8006. This probability value exceeded the 5 percent rule-of-thumb significance level, indicating that the residuals were normally distributed.

Furthermore, the long run and short run parameter stability was examined using the stability tests. This was accomplished using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMsq) tests, as recommended by Brown et al. (1975), Pesaran et al. (1996), and Pesaran et al. (2001). The graphs of CUSUM and CUSUMsq were displayed by Figures 3 and Figure 4, respectively. Both figure plots fell within the critical bounds at the 5 percent significance level. This meant that, at both the lower and upper limits, the plots remained within the critical boundaries. This verified the stability of the short- and long-run parameters, as well as the overall stability of the ARDL model with respect to structural breaks. The output of the calculated model was reliable and efficient.

Figure 3

CUSUM Test

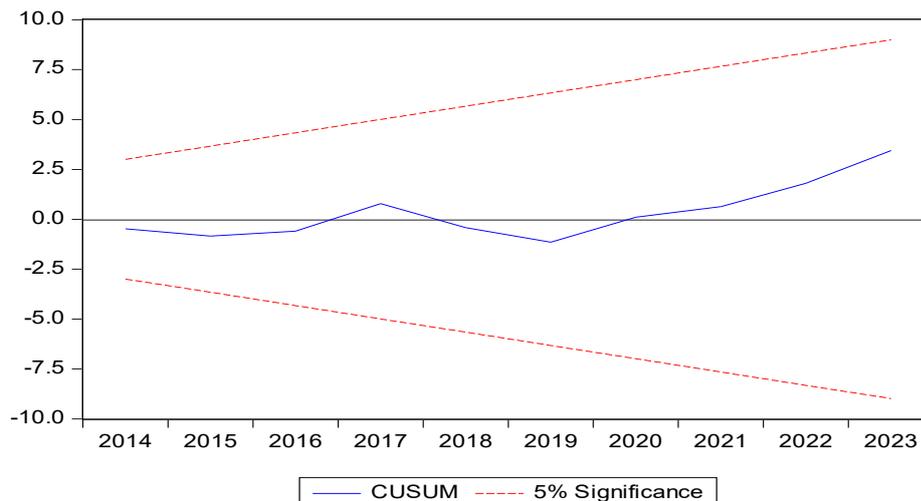
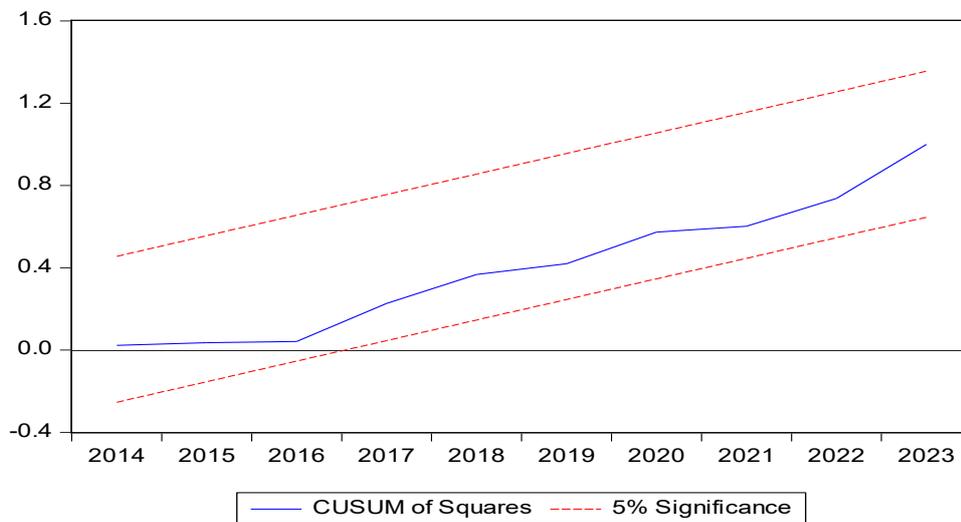


Figure 4

CUSUM Sq Test



CONCLUSION AND RECOMMENDATION

The results of this study confirm the existence of significant relationships between key determinants and Malaysian coffee production, both in the short and long term. In the long run, climate change (as proxied by rainfall) and population growth emerge as the most influential positive determinants, suggesting that favourable weather conditions and increasing domestic demand play a critical role in sustaining production. Conversely, land area (LAR) exhibits a significant negative impact. This implies potential competition in land use between coffee and other agricultural crops. The price of cocoa (PRCO) also shows a significant negative impact. This suggests is the presence of crop substitution effects that hinder coffee production expansion.

In the short term, government expenditure (GEXP) and climatic factors positively influence coffee output. This reflects the early-stage reliance of the sector on public support and favourable environmental conditions. Lagged variables, such as past coffee production, cultivated land area, cocoa prices, and government expenditure (ranging from one to three-year delays), also demonstrate significant positive effects, indicating that historical investments and environmental patterns contribute meaningfully to present production. However, adverse weather conditions in previous years tend to negatively impact current yields, underlining the vulnerability of coffee cultivation to climatic extremes.

As coffee continues to emerge as a promising agricultural commodity in Malaysia, driven by growing domestic and international demand, the sector presents valuable opportunities for agro-based industry development, employment creation, and export diversification. However, Malaysia's relatively small footprint in global coffee markets necessitates sustained and strategic government intervention. Such efforts must include targeted incentives, research and development support, technical training, and marketing strategies to strengthen the value chain and enhance competitiveness.

Importantly, the future development of Malaysia's coffee industry must integrate sustainability as a core component. Sustainable coffee production requires the adoption of environmentally sound

agricultural practices, climate-resilient crop varieties, efficient land use, and reduced reliance on chemical inputs. In addition, social sustainability—particularly through inclusive policies that support smallholders, attract youth participation, and encourage private sector investment—is essential for long-term viability. By embedding sustainability into its coffee development agenda, Malaysia can ensure resilient growth that balances economic, environmental, and social objectives.

In summary, while population growth and favourable climate conditions are key long-term drivers, and government support acts as a vital short-term enabler, the future of Malaysia's coffee sector lies in its ability to adapt to climate change, manage land-use competition, and build a sustainable, high-value coffee ecosystem.

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