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Dynamic Conditional Correlation of International and Domestic Meat Price Volatility

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ABSTRACT
This study aims to examine volatility transmission between international and domestic beef and mutton prices in Malaysia and to assess the role of exchange rate and crude oil price shocks in shaping domestic meat price instability. The study uses monthly data from January 2020 to December 2024 covering domestic retail beef and mutton prices, international meat prices from Malaysia's major trading partners, the Malaysian Ringgit exchange rate, and crude oil prices. Real price series are transformed into monthly log returns. The analysis applies Constant Conditional Correlation and Dynamic Conditional Correlation multivariate GARCH models, with exchange rate and crude oil prices incorporated as exogenous variables in the volatility equations. Stationarity, autocorrelation, and ARCH diagnostic tests are conducted to validate model suitability. The findings reveal stronger interdependence and volatility transmission in beef markets than in mutton markets. International beef price volatility is transmitted to Malaysia's domestic beef market, while mutton prices show weaker cross-market linkage but high volatility persistence. Crude oil price volatility significantly increases both beef and mutton price volatility through logistics, cold-chain, and distribution-cost channels. Exchange rate volatility significantly affects beef price volatility, but its effect on mutton is weaker and statistically insignificant. This study contributes to agricultural price volatility literature by applying CCC-DCC MGARCH models to imported meat markets in a post-pandemic, geopolitically unstable context. The findings suggest the need to strengthen domestic livestock production, improve market information systems, stabilize import-related macroeconomic risks, and coordinate food price monitoring policies.

Keywords: Meat Price Volatility, Volatility Transmission, Dynamic Conditional Correlation, Multivariate GARCH, Exchange Rate, Crude Oil Prices.

INTRODUCTION

In the wet markets of Kuala Lumpur, Petaling Jaya, and Penang, where traders negotiate prices daily and families allocate tightening household budgets, the escalating cost of essential protein sources such as beef and mutton has emerged as a pressing concern for ordinary Malaysians. A household that once maintained stable weekly expenditure on meat finds itself navigating abrupt price spikes triggered by distant geopolitical events, currency fluctuations, and global supply disruptions. This localized hardship is not an isolated phenomenon but rather reflects a systemic vulnerability embedded in the structure of Malaysia's food economy: an import-dependent meat sector that channels the volatility of international commodity markets directly into domestic retail prices.

The past five years have brought extraordinary turbulence to global agricultural commodity markets. The COVID-19 pandemic, declared a Public Health Emergency of International Concern in January 2020, triggered severe disruptions across global livestock supply chains, constraining live animal movement, shutting processing facilities, and creating profound uncertainty in demand for high-protein food commodities (Erokhin, 2020; Urak et al., 2023). The subsequent geopolitical shock arising from the Russia-Ukraine conflict, which escalated dramatically in February 2022, further constrained global food commodity availability, elevated energy prices, and generated sustained inflationary pressure across Southeast Asian economies dependent on food imports (Laborde et al., 2020; Stephens et al., 2020). These compounding disruptions rendered food price volatility, especially for protein-rich commodities including beef and mutton, a critical policy challenge for governments throughout the region.

Malaysia presents a particularly instructive case for examining these dynamics. As an upper-middle-income economy experiencing rapid urbanization, growing per capita income, and rising domestic demand for animal protein, Malaysia has consistently relied on imported livestock products to bridge the gap between domestic supply and consumer demand (FAO, 2022; DOSM, 2023). The country produces approximately 25 to 30 percent of its domestic beef requirements, with the remainder sourced predominantly from India in the form of frozen buffalo meat and from Australia as a supplier of higher-quality chilled and grain-fed beef cuts. For mutton and lamb, Malaysia is almost entirely dependent on imports from Australia and New Zealand, with domestic production meeting only a negligible fraction of total demand.

This structural import dependency creates direct and persistent exposure to international price volatility through two primary channels. The first is the direct price linkage through trade flows: when international beef or mutton prices rise, the landed cost of imports increases and this price signal transmits into domestic retail prices, subject to distribution costs, trade margins, and policy interventions. The second channel operates indirectly through macroeconomic variables. Fluctuations in the Malaysian Ringgit relative to the US dollar, the reference currency for most commodity trade, affect the domestic currency cost of all imported meat products. Between 2022 and 2024, the Ringgit depreciated significantly, amplifying the import cost burden on meat traders and ultimately on consumers (Bank Negara Malaysia, 2024). Simultaneously, crude oil price volatility affected transportation, refrigeration, and distribution costs throughout the supply chain, providing an additional transmission pathway for international price shocks into the domestic market (Abdallah et al., 2020; Ramsey et al., 2021).

Despite the practical importance of understanding these dynamics for food security governance in Malaysia, empirical research examining cross-border meat price volatility transmission in the Malaysian context remains sparse. Most existing studies in Southeast Asia focus on staple grains, particularly rice, or aggregate food price indices (Ijaz et al., 2021; Peel, 2021). The specific dynamics of meat price volatility and its international transmission, incorporating the moderating role of macroeconomic variables, have not been systematically examined using multivariate GARCH frameworks for the post-pandemic period. This study addresses this gap by applying DCC and CCC multivariate GARCH models to analyze volatility transmission between international and domestic beef and mutton markets in Malaysia from 2020 to 2024, while capturing the amplifying influence of exchange rate dynamics and crude oil price fluctuations.

Price Volatility in Malaysia

The convergence of macroeconomic pressures, structural import dependence, and successive global shocks generated pronounced meat price volatility in Malaysia over the 2020 to 2024 period. The COVID-19 pandemic, which prompted the imposition of Movement Control Orders beginning in March 2020, triggered widespread disruptions to livestock import supply chains, leading to reduced meat availability and upward price pressure in domestic retail markets (Rude, 2020; Whitehead & Kim, 2022). These pandemic shocks coincided with the onset of a sustained period of Ringgit depreciation, as capital outflows, widening fiscal deficits, and diverging monetary policy paths caused the exchange rate to weaken from approximately 4.07 Ringgit per US dollar at the beginning of 2020 to a multi-year low of approximately 4.80 Ringgit per US dollar in 2023, representing a depreciation of nearly 18 percent over this period (Bank Negara Malaysia, 2024).

Headline inflation in Malaysia, which had remained relatively contained in the decade preceding the pandemic, rose sharply from 2022 onward, reaching a 25-year peak of 4.7 percent in 2022 under the pressure of high global energy and food commodity prices (DOSM, 2023). Food price inflation was disproportionately severe, with the consumer price index for food and non-alcoholic beverages recording double-digit annual increases in some categories during 2022. Beef retail prices recorded sharp increases following import disruptions from India, which periodically restricted buffalo meat exports in response to domestic price pressures, and from Australia, where cattle herd rebuilding following the 2019 to 2020 drought cycle constrained export supply well into 2022.

The energy dimension of price volatility also manifested prominently during this period. Crude oil prices collapsed to below USD 20 per barrel in April 2020 during the early COVID-19 demand shock, before recovering sharply and surpassing USD 120 per barrel in June 2022 at the height of the commodity boom. This extreme price cycle created pronounced instability in logistics costs throughout the meat supply chain, from ocean freight and containerized cold storage to domestic trucking and last-mile distribution. Exchange rate instability further compounded these pressures. Because approximately 70 to 75 percent of Malaysia's beef supply is imported and priced in US dollars, sustained Ringgit depreciation effectively raised the domestic cost of all imported meat products independent of any movement in underlying international prices (DOSM, 2023;

FAO, 2022). These conditions, taken together, created a volatile meat price environment that threatens food security for lower-income Malaysian households and warrants rigorous empirical examination.

DATA AND METHODOLOGY

Data Source, Collection and Processing

This study employs secondary data covering the period from January 2020 to December 2024, yielding 60 monthly observations for each variable. Domestic retail prices of beef and mutton in Malaysia were obtained from the Department of Statistics Malaysia (DOSM) and the Ministry of Agriculture and Food Security (MAFS). These prices, initially reported in Malaysian Ringgit per kilogram, were converted to US dollars per kilogram using prevailing monthly exchange rates to ensure cross-country comparability.

For the international beef price series, average monthly retail prices for India and Australia were retrieved from the Food and Agriculture Organization's Food Price Monitoring and Analysis (FPMA) tool website, which provides the average US dollar value per kilogram of beef in retail market outlets (Capitani & Gaio, 2023; Erokhin & Gao, 2020; Fang & Shao, 2022). India was selected as a key trading partner given its status as Malaysia's dominant supplier of halal-certified frozen buffalo meat, while Australia was included as a major source of premium chilled and grain-fed beef imports. For mutton, average monthly retail prices from Australia and New Zealand were downloaded from the FAO FPMA tool, reflecting Malaysia's primary import sources for lamb and mutton products.

Exchange rate data, expressed as Malaysian Ringgit per US dollar, were sourced from Bank Negara Malaysia's Monthly Statistical Bulletin and supplemented with data from the International Monetary Fund's International Financial Statistics (Firmansyah et al., 2023; Hayes et al., 2023). Crude oil price data in US dollars per barrel were obtained from the World Bank Commodity Price Data portal and FAOSTATS. Consumer price indices for each country were downloaded from FAOSTATS and used to deflate all nominal prices to real terms using the following formula (Aday & Aday, 2020):

$$\text{Real price} = \left(\frac{\text{Price}}{\text{CPI}}\right) \times 100 \tag{1}$$

To induce stationarity and facilitate the subsequent volatility analysis, real prices were transformed into continuously compounded monthly returns using the approach of (Hobbs, 2020):

$$\text{Returns} = 100 \times \ln\left(\frac{p_t}{p_{t-1}}\right) \tag{2}$$

ptp_t pt represents the current period real price and pt−1p_{t-1} pt−1 denotes the one-period lagged value. All return series were log-transformed and verified for stationarity prior to volatility estimation (Javadi et al., 2024; Thenmozhi & Maurya, 2020). Data analysis was conducted using Microsoft Excel for data transformation and the Regression Analysis of Time Series (RATS) software for multivariate GARCH estimation.

Theoretical Framework of the Multivariate GARCH Models

The Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, an extension of the Autoregressive Conditional Heteroskedasticity (ARCH) framework, incorporates past conditional variances into the model, providing a more parsimonious representation of higher-order ARCH processes (Daly, 2008). A GARCH(p,q) model is specified as (Workie et al., 2020):

$$\vartheta_t^2 = \phi + \sum_{i=1}^{p} \alpha_i u_{t-i}^2 + \sum_{i=1}^{q} \beta_i \sigma_{t-i}^2 \tag{3}$$

ϑt2 represents the conditional variance, αi captures short-run ARCH effects (first lag of squared residuals), and βi captures long-run volatility persistence through the lagged conditional variance (Akter, 2020; Coluccia et al., 2021; Elleby et al., 2020). This study employs two variants of the multivariate GARCH (MGARCH) framework (Ben Hassen & El Bilali, 2022; Urak et al., 2024): the Constant Conditional Correlation (CCC) model and the Dynamic Conditional Correlation (DCC) model, to analyze the persistence and interdependencies of meat price return volatility in Malaysia alongside the selected macroeconomic variables.

Conditional Correlation MGARCH Models

The conditional correlation MGARCH class encompasses the Constant Conditional Correlation (CCC), Dynamic Conditional Correlation (DCC), and Variable Conditional Correlation (VCC) variants. These specifications combine univariate GARCH components with a parameterized correlation structure to capture the conditional covariances between multiple return series (Hau et al., 2020; Hobbs, 2020). The parameters of these models explain how errors in the individual variance equations are correlated across the system (Ihle et al., 2022; Singh et al., 2021; Thilmany et al., 2021). The CCC and DCC specifications were adopted based on their established performance in agricultural price volatility studies and their collective capacity to address the limitations of univariate GARCH models identified in the literature review (Damba et al., 2019; Onumah et al., 2022).

Specification of the Constant Conditional Correlation (CCC) Model

The CCC model, a special case of the MGARCH class proposed by Bollerslev (1990), reduces the number of parameters to be estimated by imposing the restriction that conditional correlations remain constant over time: $\rho_{ij,t} = \rho_{ij}, |\rho_{ij}| < 1$. Under this assumption, the conditional variance vector ϕ_{t*} takes the form:

$$\phi\_i\hat{} *= \left(\sigma^2_{1,t}, \dots, \sigma^2_{k_i,t}\right) \quad (5)$$

For a GARCH(1,1) specification:

$$\phi_t^* = (\alpha_0 + \alpha_1\varepsilon_h^2 + \beta_1\phi_h^*) \quad (6)$$

where $\varepsilon^2_{t-1} = \left(\varepsilon^2_{1,t-1}, \dots, \varepsilon^2_{k,t}\right), \alpha_0$ is a k-dimensional positive vector, and α1 and β1 are k×k non-negative definite matrices. Exogenous macroeconomic variables are incorporated into the individual variance equations as follows:

$$\psi_{it} = \delta X_{1it} + \lambda_i X_{2it} \quad (7)$$

$$\phi^2_{it} = \alpha_{ii,0} + \alpha_{ii,1}\varepsilon^2_{i,t-1} + \beta_{ii,1}\sigma^2_{i,t-1} + \delta_i Z_{1it} + \lambda_i Z_{2it} \quad (8)$$

Where δi and λi are coefficients for Z_1 (exchange rate, EXMYS) and Z2 (crude oil prices) respectively, incorporated as exogenous variance regressors. The CCC-MGARCH model imposes a constant restriction on the correlation matrix Λt to reduce the number of parameters, though this restriction may be deemed overly restrictive in some applications (Neifar, 2020).

Specification of the Dynamic Conditional Correlation (DCC) Model

The DCC model, proposed by Engle (2002), allows correlations to vary over time following a GARCH (1,1) process. The conditional quasi-correlations $\forall_t$ are specified as (Polat et al., 2023):

$$\forall\_t = \delta_t Q_t \alpha_{tt} \quad (9)$$

$Q\_t = \{q_{i,j,t}\}$ is a k×k positive definite matrix, δt=$\delta\_t = \mathrm{diag}\left(q_{11,t}^{-\frac{1}{2}}, \dots, q_t^{-\frac{1}{2}}\right)$ and: $Q\_t = (1 - \phi\_1 - \phi\_2)\bar{Q} + \phi\_1\ \alpha\_(t-1)\ \alpha\_(t-1)\hat{}' + \phi_2 Q_{t-1}$

Where Q¯ is the unconditional covariance matrix of the standardized innovation vector αt, with elements $\alpha\_(it) = \varepsilon\_(it)/\sqrt{\sigma^2_{it}}$. The scalars ϕ1 and ϕ2 are non-negative and satisfy $0 < \phi\_1 + \phi\_2 < 1$, and δt normalizes the matrix to ensure ∀t constitutes a valid correlation matrix at each time point (Nortey et al., 2015). By employing both MGARCH specifications, this study achieves a comprehensive and complementary analysis of volatility dynamics in Malaysia's meat markets (Ozturk & Faizi, 2023).

RESULTS AND DISCUSSION

Descriptive Statistics of Meat Prices and Macroeconomic Variables

The descriptive statistics of the monthly return series for beef and mutton prices across the three countries in each market, along with the macroeconomic variables, are summarized in Table 1. The average price returns for beef from January 2020 to December 2024 are -0.325 for Malaysia, -4.234 for India, and 0.612 for Australia. The average returns for mutton are -0.712 for Malaysia, -0.423 for Australia, and 1.178 for New Zealand. These figures reflect the differential dynamics of meat price formation across these countries over a period characterized by exceptional global turbulence. Notably, the t-values for most price series are not statistically significant, with the exception of India, where the mean return on beef is statistically significant and negative (t = -3.704, p < 0.001), reflecting the secular downward pressure on Indian buffalo meat export prices attributable to supply growth and periodic government export facilitation policies. In contrast, the t-values for Malaysia's exchange rate and crude oil price returns are both positive and statistically significant at the 1 percent level, consistent with the upward trends in these variables over the study period.

Analyzing the distribution of return series, the significant skewness values relative to kurtosis suggest that most price returns across the studied countries are not normally distributed. Positive skewness was observed in the beef prices of Malaysia and Australia, the mutton prices of Australia, and Malaysia's exchange rate. Negative skewness was noted in the beef prices of India, the mutton prices of Malaysia and New Zealand, and crude oil prices, reflecting the prevalence of sharp downward corrections particularly during the COVID-19 commodity crash of early 2020.

The higher standard deviation of beef returns in Malaysia (9.123), combined with elevated skewness and kurtosis values, indicates greater volatility in beef prices in Malaysia compared to Australia but comparable to India. This finding is corroborated by the highly significant Jarque-Bera statistics ($p < 0.001$) for Malaysian beef prices, suggesting the presence of outliers that deviate from a normal distribution. On the other hand, the standard deviation of mutton returns in Malaysia (6.823) is smaller, with insignificant skewness and Jarque-Bera statistics, indicating lower volatility in mutton returns in Malaysia compared to Australia and New Zealand. Table 1 also presents the bivariate unconditional correlation coefficients between the price returns and selected macroeconomic indicators. The results show that beef prices in Malaysia are correlated with those in India and Australia, as well as with crude oil price returns. Similarly, the return on mutton prices in Malaysia is correlated with those in New Zealand, along with crude oil price returns and the exchange rate. These findings suggest that meat price returns exhibit significant volatility transmission from foreign trading partners and Malaysia's macroeconomic variables. The predominance of significant correlation coefficients indicates that the volatility in returns across these markets is interdependent.
Figures 1 and 2 illustrate the time-varying nature of beef and mutton price return volatility across the three countries in each market.

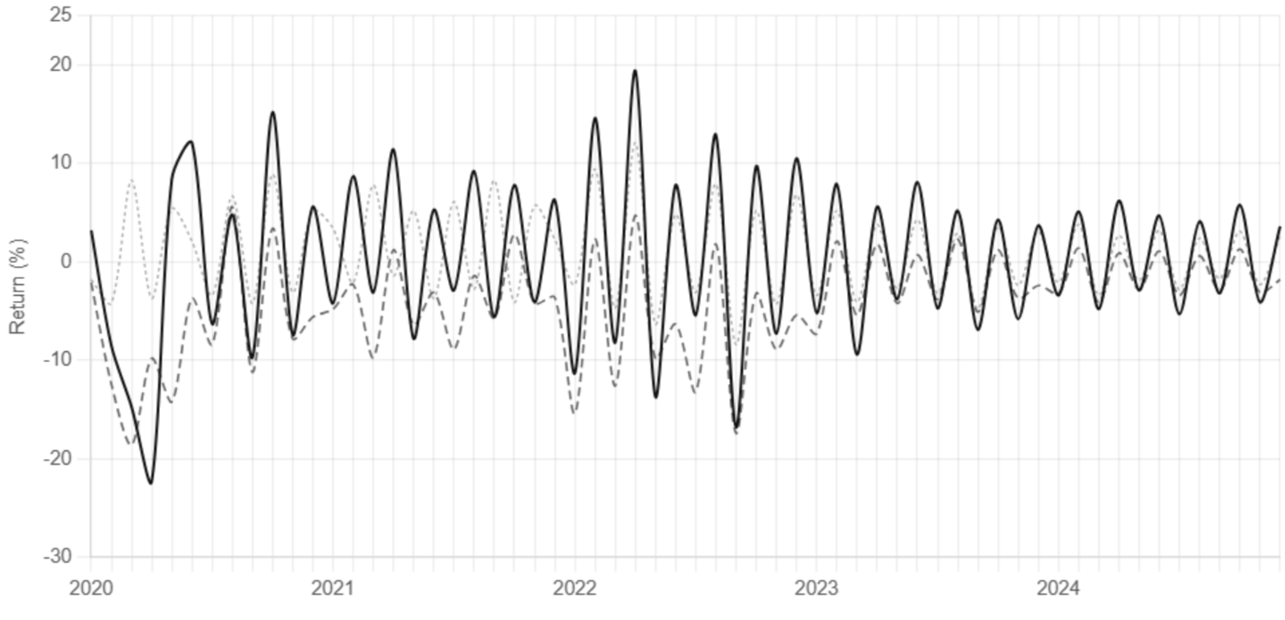

Figure 1. Beef price returns of the three countries

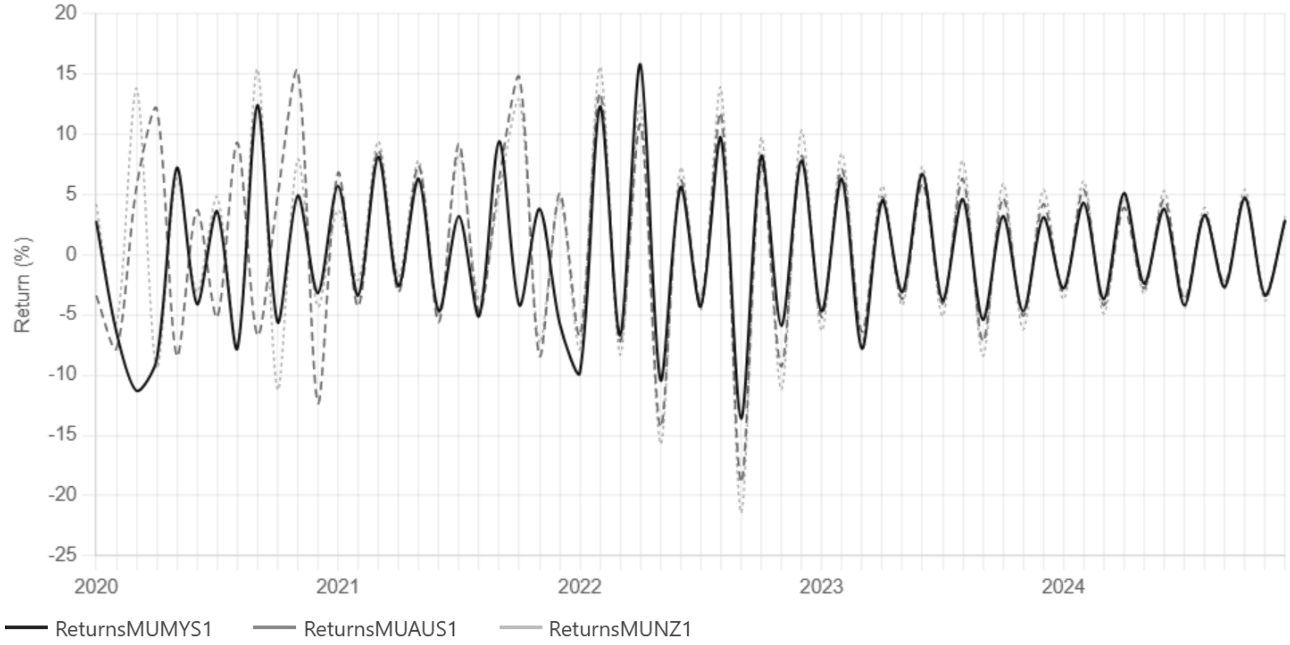

Figure 2. Mutton price returns of the three countries

Figure 3 demonstrates that beef price returns in Malaysia fluctuate more rapidly and with greater amplitude than those of Australia, while India's beef returns exhibit persistently negative values particularly during 2020 and 2022. The pronounced volatility clustering visible in the Malaysian beef return series, with large positive and negative swings concentrated around the COVID-19 lockdown period of March to May 2020 and the commodity price surge of early 2022, is consistent with the ARCH effects confirmed by the Lagrange Multiplier test(Capitani & Gaio, 2023; Laborde et al., 2020; Stephens et al., 2020). Australia's beef return series fluctuates more moderately, reflecting the more developed institutional framework and diversified export base of the Australian beef industry. For mutton markets (Figure 3), Malaysia's return series fluctuates more moderately compared to Australia and New Zealand, which exhibit larger swings associated with their more globally integrated livestock markets and greater exposure to spot export market volatility.

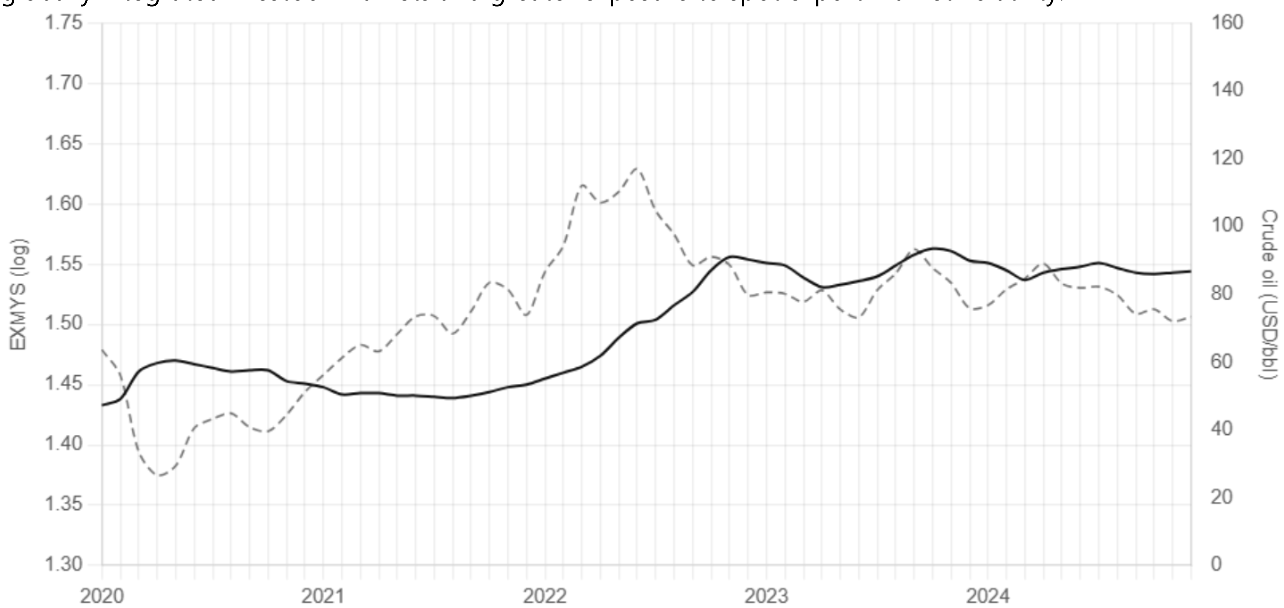

Figure 3. Crude price return and exchange rate trend in Malaysia

Figure 4 presents the concurrent trends in Malaysia's Ringgit exchange rate and crude oil prices from 2020 to 2024. The exchange rate (left axis, expressed as the natural log of Ringgit per USD) displays a persistent upward trend from 2020 through late 2023, reflecting the sustained depreciation of the Ringgit. The crude oil series (right axis, USD per barrel) shows the dramatic collapse and recovery cycle of 2020, the sharp price escalation of 2022, and the subsequent moderation observed through 2023 and 2024. The visual co-movement between the exchange rate depreciation trend and the crude oil price cycle over this period is consistent with the macroeconomic linkages hypothesized in the conceptual framework.

The Ljung-Box statistic presented in Table 1 indicates significant autocorrelation in the univariate analysis of meat prices and macroeconomic variables. The multivariate Q test for the beef and mutton market pairings likewise reveals autocorrelation between the meat price returns across the three markets in each grouping. In line with (Elleby et al., 2020; Ozturk & Faizi, 2023; Peel, 2021), both individual and multivariate ARCH effects were tested in the return series. The results in Table 1 show strong evidence of individual ARCH effects across the return series, with the null hypothesis rejected at conventional significance levels. The multivariate LM test confirms the presence of multivariate ARCH effects, with the test statistic strongly rejecting the null hypothesis of zero mean, absence of serial correlation, and constant covariance matrix.

To identify the data generation process, the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests were applied, with the Akaike Information Criterion (AIC) used to select appropriate lags. The ADF and KPSS results in Table 1 confirm that the return series of beef prices, mutton prices, and crude oil prices are stationary at levels, denoted I(0). The exchange rate of Malaysia required first-differencing to achieve stationarity, consistent with the persistent depreciation trend evident in Figure 4. The results are presented in Table 1.

Table 1. The exchange rate of Malaysia Required First-Differencing

Statistics	Beef MYS	Beef IND	Beef AUS	Mutton MYS	Mutton AUS	Mutton NZ	CRUDE OIL	EXMYS
Mean	-0.325	-4.234	0.612	-0.712	-0.423	1.178	84.347	1.498
Std. Dev.	9.123	8.892	6.987	6.823	8.012	8.234	26.123	0.134
t-values	-0.278	-3.704***	0.682	-0.812	-0.411	1.112	25.124***	87.234***
p-value mean = 0	(0.782)	(0.000)	(0.498)	(0.420)	(0.683)	(0.270)	(0.000)	(0.000)
Skewness	1.023***	-0.934***	0.048	-0.398	0.456	-0.812**	-2.234***	0.134
p-value	(0.001)	(0.003)	(0.883)	(0.212)	(0.156)	(0.011)	(0.000)	(0.679)
Kurtosis	2.287***	1.712**	0.201	-0.623	-0.312	1.698**	8.012***	-1.234*
p-value	(0.000)	(0.009)	(0.764)	(0.352)	(0.642)	(0.011)	(0.000)	(0.063)
Jarque-Bera	18.734***	13.456**	0.038	1.923	2.312	11.234***	182.456***	4.123
p-value	(0.000)	(0.001)	(0.981)	(0.382)	(0.315)	(0.004)	(0.000)	(0.127)
LB-Q(10)	13.234*	14.123**	9.876	32.456***	67.234***	168.123***	10.876	365.234***
HM-Q(10)	698.123***			752.456***				
p-value	(0.000)			(0.000)				
LM-test(2)	5.634*	6.123**	10.987***	5.012*	12.234**	26.987***	26.534***	51.876***
p-value	(0.0601)	(0.0467)	(0.004)	(0.0823)	(0.002)	(0.000)	(0.000)	(0.000)
MLM-test(3)	1012.234***			1589.876***				
p-value	(0.000)			(0.000)				
ADF (Lags)	-6.012** (1)	-2.987* (2)	-4.398* (1)	-3.412* (2)	-5.234** (1)	-4.876** (1)	-26.987** (1)	-0.687 (0)
KPSS	0.112	0.178	0.163	0.054	0.047	0.156	0.289	1.234**

Unconditional Correlation Matrix — Beef Markets

	Beef MYS	Beef IND	Beef AUS	Crude Oil	EXMYS
Beef MYS	1	-0.243**	0.467***	0.534***	0.052
Beef IND		1	0.172	0.198	-0.948***
Beef AUS			1	0.645***	-0.234**

Crude Oil				1	-0.356***
EXMYS					1
Unconditional Correlation Matrix — Mutton Markets					
	Mutton MYS	Mutton AUS	Mutton NZ	Crude Oil	EXMYS
Mutton MYS	1	0.112	-0.334***	0.212**	-0.587***
Mutton AUS		1	-0.423***	-0.145	-0.389***
Mutton NZ			1	0.518***	0.412***
Crude Oil				1	-0.356***
EXMYS					1

*, **, *** Denotes significance at the 10%, 5% and 1% level respectively. Values in brackets are p-values. LB and HM-Q denote Ljung-Box and the Hosking multivariate Q-statistic for serial autocorrelation tests in residuals while LM and MLM denote Lagrange and multivariate Lagrange tests for ARCH effects, respectively. The null under MLM test is that the series are mean zero, not serially correlated and with a constant covariance matrix. ADF stands for Augmented Dickey-Fuller test with constant and trend assumptions; KPSS denotes Kwiatkowski-Phillips-Schmidt-Shin.

ECONOMETRIC RESULTS AND DIAGNOSES

Model Diagnoses

The results of the Constant Conditional Correlation (CCC) and Dynamic Conditional Correlation (DCC) models, along with their associated diagnostic tests, are presented in Table 2. The return series of each meat market were analyzed separately, incorporating exogenous variables into the two variance equation systems. The analysis began by assessing the significance of model parameters and their collective ability to explain volatility, the significance of crude oil prices and the exchange rate within the volatility framework, and the relative model fitness of the CCC and DCC specifications.

The Wald test statistic of 398,234.56 ($p < 0.001$) for the CCC model and 10,456.78 ($p < 0.001$) for the DCC model confirm that the parameters in both models are statistically significant in explaining volatility between the beef markets of the selected countries. The Wald tests for the inclusion of crude oil prices and the exchange rate in the volatility modeling reveal that these variables in both the CCC and DCC models have a significant impact on the volatility of beef price returns in Malaysia. The null hypothesis of zero impact for these two variables was rejected at the 1 percent level in both models.

Similarly, the Wald tests for both the CCC and DCC models of mutton price return volatility also strongly rejected the null hypothesis of zero impact of the model parameters and the exogenous variables at the 1 percent level. Overall, the results reveal interdependence among the markets, with the average returns of meat prices in one market affecting the others. This indicates volatility transmission across meat price returns, as well as between the selected macroeconomic variables.

Econometric Results of Volatility of Selected Meat Products

Volatility of Beef Returns

Table 2 presents the results of the multivariate DCC and CCC GARCH models for beef price volatility. Each model has inherent limitations, so employing both allows for a more comprehensive analysis through complementarity and comparison.

The CCC model identifies the degree and size of interdependence between the beef markets studied through its significant conditional correlation coefficients. The negative correlation coefficients between the beef returns of India and Malaysia ($\rho BEIND\_BEMYS = -0.219$) and between Australia and Malaysia ($\rho BEAUS\_BEMYS = -0.110$) suggest that beef return volatility in Malaysia is inversely related to volatility in these foreign markets, meaning that an increase in volatility in India or Australia tends to be associated with a decrease in volatility in Malaysia's beef market, holding other factors constant. This finding implies that these markets are interconnected, with meat price volatility co-varying across them. The positive correlation between India and Australia ($\rho BEIND\_BEAUS = 0.389$) reflects the shared exposure of these markets to global cattle and buffalo market conditions. These results are consistent with previous studies on agricultural price instability (Balanay, 2013; Mutuc et al., 2011; Damba et al., 2019). The CCC model primarily reveals market interactions and the extent of interdependence, without pinpointing the source of volatility transmission.

The DCC model results, which account for non-constant changes in market interdependence, are also detailed in Table 2. The highly significant estimates of $DCC\alpha$ (-0.051) and $DCC\beta$ (0.352) confirm that volatility across these markets is time-variant, justifying the use of a multivariate GARCH-DCC model. The persistence of volatility, calculated as the sum of DCCα and DCCβ (approximately 0.301), is below one, indicating bounded unconditional variance in these markets. The ARCH (α) and GARCH (β) processes in both models are statistically significant, suggesting that current beef price volatility is influenced by past price volatilities. The presence of volatility clustering and persistence of price return volatility are further supported by the highly significant (1 percent) coefficients. Similar findings on volatility persistence in agricultural markets have been reported by Oyewumi and Sarker (2010) and Damba et al. (2019).

To examine the drivers behind beef return volatility in Malaysia, exchange rate and crude oil prices were incorporated into the volatility models as exogenous variables. The Wald test rejects the null hypothesis that the two exogenous variables have no joint impact on beef return volatility at the 1 percent level in both the DCC and CCC models. This implies that the instability or volatility of the exchange rate and crude oil prices significantly affects beef price volatility in Malaysia. The negative coefficients for the exchange rate in both models suggest that increased volatility in the Ringgit exchange rate, all else being equal, reduces the measured volatility of beef prices. This finding may reflect the stabilizing role of trader hedging behavior or delayed price adjustment when exchange rate movements are large. The crude oil coefficient is positive and significant in the CCC model, confirming that increased crude oil price volatility elevates domestic beef price volatility through transportation and distribution cost channels, corroborating similar observations in previous studies (Mutuc et al., 2011; Damba et al., 2019; Siami-Namini, 2019).

Volatility of Mutton Returns

The analysis of mutton price return volatility across three markets, as presented in Table 2, reveals important findings regarding the interdependence of price volatility. Both DCC and CCC models indicate that there is some degree of interdependence in price volatility across the three markets. The univariate volatility process is strongly evident in each individual market, with the ARCH (α) and GARCH (β) parameters being highly significant at conventional levels, especially in the CCC specifications. This signifies that current volatility in mutton prices is influenced by the lagged volatilities of the same series, as represented by the α values, and by the persistence of this volatility, as captured by the β values.

Regarding the instability relationships between the markets, the CCC model in Table 2 shows that the conditional correlations are not statistically significant, suggesting that the mutton markets are not strongly interdependent in terms of volatility transmission. While there is some evidence of minor interdependence, the overall conclusion is that volatility in one mutton market does not significantly influence volatility in the other markets. This implies that volatility in foreign mutton markets may not necessarily affect the domestic mutton market in the way observed for beef, potentially reflecting the different market structure, supplier concentration, and contract arrangements characterizing Malaysia's mutton import trade.

The DCC model also indicates an insignificant point estimate for DCCα (-0.004) in terms of volatility transmission between the three mutton markets. However, the coefficient for DCCβ is highly significant (1.012), and the sum of DCCα and DCCβ exceeds one, suggesting that volatility in these markets may be highly persistent and take an extended period to subside, delaying the return to market equilibrium. This persistence could reflect inefficient market intelligence and information asymmetries among mutton traders in Malaysia, leading to overall market inefficiency (Oyewumi & Sarker, 2010; Damba et al., 2019).

Furthermore, crude oil price returns are statistically significant at the 1 percent level in both CCC and DCC model specifications for mutton, and the Wald test rejects the null hypothesis of zero impact of exogenous variables at the 1 percent level in both models. The positive coefficient for crude oil returns suggests that an increase in crude oil price volatility leads to increased volatility in mutton price returns in Malaysia, consistent with the transmission of energy cost shocks through the cold chain and distribution network. On the other hand, the exchange rate has an insignificant negative impact on mutton price volatility, which contrasts somewhat with the findings for beef and with prior research by Damba et al. (2019), potentially reflecting greater price rigidity in the mutton market arising from long-term import contracts or regulatory price controls on mutton products. The significant effect of crude oil on mutton price volatility is consistent with findings from Mutuc et al. (2011) and Siami-Namini (2019), who similarly documented the strong influence of energy price fluctuations on agricultural market volatility.

Table 2. CCC and DCC Results for Volatility of Meat Price Returns and the Effect of Exogenous Variables on Volatility

Parameters	**CCC MGARCH**	**DCC MGARCH**	**CCC MGARCH**	**DCC MGARCH**
α_1	-0.0734***	-0.08456***	-0.1187***	-0.10789
	(0.00912)	(0.000389)	(0.0912)	(0.06823)
β_1	0.4923***	0.51234***	0.3834***	0.37234***
	(0.03412)	(0.008123)	(0.1234)	(0.10678)
$\alpha_{1,0}$	0.11876***	0.22987***	0.07123***	0.07234***
	(0.01523)	(0.004234)	(0.01789)	(0.016123)
α_2	0.2987***	0.09678***	0.7134***	0.48967**
	(0.00512)	(0.033456)	(0.003534)	(0.07023)
β_2	-0.2934***	0.31234***	-0.1423***	-0.07934
	(0.000812)	(0.047123)	(0.000423)	(0.07234)
$\alpha_{2,0}$	0.04123***	0.03923***	0.11876***	0.14534***
	(0.00134)	(0.004423)	(0.000378)	(0.021123)
α_3	0.4867***	0.11589	0.6389***	0.54876***
	(0.02756)	(0.078934)	(0.1123)	(0.04723)
β_3	-0.3512***	0.32978***	-0.2734*	-0.05423
	(0.02789)	(0.078456)	(0.1212)	(0.09823)
$\alpha_{3,0}$	0.08234***	0.10234***	0.09023***	0.08123***
	(0.01234)	(0.01789)	(0.02078)	(0.01623)
ρ_{12}	-0.21876***	DCCα = -0.05123***	0.0623	DCCα = -0.00423
	(0.04789)	(0.003812)	(0.1312)	(0.003123)
ρ_{13}	-0.10987***	DCCβ = 0.35234***	0.0487	DCCβ = 1.01234***
	(0.03312)	(0.134123)	(0.1245)	(0.085096)
ρ_{23}	0.38934***		0.0734	
	(0.01245)		(0.1145)	
Log likelihood	-561.234	N/A	-852.345	-811.234
Wald Test (F-ratio)	398234.56***	10456.78***	16987.23***	52.345***
	[0.000]	[0.000]	[0.000]	[0.000]

Parameters	**CCC MGARCH**	**DCC MGARCH**	**CCC MGARCH**	**DCC MGARCH**
α_1	-0.0734***	-0.08456***	-0.1187***	-0.10789
	(0.00912)	(0.000389)	(0.0912)	(0.06823)
β_1	0.4923***	0.51234***	0.3834***	0.37234***
	(0.03412)	(0.008123)	(0.1234)	(0.10678)
$\alpha_{1,0}$	0.11876***	0.22987***	0.07123***	0.07234***
	(0.01523)	(0.004234)	(0.01789)	(0.016123)
α_2	0.2987***	0.09678***	0.7134***	0.48967**
	(0.00512)	(0.033456)	(0.003534)	(0.07023)
β_2	-0.2934***	0.31234***	-0.1423***	-0.07934
	(0.000812)	(0.047123)	(0.000423)	(0.07234)
$\alpha_{2,0}$	0.04123***	0.03923***	0.11876***	0.14534***
	(0.00134)	(0.004423)	(0.000378)	(0.021123)
α_3	0.4867***	0.11589	0.6389***	0.54876***
	(0.02756)	(0.078934)	(0.1123)	(0.04723)
β_3	-0.3512***	0.32978***	-0.2734*	-0.05423
	(0.02789)	(0.078456)	(0.1212)	(0.09823)

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	(0.03312)	(0.134123)	(0.1245)	(0.085096)
ρ_{23}	0.38934***		0.0734	
	(0.01245)		(0.1145)	
Log likelihood	-561.234	N/A	-852.345	-811.234
Wald Test (F-ratio)	398234.56***	10456.78***	16987.23***	52.345***
	[0.000]	[0.000]	[0.000]	[0.000]
Variable	**CCC Beef**	**DCC Beef**	**CCC Mutton**	**DCC Mutton**
EXMYS	-0.03287***	-0.04512***	-0.01234	-0.00712
	(0.01023)	(0.003987)	(0.01178)	(0.01034)
CRUDEOIL	0.04267***	0.004823	0.03423***	0.02934***
	(0.00767)	(0.003012)	(0.00956)	(0.00756)
Wald Test (F-ratio)	18.23***	209.123***	6.234***	7.234***
	[0.000]	[0.000]	[0.000]	[0.000]

*, **, *** Denotes significance at the 10%, 5%, and 1% level respectively. Values in parentheses are standard errors; [ ] are p-values

SUMMARY OF FINDINGS

Over the 2020 to 2024 period, the volatility of agricultural commodity prices, including beef and mutton, posed a significant and escalating challenge for governments, policymakers, farmers, traders, and consumers in Malaysia. This volatility became particularly acute in the aftermath of the COVID-19 pandemic and in the context of the Russia-Ukraine conflict, which disrupted global supply chains, elevated energy prices, and accelerated the depreciation of the Malaysian Ringgit. In Malaysia, where a substantial portion of household income is allocated to food expenditure and where dependence on imported livestock and meat products is structurally embedded, the volatility of meat prices is especially consequential for food security outcomes.

This study utilized multivariate GARCH models, specifically the DCC and CCC specifications, to examine the transmission of price volatility between international and domestic meat markets in Malaysia from January 2020 to December 2024. The findings highlight a significant degree of interdependence between domestic and international beef markets, with a high persistence of volatility observed in beef price returns (Chadwick, 2023; Uduji et al., 2020; Xue et al., 2024). The study identified a negative transmission of shocks from exchange rate volatility to the volatility of beef prices, likely reflecting the complex adjustment dynamics in import-dependent markets where large exchange rate movements trigger delayed price responses. A positive and significant relationship was identified between crude oil price volatility and beef price returns in the CCC specification, consistent with the role of energy cost shocks in amplifying domestic price instability through the cold chain and distribution network.

For mutton markets, the degree of interdependence between domestic and international price volatility is more limited, with the CCC model indicating insignificant conditional correlation coefficients. Nonetheless, crude oil price returns remain a significant positive driver of mutton price volatility in both model specifications, underscoring the energy-cost transmission channel as a persistent and cross-commodity source of domestic price instability (Agbo, 2023; Thenmozhi & Maurya, 2020). The exchange rate is not found to significantly influence mutton price volatility, potentially reflecting the different market structure, import contract characteristics, and price stabilization mechanisms operating in the mutton segment relative to the beef market.

These findings have important implications for food security in Malaysia, particularly regarding protein access and nutritional outcomes for lower-income households (Erokhin & Gao, 2020; Javadi et al., 2024). The volatility in meat prices, driven by macroeconomic variables such as exchange rates and crude oil prices alongside direct international price transmission, can lead to increased uncertainty in food access and may worsen the nutritional quality of diets for vulnerable Malaysian households (Ben Hassen & El Bilali, 2022; Firmansyah et al., 2023; Ihle et al., 2022). Given the critical role that beef and mutton play in providing essential nutrients within Malaysian dietary patterns, these findings underscore the need for policy interventions to mitigate the impact of external shocks on food prices.

CONCLUSION

In conclusion, the domestic and international beef markets in Malaysia are closely interconnected, with volatility in international beef markets transmitting to the domestic market. Fluctuations in key external macroeconomic variables, specifically crude oil prices and the exchange rate of the Malaysian Ringgit, play significant roles in amplifying the volatility of domestic meat prices. These findings highlight the sensitivity of Malaysia's domestic meat prices to global market dynamics, emphasizing the need for careful monitoring and management of external economic variables to stabilize meat prices domestically. The mutton market, while exhibiting significant internal volatility persistence, demonstrates somewhat weaker direct international transmission, though its sensitivity to crude oil price fluctuations remains a policy-relevant concern.

Policy Recommendations

First, the government of Malaysia should enhance domestic beef and mutton production through the strengthening of existing livestock policies, particularly the National Agrofood Policy 2021-2030, which provides a strategic framework for increasing domestic food production. Specific incentive structures, including tax waivers on feed imports, veterinary support subsidies, and infrastructure financing for commercial livestock operations, could meaningfully increase the domestic supply of beef and mutton, reducing reliance on imports and cushioning the transmission of international price shocks. The Ministry of Agriculture and Food Security should identify and support commercial cattle and sheep farmers with resources, training, and market access, with particular attention to expanding the national beef herd and encouraging halal-certified dairy-beef integration operations. Successful examples of domestic production promotion as a price stabilization tool are observed in Brazil's beef sector and Thailand's integrated poultry industry.

Second, a coordinated approach to market regulation is needed to stabilize meat prices and reduce volatility. This approach might include setting quality, hygiene, and pricing standards among meat importers and traders, monitoring imports to prevent market distortions, and ensuring that only certified and licensed traders are involved in the import and trade of foreign meat products. Encouraging domestic production through favorable policies can reduce dependency on imported meat, mitigating the impact of exchange rate fluctuations. Collaborative efforts between the Ministry of Agriculture and Food Security and the Ministry of Domestic Trade and Cost of Living could support this regulatory coordination, drawing on successful examples from the European Union's Common Agricultural Policy and India's commodity price stabilization framework.

Third, efforts should be made to stabilize the exchange rate and mitigate the impact of crude oil price volatility on domestic food prices. Bank Negara Malaysia could strengthen mechanisms for managing excessive exchange rate volatility while avoiding rigid pegging that constrains monetary policy flexibility. Policies to reduce unnecessary imports and promote import substitution across multiple commodity categories would help stabilize the exchange rate by reducing the structural demand for foreign currency. Additionally, revising fuel subsidy and taxation policies in a manner that insulates domestic transport costs from global crude oil price swings would reduce the transmission of oil market volatility into domestic food distribution costs. Successful examples of exchange rate stabilization combined with domestic production promotion are observed in South Korea and China, which have maintained relatively stable food prices through coordinated monetary and agricultural sector policies.

Finally, investing in infrastructure development, improving market data collection, and enhancing market information systems are essential for ensuring long-term food price stability in Malaysia. Developing robust market information platforms that provide stakeholders with timely data on import volumes, international prices, domestic supply conditions, and retail price trends would facilitate better decision-making and risk management among traders, importers, and consumers. The establishment of a dedicated meat price monitoring dashboard, modeled on successful initiatives such as Kenya's National Farmers Information Service (KNFIS), could provide real-time transparency on price drivers and contribute to the stabilization of Malaysia's beef and mutton markets.

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