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EXAMINING THE DRIVERS OF MALAYSIA'S PEPPER EXPORT COMPETITIVENESS: EVIDENCE FROM AN AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) FRAMEWORK

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ABSTRACT

This research explores the key drivers shaping the export competitiveness of Malaysian pepper from 2001 to 2022, utilizing the Autoregressive Distributed Lag (ARDL) framework. Competitiveness is assessed through the Revealed Comparative Advantage (RCA) index, with particular attention to the roles of Gross Domestic Product (GDP), Foreign Direct Investment (FDI), the Real Effective Exchange Rate (REER), and population dynamics. The long-run analysis indicates that both GDP and REER exert a statistically significant and positive influence on Malaysia's pepper export performance. In contrast, FDI is associated with a negative long-term effect, while population changes appear to have no meaningful impact over the same horizon. Short-run estimates reveal more nuanced relationships: FDI initially dampens competitiveness before contributing positively, and REER demonstrates a shifting influence over time. Population, though insignificant in the long run, emerges as a supportive factor in the short term. These findings highlight the importance of fostering sustained economic growth, maintaining exchange rate stability, and strategically channelling FDI to reinforce Malaysia's competitive edge in the global pepper trade.

***JEL classification**: C32, F14, Q17*
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1. INTRODUCTION

The global competitiveness of agricultural exports is a critical research focus, particularly for economies like Malaysia, where agriculture plays a significant economic role. Pepper, renowned as the 'King of Spices', is a key export, with Sarawak pepper holding a distinguished position in global markets. Analyzing the determinants of competitiveness in Malaysian pepper exports is essential for policymakers and industry stakeholders seeking to enhance sectoral performance and sustainability. This study employs the Autoregressive Distributed Lag (ARDL)

model, selected for its efficacy in handling small sample sizes and mixed-order variables (Pesaran et al., 2001).

As the world's fifth-largest pepper exporter, Malaysia ships approximately 90% of its production, primarily from Sarawak, famed for its premium black and white pepper. Global demand for pepper is influenced by price competitiveness, quality standards, and trade policies. Prior research highlights the role of both price and non-price factors in export competitiveness. For example, Wong et al. (2010) applied the ARDL model to Sarawak pepper exports, identifying relative prices, global income, and exchange rate volatility as key determinants. Similarly, Wong (2019) underscored the impact of exchange rate fluctuations and international demand on Malaysian exports.

This study contributes to the literature by examining the determinants of Malaysian pepper export competitiveness through an ARDL framework, focusing on GDP, FDI, REER, and population dynamics. The insights offer actionable visions for decision makers and interested parties to strengthen Malaysia's position in the global pepper market. Additionally, the research advances empirical understanding of agricultural export competitiveness, providing a case study from a leading spice-exporting nation. By leveraging the ARDL model's robustness, the study elucidates the complex interplay of economic and demographic factors shaping export performance, supporting strategies for a more competitive and sustainable pepper industry.

2. LITERATURE REVIEW

The global competitiveness of agricultural exports, particularly pepper, is still of great interest owing to its economic implications for producing countries such as Malaysia. Pepper is one of Malaysia's key agricultural exports, with Sarawak renowned for producing high-quality varieties that are well-regarded internationally. Despite its historical prominence, the Malaysian pepper industry faces mounting challenges, including high production costs, labour shortages, and increasing competition from other major pepper-producing nations (Entebang et al., 2020). In response to these pressures, the National Commodity Policy 2011–2020 was introduced to enhance the sector's competitiveness and sustainability through modernization efforts and value-added strategies (MPIC, 2012).

Export competitiveness, in this context, reflects a country's strength in sustaining or boosting its market position in global trade by offering products at competitive prices without compromising quality. This concept is influenced by a range of factors, including relative pricing, product standards, and exchange rate stability (Demir and Javorcik, 2018; Caselli, 2018). A common metric used to assess this is the Revealed Comparative Advantage (RCA) index, which evaluates whether a country holds a comparative advantage in a specific product by comparing its share of global exports to the world average (Balassa, 1965). In studies of Malaysian pepper, the RCA index is typically used as the dependent variable to measure export competitiveness. Previous research has shown that Malaysia's pepper industry has struggled to maintain its competitive position due to a combination of internal inefficiencies and external market dynamics (Wong et al., 2010).

To better understand the drivers of export competitiveness, several independent variables are considered, including Malaysia's Gross Domestic Product (GDP), Foreign Direct Investment (FDI), Real Effective Exchange Rate (REER), and

population size. GDP serves as a broad indicator of economic strength; a higher GDP often correlates with improved infrastructure and production capacity, which can enhance the quality and global appeal of agricultural exports (Wong, 2019). FDI is another critical factor, as it brings in capital, technology, and expertise that can improve production efficiency and product quality. Studies such as Athukorala and Menon (1995) have demonstrated the positive impact of FDI on Malaysia's manufacturing exports, with similar implications for agriculture. The REER, which measures the value of the Malaysian ringgit against a basket of foreign currencies adjusted for inflation, also plays a key role. A stable or depreciating REER can make Malaysian exports more price-competitive in international markets. Bahmani-Oskooee and Kara (2005) emphasized that exchange rate stability is essential for maintaining export competitiveness, as volatility can disrupt pricing and demand.

Production volume is equally important, as higher output levels can lead to economies of scale, reducing unit costs and enhancing global competitiveness. Entebang et al. (2020) highlighted the importance of improved farm management and production efficiency in strengthening Malaysia's position in the pepper trade. Additionally, population size can influence export performance. A larger population often translates into a more substantial labour force, which supports agricultural productivity. It also creates a broader domestic market, allowing producers to achieve scale and stabilize prices before entering international markets. This dual effect enhanced production capacity and internal market resilience can contribute positively to export competitiveness (Ketels, 2010). However, to fully leverage these demographic advantages, Malaysia must continue to address structural challenges such as high input costs and external competition (Entebang et al., 2020; Liew et al., 2021).

Essentially, Malaysian pepper export competitiveness is driven by a multifaceted mix of economic, structural, and market dynamics. The ARDL model provides a rigorous approach to disentangle both immediate and enduring effects on export trends. Gaining clearer insight into these factors is vital for policymakers and industry players aiming to strengthen the sector's resilience, long-term viability, and international position.

3. METHODOLOGY

3.1 Source of Data

The study utilized secondary time series data on Malaysia's pepper export values, sourced from the UN COMTRADE and International Trade Centre (ITC) databases. For analytical consistency, the export data classified under HS090411 and HS090412 were aggregated into a single category representing total pepper exports. Covering 2001–2022, the study captures two decades of structural evolution and long-term changes. A complete overview of the variables employed in the study is presented in Table 1. To strengthen the econometric model, all variables were log-transformed, enhancing interpretability and mitigating scale disparities and heteroscedasticity, providing a more robust alternative to linear specification (Shahbaz et al., 2017).

Table 1: Variables description

Variables	Description	Source
RCA	Revealed Comparative Advantage indicates a country's export efficiency in a specific good relative to global export performance.	UN COMTRADE and International Trade Centre (ITC)
GDP	Gross Domestic Product (GDP) quantifies a nation's annual output of final goods and services, adjusted for inflation using constant 2015 USD	World Development Indicators, World Bank
FDI	Foreign direct investment refers to the acquisition of at least a 10% equity stake in overseas enterprises, typically accompanied by capital inflows, technology transfer, and managerial or technical expertise. It is quantified in current U.S. dollars.	World Development Indicators, World Bank
REER	The Real Effective Exchange Rate reflects a country's inflation-adjusted currency value relative to major trading partners, using a weighted index benchmarked to 2010, where a value of 100 indicates the base level.	International Monetary Fund, International Financial Statistics
POP	Population figures are estimated by the U.S. Census Bureau using a combination of decennial census data, vital statistics, and nationally representative surveys.	CIA World Factbook

3.2 Competitiveness of Malaysian pepper exports

This metric compares a country's export share to its overall share in global trade. The formula for RCA is:

$$\mathrm{RCA_{ij}} = \frac{\mathrm{X_{ij}}/\mathrm{X_i}}{\mathrm{X_{wj}}/\mathrm{X_w}} \quad (1)$$

Where:

$\mathrm{RCA_{ij}}$ = of a country *i* in group of commodity *j*

X_{ij} = Total export of country *i* in group commodity *j*

X_i = Total exports of country *i*

X_{wj} = World exports in group commodity *j*

X_w = Total world exports

3.3 Specification of the econometric ARDL model

This study applies the ARDL model (Pesaran et al., 2001), a flexible econometric technique well-suited for I(0) and I(1) variables. As noted by Muhammad et al. (2021), it effectively captures short- and long-run effects on Malaysia's pepper export competitiveness, even with limited sample size. Using ordinary least squares (OLS) for cointegration (Duasa, 2007), ARDL accommodates mixed integration orders (Frimpong and Oteng, 2006), but excludes I(2) variables. The following specification was used to examine the variable relationships.

$$RCA_t = \alpha_0 + \alpha_1 GDP + \alpha_2 FDI + \alpha_3 REER + \alpha_4 POP + \varepsilon_t \quad (2)$$

The equation in 2 is then transformed into natural log, and it can be rewritten as:

$$lnRCA_t = \alpha_0 + \alpha_1 lnGDP + \alpha_2 lnFDI + \alpha_3 lnREER + \alpha_4 lnPOP + \varepsilon_t \quad (3)$$

In this context, RCA denotes the revealed comparative advantage of Malaysian pepper exports, with *t* representing the period from 2001 to 2022. The term α_0 signifies the constant, while $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are the coefficients of the variables. GDP, FDI, REER and POP correspond to Malaysia's Gross Domestic Product,

Foreign Direct Investment, and Real Effective Exchange Rate, and Population respectively. The term ε_t signifies the error term. Equation 3 can be expressed in ARDL model as shown below:

$$\Delta \ln RCA_t = \alpha_0 + \sum_{k=1}^{n} \alpha_1 \Delta lnRCA_{t-k} + \sum_{k=1}^{n} \alpha_2 \Delta GDP_{t-k} + \sum_{k=1}^{n} \alpha_3 \Delta FDI_{t-k} + \sum_{i=1}^{s} \alpha_4 \Delta \ln REER_{t-k} + \lambda_1 \ln RCA_{t-1} + \lambda_2 \ln GDP_{t-1} + \lambda_3 \ln FDI_{t-1} + \lambda_4 \ln REER_{t-1} + \lambda_5 \ln POP_{t-1} + \varepsilon_t \quad (4)$$

α_0 denotes the constant, Δ represents first differences, and ε_t captures the white noise. Lag selection is guided by the Akaike Information Criterion (AIC). Once long-run cointegration is confirmed, the study applies an Error Correction Model (ECM) to assess short-run dynamics, with its structure defined in Equation 5, following the general form in Equation 4.

$$\Delta \ln RCA_t = \alpha_0 + \sum_{k=1}^{n} \alpha_1 \Delta lnRCA_{t-k} + \sum_{k=1}^{n} \alpha_2 \Delta GDP_{t-k} + \sum_{k=1}^{n} \alpha_3 \Delta FDI_{t-k} + \sum_{k=1}^{n} \alpha_4 \Delta \ln REER_{t-k} + \sum_{k=1}^{n} \alpha_5 \Delta \ln POP_{t-k} + \emptyset ECM_{t-1} + \varepsilon_t \quad (5)$$

$\emptyset$ denotes the short-run coefficients within the ECM, reflecting how quickly the system corrects back to its long-run equilibrium after a temporary shock.

3.4 Unit root test

Establishing stationarity is essential in ARDL modelling to ensure result validity. This is commonly tested using Augmented Dickey Fuller **(**ADF) and Phillips-Perron **(**PP) procedures, where ADF accounts for serial correlation via lagged terms, and PP addresses both serial correlation and heteroskedasticity non-parametrically. Both tests assess the presence of unit roots, confirming stationarity when the null is rejected. ARDL requires the dependent variable to be I(1), while predictors must be I(0) or I(1); I(2) variables are excluded. Optimal lag lengths are selected using Akaike Information Criterion (AIC) to determine integration order via test statistics.

3.5 Estimating optimal lag

To determine the optimal ARDL lag structure in EViews via a VAR based approach, estimate a VAR model within a defined lag range and evaluate Akaike Information Criterion (AIC), Schwarz Criterion (SC), and Hannan-Quinn Criterion (HQ) in the Lag Structure view. Select the lag with the lowest criterion value, then apply it in the ARDL setup to ensure model precision and robust estimation.

3.6 Estimation process

Bounds testing was conducted to evaluate long-run equilibrium among variables. After estimating Equation 3, the Wald F-test was applied in Equation 4 to jointly test the null of no cointegration (H_0: $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$). The F-statistic was assessed against Pesaran and Shin (1999) critical bounds values below, within, or above these thresholds respectively indicate no cointegration, inconclusive results, or confirmed

long-run association. This step validates the suitability of a long-run ARDL framework by confirming variable co-movement.

3.7 Stability test – CUSUM and CUSUMSQ

The study employs CUSUM and CUSUMSQ tests (Brown et al., 1975), widely applied in ARDL diagnostics, to verify long-run stability. By charting ECM residuals, these tests determine whether model coefficients remain consistent, evidenced when plots lie within the 5% significance bounds (Pesaran and Shin, 1999; Pesaran et al., 2001).

4. RESULTS AND DISCUSSION

4.1 Competitiveness of Malaysian pepper exports

An examination of Malaysia's RCA in pepper exports from 2001 to 2022 reveals a clear downward trajectory in global competitiveness (Figure 1). While the country maintained an average RCA of 3.21 well above the threshold of 1, indicating a comparative advantage this strength has steadily diminished, particularly since 2017. This trend mirrors broader patterns in agricultural trade, where intensifying global competition and evolving market conditions have challenged many exporters' ability to sustain their positions (Mizik et al., 2020).

In 2001, Malaysia's RCA peaked at 6.01, reflecting a strong export-oriented posture consistent with the strategies highlighted by Wong et al. (2021). However, the fluctuations observed between 2001 and 2011 suggest that this early advantage lacked long-term resilience. From 2012 to 2016, RCA values stabilized around 3, indicating a shift from strong to moderate competitiveness. This decline likely stems from both rising competition particularly from emerging producers like Indonesia and internal inefficiencies in Malaysia's pepper sector (Azahari et al., 2021).

The period from 2017 to 2022 marked a sharper decline. RCA values fell below 2 in 2018 and reached a low of 1.26 in 2021, signalling a near loss of Malaysia's comparative edge. This erosion aligns with Abdullahi et al. (2021), who note the increasing difficulty for countries to maintain export advantages amid global market pressures. The narrowing gap between Malaysia's RCA and the global average underscores the urgency of strategic reform, as emphasized by Maulana et al. (2023).

Several structural and external factors have contributed to this decline. Indonesia's growing dominance in pepper exports (Azahari et al., 2021), coupled with shifting global demand and evolving consumer preferences (Prasada and Dhamira, 2021), have intensified competitive pressures. Internally, production inefficiencies and limited value-added diversification have further constrained Malaysia's ability to adapt.

Although Malaysia sustained a relatively high RCA for pepper exports over two decades, the overall trend points to a weakening competitive position. This decline reflects broader challenges in agricultural trade and highlights the need for targeted policy responses. Enhancing productivity, investing in quality improvements, and expanding into value-added segments will be critical for Malaysia to reclaim and sustain its standing in the global pepper market.

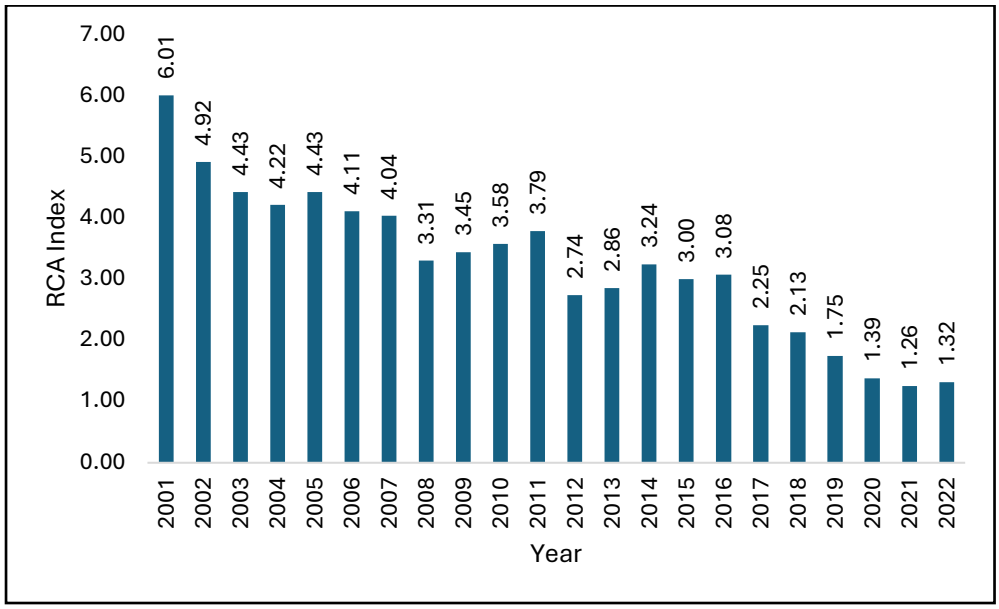

Figure 1: The revealed comparative advantage of Malaysian pepper

4.2 Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests

As shown in Table 2, the unit root test results provide essential insights into the stationarity properties of the variables used in the ARDL model. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests reveal that LogRCA, LogGDP, and LogREER are non-stationary at their levels, as their test statistics fail to reach conventional significance thresholds. This outcome aligns with established econometric literature, which cautions that non-stationary time series can lead to spurious regressions if not properly addressed (Ullah et al., 2018; Petrică et al., 2017; Gurung, 2023). The presence of unit roots in these variables suggests they are not mean reverting, underscoring the importance of appropriate transformation prior to model estimation (Sarker and Khan, 2020; Afriyie et al., 2020).

In contrast, LogFDI and LogPOP exhibit stationarity at level under certain specifications, particularly when trend and intercept are included. Their mixed stationarity profiles are consistent with prior studies that emphasize the need for careful diagnostic testing and variable treatment in ARDL applications (Rehman and Zhang, 2018; Islam et al., 2018). These variations highlight the context-dependent nature of stationarity and the importance of tailoring econometric strategies to the specific characteristics of the data (Kipiński et al., 2011; Rehman, 2019).

After first differencing, all variables - LogRCA, LogGDP, LogFDI, LogREER, and LogPOP—achieve stationarity, indicating they are integrated of order one, I(1). This transformation confirms that the variables become mean reverting once differenced, a prerequisite for valid ARDL modelling. These results align with existing empirical findings that advocating for the use of I(1) variables in ARDL frameworks to ensure model stability and avoid specification errors (Gereziher and Nuru, 2021; Abugwu et al., 2022). Ensuring stationarity through differencing enhances the reliability of the estimated relationships and strengthens the overall robustness of the analysis (Yildirim et al., 2021; Demmler and Domínguez, 2022).

The unit root tests underscore the foundational role of stationarity in time series modelling. Properly addressing non-stationarity through transformation is essential for producing valid and interpretable results. This methodological rigor not only

safeguards the integrity of the ARDL model but also ensures that the dynamic interactions among economic variables are accurately captured (Guo, 2023; Irwandi, 2018).

Table 2: Unit root tests

	ADF		PP	
	Intercept	Trend and Intercept	Intercept	Trend and Intercept
Variables		Level		
logRCA	-0.2994	-1.7867	-0.2523	-1.8437
logGDP	-1.2783	-2.3950	-2.9932	-2.0142
logFDI	-4.4100**	-5.0322**	-4.4492**	-6.4069***
logREER	-0.6782	-1.5982	-0.6782	-1.5982
logPOP	-3.4310**	-3.0093	-25.0834***	-2.5953
Variables		First Difference		
logRCA	-4.7627***	-4.8100***	-4.7905***	-5.2186***
logGDP	-4.0009***	-4.0394*	-3.9654**	-5.6461**
logFDI	-5.0774***	-4.9086**	-19.6415***	-18.8113***
logREER	-3.5745*	-3.4794*	-3.5695*	-3.4674*
logPOP	-2.9790***	-2.0713*	-1.1438*	-1.4675*

*, **, and *** represent significance at the 10%, 5%, and 1% thresholds, respectively. Source: Based on author's calculations

4.3 Optimal lag selection criteria

Table 3 presents VAR based lag selection outcomes using Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Criterion (SC), and Hannan-Quinn (HQ) criteria. Based on the lowest information value, AIC identifies three lags as optimal signaling a well-fitted model with minimal data loss.

Table 3: Lag selection criteria for ARDL model

Lag	Log	LR	FPE	AIC	SC	HQ
0	155.3203	NA	9.25e-14	-15.82319	-15.57466	-15.78113
1	284.5584	176.8522	1.77e-18	-26.79563	-25.30441	-26.54325
2	343.2027	49.3847	1.04e-19	-30.33713	-27.60323	-29.87445
3	857.2873	162.3425*	9.58e-41*	-81.81971*	-77.84313*	-81.14672*

* Based on tests conducted at the 5% significance level. Source: Based on author's calculations

Table 4: ARDL bound test

Null Hypothesis: No long-run relationship		
Test Statistic	Value	K
F - Statistic	5.822961	4
Critical Value Bounds		
Significance	I(0)	I(1)
10%	2.20	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Source: Based on author's calculations

4.4 Cointegration bound test

Table 4 shows ARDL Bounds Test results that confirm a long-run equilibrium link between Malaysia's pepper export performance (LogRCA) and core macroeconomic indicators i.e. LogGDP, LogFDI, LogREER, and LogPOP. The F-statistic of

5.822961 surpasses critical upper bounds at all conventional significance thresholds, rejecting the null of no cointegration. This underscores the sustained influence of these factors on export competitiveness and affirms the model's integrity for analyzing both short - and long-run dynamics.

4.5 Long-run relationship

The long run ARDL model outcomes (3, 0, 2, 2, 1), presented in Table 5, offer critical insights into the structural forces shaping Malaysia's pepper export competitiveness. A key finding is the strong positive association between GDP and competitiveness: a 1% rise in GDP is linked to a 4.62% increase in export performance ($p = 0.0053$). This supports the broader consensus in the literature that economic growth enhances export capacity by fostering investment, innovation, and production efficiency. Studies by Garces and Adriatico (2019) and Aktaş (2022) similarly argue that expanding GDP creates a more dynamic environment for trade through improved infrastructure, technology, and labor productivity.

In contrast, the negative long-run effect of foreign direct investment (FDI), where a 1% increase corresponds to a 0.31% decline in competitiveness ($p = 0.0124$) challenges the conventional assumption that FDI uniformly benefits exports. This result resonates with Kastratović (2020) meta-analysis, which found that FDI's impact varies widely across sectors and contexts. Mukhtarov et al. (2019) further suggest that unless strategically directed, FDI can strain domestic resources or crowd out local firms, particularly in sectors not prioritized for export. This underscores the importance of aligning FDI flows with national export priorities, as advocated by Zhang and Mohd (2023), especially in agriculture-based industries like pepper.

The REER is a central determinant of export competitiveness. Long-run estimates show that a 1% increase in REER corresponds to a 5.79% rise in competitiveness ($p = 0.0028$). A higher REER reflects currency appreciation, which typically reduces competitiveness by raising the relative cost of domestic goods abroad (Dahal et al. 2025). The positive coefficient observed here suggests that exchange rate movements may shape export performance through broader structural factors beyond price effects.

On the other hand, population growth appears to have no meaningful long-term effect on competitiveness. A 1% increase in population is linked to a statistically insignificant 3.26% decline in competitiveness ($p = 0.4751$), suggesting that demographic expansion alone does not translate into export gains without parallel improvements in productivity, infrastructure, or market access. This is consistent with Vissak et al. (2018), who argue that population size is not a reliable predictor of export performance in the absence of structural support. The insignificant constant term further implies that unobserved factors may have limited influence, pointing to the need for future research to explore additional variables.

The long-run ARDL findings underscore the central roles of GDP and REER in driving Malaysia's pepper export competitiveness, while highlighting the potentially adverse effects of misaligned FDI. These results contribute to the broader discourse on trade strategy, emphasizing the need for targeted economic policies that integrate growth, investment, and exchange rate management to sustain export performance in the agricultural sector.

Table 5: Long-run relationship (3,0,2,2,1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGGDP	4.623873	1.085648	4.259093	0.0053
LOGFDI	-0.308117	0.087284	-3.530050	0.0124
LOGREER	5.788746	1.185234	4.884054	0.0028
LOGPOP	-3.259458	4.278891	-0.761753	0.4751
C	-37.82042	30.84430	-1.226172	0.2661

Source: Based on author's calculations

4.6 Short-run relationship

Table 6 summarizes the ARDL model estimates, shed light on the short-run dynamics influencing Malaysia's pepper export competitiveness, revealing nuanced relationships that merit deeper engagement with the existing literature.

Table 6: Short-run relationship (3, 0, 2, 2, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOGRCA(-1))	0.342883	0.132902	2.579971	0.0418
D(LOGRCA(-2))	0.489712	0.135149	3.623497	0.0111
D(LOGFDI)	-0.078846	0.016831	-4.684588	0.0034
D(LOGFDI(-1))	0.162543	0.021889	7.425850	0.0003
D(LOGREER)	3.784889	0.686703	5.511679	0.0015
D(LOGREER(-1))	-4.679299	0.739799	-6.325096	0.0007
D(LOGPOP)	203.0542	25.87561	7.847322	0.0002
CointEq(-1)	-1.050427	0.131249	-8.003285	0.0002

Source: Based on author's calculations

FDI exerts a dual effect. In the short term, a 1% rise in FDI corresponds to a 0.0788% decline in competitiveness ($p = 0.0586$), suggesting initial adjustment costs or sectoral disruptions. This aligns with Tùng (2019), who notes that FDI may temporarily unsettle domestic markets before generating long-term gains. Indeed, the model captures this delayed benefit: lagged FDI improves competitiveness by 0.1625% ($p = 0.0062$), likely reflecting the absorption of new capital, technology, and expertise. Mukhlis and Qodri (2019) similarly highlight this temporal divergence, emphasizing FDI's delayed contribution to growth.

The REER also exhibits short-run dynamics. A 1% increase in REER is initially linked to a 3.78% rise in competitiveness ($p = 0.0163$), but this is followed by a significant negative lagged effect of 4.68% ($p = 0.0055$). As REER appreciation reflects a stronger currency, these results suggest temporary short-term gains, while sustained appreciation ultimately erodes export competitiveness (Nthebe and Mosikari, 2025).

Population growth emerges as a powerful short-run driver. A 1% increase in population correlates with a striking 203.0541% rise in competitiveness ($p = 0.0306$), highlighting the role of demographic expansion in strengthening labor supply and domestic demand. This supports Acaravci et al. (2011), who argue that population growth can catalyze broader economic and export development.

Notably, GDP was not excluded from the short-run specification on methodological grounds. Under the selected ARDL (3,0,2,2,1) model, the optimal lag selection assigned zero lag to GDP. Consequently, no differenced GDP terms appear in the error correction representation. This indicates that GDP affects export competitiveness primarily through the long-run equilibrium relationship rather than short-run dynamic adjustments. Consistent with Nguyen (2017), GDP exerts stronger

influence over longer periods, emphasizing the critical role of temporal context in economic evaluation.

The short-run ARDL findings reveal a layered interplay: FDI and REER exert both immediate and delayed effects, while population growth consistently enhances competitiveness. These insights suggest that policymakers should adopt a calibrated approach stabilizing FDI flows, managing exchange rate volatility, and harnessing demographic momentum to strengthen Malaysia's position in the global pepper market.

4.7 Residual diagnostic tests

To assess the ARDL model's reliability, the study performed diagnostic tests addressing three key econometric assumptions: residual normality, homoskedasticity, and absence of serial correlation. The LM test confirmed no evidence of serial correlation, the heteroskedasticity test revealed stable variance across residuals, and the normality test indicated that residuals followed a normal distribution. These results, summarized in Table 7, affirm the model's statistical soundness.

The absence of serial correlation aligns with prior findings, such as those by Rostin et al. (2019), who also reported no autocorrelation in ARDL models using the Breusch-Godfrey LM test. This consistency reinforces the LM test's credibility as a diagnostic benchmark in time series analysis. Similarly, the confirmation of homoskedasticity supports the conclusions of Azaare et al. (2022), who emphasized that unchecked variance instability can distort parameter estimates and weaken inference, making heteroskedasticity testing essential for model validation.

The normality of residuals observed here is also in line with much of the ARDL literature. However, some studies like Nordin and Ismail (2014) have noted deviations due to excess kurtosis. While such departures may not always undermine model validity, they highlight the importance of testing and acknowledging potential limitations in residual behavior.

The diagnostic results confirm that the ARDL model satisfies key econometric assumptions, reinforcing its robustness and reliability. These findings not only validate the model's internal consistency but also contribute to the broader empirical discourse on best practices in econometric modelling, particularly in the context of export competitiveness analysis.

Table 7: Residual diagnostic tests

Test	T-Statistics	P-Value
Breusch-Godfrey Serial Correlation – LM Test	1.628015	0.3039
Normality	0.948356	0.6223
Heteroskedasticity – ARCH	0.400071	0.5360

Source: Based on author's calculations

4.8 Stability test of long-run relationship analysis

Structural stability of Malaysia's pepper export model was tested using CUSUM and CUSUMSQ methods. Figures 2 and 3 show the test statistics remained within critical bounds, confirming model consistency across the sample period. This stability is essential for ensuring the reliability of inferences drawn from the model, particularly when evaluating long-term determinants of export competitiveness.

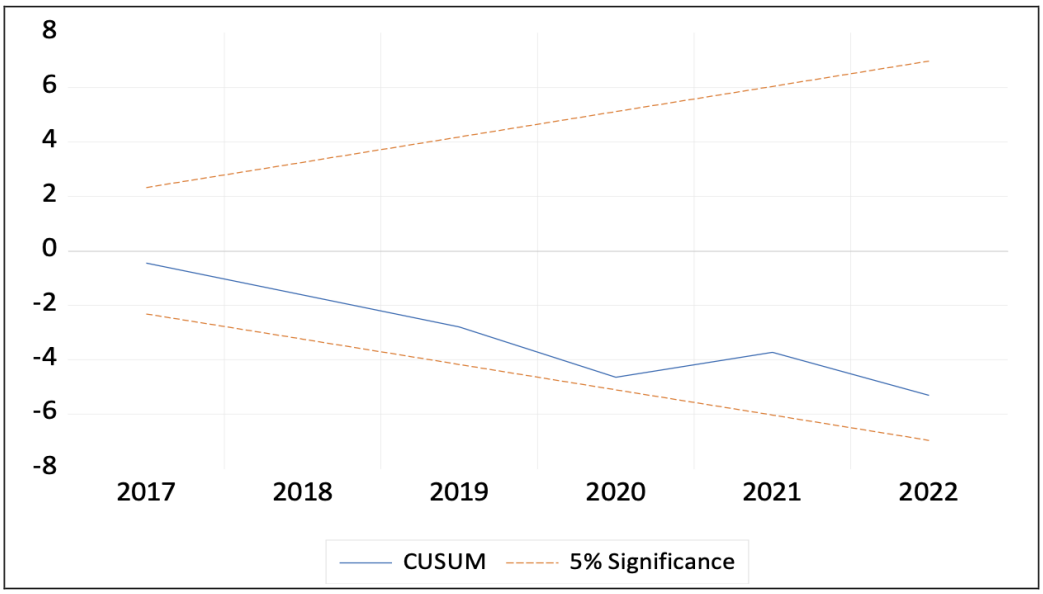

Figure 2: CUSUM test

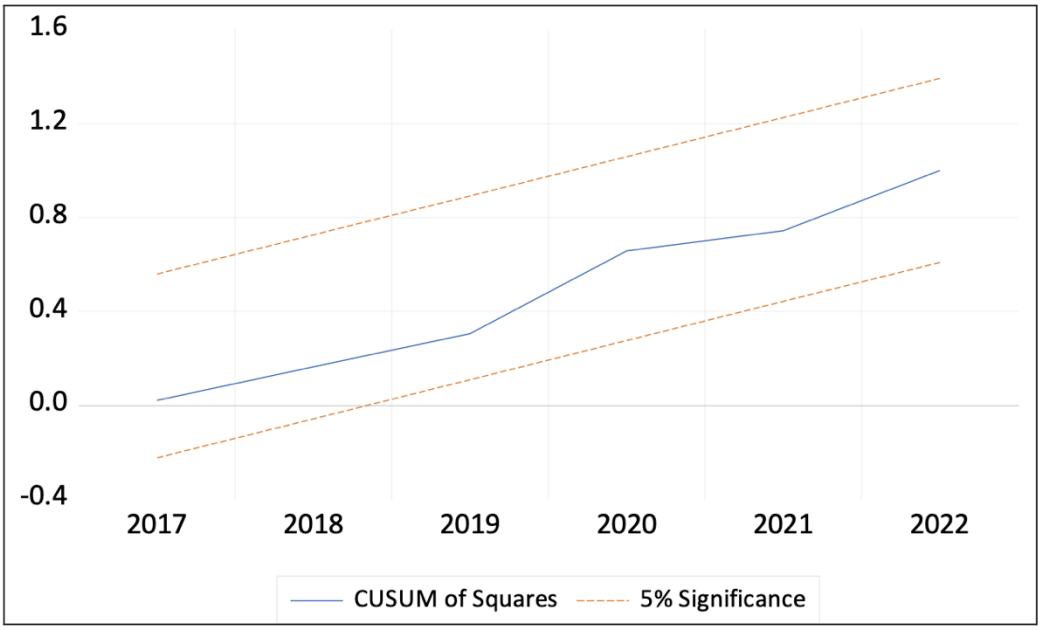

Figure 3: CUSUM of squares test

The absence of structural breaks reinforces the model's robustness, echoing concerns raised in the literature about the risks of ignoring such shifts. Baltagi et al. (2016) caution that overlooking structural instability can lead to biased estimates and flawed conclusions, while Antoch et al. (2018) emphasize the growing importance of structural break analysis in time series and panel data models. The findings here confirm that the estimated parameters remain consistent over time, validating the model's predictive power.

This result also aligns with Agosín et al. (2011), who argue that structural stability is fundamental to understanding export dynamics, especially in the context of

diversification. The confirmed stability enhances the model's credibility as a tool for policy guidance, enabling stakeholders to make informed decisions grounded in reliable econometric evidence. In volatile trade environments, where structural breaks can distort performance metrics as noted by Silva and Hassani (2015) such robustness is particularly valuable.

Moreover, the study adds to the structural break discourse in economic modelling, echoing Yu et al. (2019) on the role of change-point detection for model reliability and Okui and Wang (2017) on accounting for heterogeneous breaks in panel data. The absence of such breaks reinforces the ARDL approach for assessing agricultural export competitiveness. CUSUM and CUSUMSQ diagnostics confirm the Malaysian pepper export model's structural stability, bolstering the credibility of ARDL estimates and offering a reliable basis for future research and policy design.

5. CONCLUSION

This present study examines key drivers of Malaysia's pepper export competitiveness through the Revealed Comparative Advantage (RCA) index. Despite maintaining an RCA above unity, the downward trend highlights weakening global standing, prompting a call for targeted strategic measures to sustain export strength. Employing a long-run ARDL framework, the analysis reveals that GDP growth significantly enhances competitiveness, implying that broader economic expansion indirectly supports the pepper industry. Conversely, FDI exerts a negative long-term effect on RCA, likely reflecting investment flows into non-agricultural sectors. This highlights the need for more targeted FDI strategies that align with agricultural export priorities.

The REER emerges as another key factor: currency depreciation tends to improve RCA by enhancing price competitiveness. Population size, however, shows no meaningful long-run impact, suggesting that demographic changes alone do not drive export strength in this context.

Short-run ARDL estimates add further depth. FDI initially dampens competitiveness but turns positive over time, while REER has an immediate but diminishing effect. Interestingly, population growth contributes positively to the short term, potentially cushioning temporary shocks. The significant and negative error correction term confirms a stable long-run equilibrium, with short-term fluctuations correcting over time.

In sum, the findings emphasize the critical role of sustained economic growth and prudent exchange rate policy in preserving Malaysia's pepper export advantage. FDI must be better aligned with sectoral needs, and while population growth may not shape long-term trends, it can enhance short-term adaptability. These insights offer practical direction for policymakers and industry stakeholders aiming to restore Malaysia's global competitiveness in pepper exports. Future research should explore the roles of trade policy, market access, and structural reforms in shaping export outcomes.

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