Cointegration Analysis of the World's Black Pepper Export Market Among Major Producers

[1,2*]Allan, R., [1,2]Daud, A., and [1,2]Rosli, A.

[1]Institute of Ecosystem Science Borneo, Universiti Putra Malaysia Bintulu Campus

[2]Department of Social Science and Management, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus

Selected paper prepared for presentation at the 1st ASEAN University Symposium for Sustainable Food System, Faculty of Economics, Kasetsart University, Bangkok, Thailand 18-19 April 2024.

Cointegration Analysis of the World's Black Pepper Export Market Among Major Producers

Rhemaneeta Allan[1,2,*], Adrian Daud[1,2], Anita Rosli[1,2]
[1] *Institute of Ecosystem Science Borneo, Universiti Putra Malaysia Bintulu Campus*
[2] *Department of Social Science and Management, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus*
**Corresponding author Email: rhemaneeta@gmail.com*

Abstract
Pepper, the world's most used spice has been widely used ever since ancient times. This spice has a high value in terms of monetary due to its medicinal properties. This berry-like spice has never lost its popularity as the world's most traded and used spice. In response to its market value, a study was conducted to analyse the market price movement of black pepper among four world major producers – India, Indonesia, Vietnam, and Malaysia. This study addresses the co-movement among these four major pepper-producing markets by setting the world's top producer Vietnam, as the dependent variable whilst India, Indonesia, and Malaysia are set as the independent variables. Due to the high price fluctuation of this storable commodity and significant price diversity in different markets, market integration among major producers is essential to study. The unison among the global pepper market is important, not only regarding producers and consumers but also in terms of profit maximization and economic risk management. The study uses the Johansen cointegration approach and the vector error correction model to analyse and evaluate the presence and strength of co-movement of price amongst the market, from the perspective of export freight on board price. The study has found that there are co-movements in the market—Vietnam, India, Indonesia, Malaysia, and Sri Lanka, despite obvious price differences and frequent fluctuations. The markets are found to be operating as a single organism. The convergence of pepper prices is found to be significant, and the model is stable for the export of black pepper.

Keywords: Black Pepper, Johansen Cointegration, VECM
JEL code: C10, C31, Q11
SDG goals: Reduced Inequalities; Peace, Justice, and Strong Institutions

Introduction
Origin and History of Black Pepper
Pepper, or *Piper nigrum* L., is a plant originating from the Western Ghats of India. The worth of the peppercorn in the form of monetary and medicinal value has made it to be well-known throughout the world dating back as early as the time of Queen Sheeba and King Solomon (B.C. 1015–B.C. 66) (Nair, 2020). Wars and colonization have happened throughout history, just for precious spices like pepper (Thomas & Sanil, 2019; Tripati & Raut, 2006).
Thomas and Sanil (2019) in their paper on 'Competitiveness in the Spice Trade from India' stated that spices are the most traded agricultural commodity across the globe. Spices like pepper form a vital component of trade, influencing the dynamics of economic, social, and political growth across the world.

Today, pepper still remains the world's oldest and most traded spice followed with vanilla and ginger (International Trade Centre, 2018). This small, berry-like spice is widely traded in the form of black and white pepper. Due to its widespread distribution, since ancient times, pepper has now become one of the popular spices used in many cuisine and medicine from east to west (Parry, 1969).

Sivaraman, Kandiannan, Peter, and Thankamani (1999) state that this plant is being grown extensively in tropical nations. The pepper plant is highly adaptable, growing from sea level to 1500 metres above mean sea level. It may be found between 20°N to 20°S of the equator. This plant belongs to the humid tropical family and requires 2000–3000 mm of annual rainfall, tropical temperatures, high relative humidity, and minimal fluctuation in day length throughout the year.

Black Pepper Production and Economy

Based on the annual statistical report by International Pepper Community (2019), the total global production of black pepper for the year 2019 was 479,068 tonnes, with a cultivated area of 493,400 hectares, approximately. Countries that are majorly producing pepper are Vietnam, Indonesia, Sri Lanka, India, Malaysia, Brazil, China, Madagascar, Thailand, Cambodia, Ecuador, and others. The purpose of cultivation was to supply for the domestic and international demands. The value of the global pepper industry is currently worth 1.298 billion USD. The demand for black pepper is fuelled by major importing countries such as the United States, Germany, Egypt, Netherlands, Pakistan, Russia, France, Poland, South Korea, Turkey, and others, which are involved in the re-export of the product.

The statistics released by International Pepper Community (2019) also indicated that among all the top producing countries, Vietnam holds the highest production of black pepper, with 257,000 tonnes, approximately, which accounts for approximately 53.6 percent of the total global production. It is also the largest exporter of black pepper in the world, with 257,396 tonnes exported in 2019, which exceeded its level of production, with a value of 631 million USD. The excess demand for the export of black pepper was catered by importing pepper from other producing countries such as Brazil, Malaysia, and Indonesia and re-exporting (International Pepper Community, 2019).

The remaining 46.4 percent of the production of black pepper were contributed by Brazil (15.8 percent), India (9.7 percent), Indonesia (6.26 percent), Malaysia (3.73 percent), Sri Lanka (3.98 percent), Cambodia (3.46 percent), Thailand (1.04 percent), Madagascar (0.83 percent), and others, including China and Ecuador (1.6 percent) (International Pepper Community, 2019).
India holds the largest cultivation area with 134,838 hectares (International Pepper Community, 2019). Yet, the polyculture cropping system implemented depleted the yield efficiency of the pepper crops by causing diseases and nutrient competition (Nair, 2020; Ravindran & Kallupurackal, 2012).

Black Pepper Price Variation in Markets

Due to differences in geographical positions of the countries, the market price of a commodity may vary from one place to another. Difference in market prices, due to geographical difference is a natural market phenomenon (Rashid, Minot, & Behute, 2010). The difference of price is due difference in government policy, service tax, transportation cost, competition, and other variable cost in production and supply chain.

Due to variability in price, market integration across different countries is essential to prevent any form of exploitation or unfair competition (Rashid et al., 2010). Market integration is defined as the similar pattern of movement in price across different markets over a long period of time. The correspondent movement in the same direction of a market price, due to another market's movement, is proof of market integration. Evidence of excellent market convergence is defined as prices from physically split regions moving together; this suggests that the underlying market is sufficiently active and linked to allow price discrepancies to be arbitraged away with ease. Prices that are not strongly integrated, on the other hand, may indicate the presence of frictions, such as market power or transportation bottlenecks (Birge, Chan, Pavlin, & Zhu, 2020).

Previous Studies on Market Price Integration

Prabha, Sivakumar, Murugananthi, and Palanichamy (2022) studied the market integration of India coffee (Arabica and Robusta coffee) price by comparing between domestic and international markets from the year 2008 to 2020. Two significant worldwide markets, New York (for Arabica) and London (for Robusta), as well as three significant Indian local markets, Bangalore, Chennai, and Hyderabad, were chosen for the study. The Johansen Cointegration Test and the Vector Error Correction Model (VECM) were used by Prabha et al. (2022) to examine the effectiveness of the Arabica and Robusta markets. From the study it was found that only Robusta markets were integrated in the long run.

Another similar study conducted Sivasankari & Vasanthi (2015) on black pepper domestic and international market utilised the Engle-Granger Test, as only 2 variables were tested. The monthly prices were compared from the year 2000 to 2012. From the results, Sivasankari & Vasanthi (2015) found that the domestic and international market were at unison suggesting that the markets are efficient and effective in mitigating price instability.

Khatkar, Singh, Karwasra, & Bhatia (2013) used the Johansen Cointegration Test and VECM to study the market integration domestic mustard markets in India. Out of four markets tested only two markets were found to be cointegrated.

Pardhi, Singh, Tingre, and Potdar (2022) studied the market integration of mango prices between Varanasi, India and international market. Varanasi was selected purposively as it is the major producing state. The semi-annual data were collected from 1993 to 2015. Johansen Cointegration Test and VECM were used to analyse the markets. From the results, both markets were found to be cointegrated.

Study purpose/Aim

Policy action is needed to reduce unpredictability and preserve market sustainability. India, Indonesia, Sri Lanka, Malaysia, and Vietnam are the permanent members of the International Pepper Community (IPC), an intergovernmental organisation of pepper-producing nations that is vital to the promotion, coordination, and harmonisation of all pepper-related economic activities, including ongoing price reviews.

The aim of this paper is to determine whether the prices of various black pepper markets with lion shares are parallel to each other. It is essential to compare one market price with the other to ensure that the markets are competitive and efficient in the long run. A cointegration analysis is implemented to evaluate the equilibrium of export prices of pepper.

Methodology

The economic growth within regions and countries varies at different magnitude. Difference in space also means different environment, culture, institution, policy, law, technology, innovation, etc. All this difference changes the value of a product in terms of input and output. This causes the price of product to differ from one place to another.

All firms at different space will experience a deviation in the price of inputs which will result in divergence of the output price from other markets, hence leading to price differential of commodities (Schrimper, 2001). However, this price differential scenario is subjected to arbitrage, a scenario where inefficient markets are taken advantage by exploiters to benefit from the price differences.

Steinwender (2014) reported that despite various efforts to implement fairtrade and Law of one price, many empirical studies have documented a large deviation in price encouraging arbitrage. Hence understanding the properties of commodity price variability is important especially to countries that are relying on a few commodities with lion's share in the global market to generate income (Conforti, 2004). A high variability and a lack of integration in prices has severe consequences on commodity dependent countries. Furthermore, market integration is one of the vital aspects in evaluating the impacts of market development and liberalisation policies (Sivasankari & Vasanthi, 2015).

This study is constructed based on the theory of the law of one price (LOOP) which states that 'when items are distributed effectively throughout marketplaces, the price difference between the same goods in two locations shouldn't be greater than the cost of transportation.' The primary focus of this study is to determine the integration of export price among major producers.

To study the price, a time series has to be tested for its' unit root to identify whether its' trend is stationary or stochastic. A time series that has a stochastic trend and permanent effect of shocks in price will have a unit root. In contrary, a time series that is stationary in a long-run deterministic process is proven to have price shocks that would revert back with temporary effect.

In order to analyse the non-stationary time series, the series has to be detrend. This could be done by differencing the series *N* times. Variables that are stationary in the same order and have a stationary linear combination are considered cointegrated.

The two well established approach for cointegration analysis are the Engle-Granger (1987) two step estimation method and Johansen's (1997) maximum likelihood method. The Engle-Granger method has a limiting factor where there the estimation is limited to two variables. Since there are more than two variables, the suitable methodology to be implemented for the estimation is the Johansen's method which enables multivariate framework.

The cointegration analysis evaluates the co-movement of a long-term good price within an equilibrium model. Market integration is a phenomenon in which two or more markets are linked together through their geographical separation. The term "market integration" is often used to refer to "spatial integration." When markets are linked together, they are said to be running as a single system.

Data Collection

To evaluate the efficiency of the pepper markets of different countries, secondary data on monthly exports prices for black pepper were collected from International Pepper Community's Pepper Statistical Yearbook 2019. The countries selected for the analysis were based on significance in production capacity and availability of data. In this study, four major producing countries-Vietnam, India, Indonesia, and Malaysia were selected for analysis. Data collected were monthly average prices from January 2010 to December 2019.

Statistical Analysis

The cointegration analysis were focused on main producing and exporting countries as target variables, where the top producer Vietnam represents dependent variable, whilst India, Indonesia and Malaysia as independent variable. The movement behaviour of pepper prices throughout the years was studied. The patterns of movement were identified by screening the movement of prices from one year to another year using the plotted linear graph pattern.

The stationarity of the variables must be ensured in order to translate the sequence into a cointegration equation. The term "stationarity" refers to a sequence that has no pattern and a constant mean and variance. In contrast, the non-stationary time series' mean, variance, and co-variance all fluctuate over time because it lacks a tendency to revert to its long-run average value. Stationary variables refer to variables with constant mean, variance, and covariance through time, which means they are not random.

Unit root tests for each variable in the regression equation should be used to convert non-stationary time series variables into stationary before performing a regression. If the series have unit roots, then all of the typical regression findings might be false and inaccurate. The term for this issue is spurious regression.

If a series has to satisfy the Johansen Cointegration test, it must be stationary at first difference and non-stationary at level. However, the data used in the analysis must be at level. If the data is found to be stationary at level, the analysis for cointegration will be deterred and proceed will vector autoregression (VAR) model.

The stationarity of the variables was determined using the Augmented Dickey-Fuller (1979) test, Phillips-Perron (1988) test and Kwiatkowski–Phillips–Schmidt–Shin (1992) test which are unit root test.

For the Augmented Dickey-Fuller (ADF), the test is based on the t-statistic of β_1, which can be calculated using the equation:

$$\Delta P_t = \beta_0 + \beta_1 P_{t-1} + \sum_{k=1}^{N} \delta_k \Delta P_{t-k} + \eta_t \qquad \textbf{(1)}$$

where P_t is equal to $t - t_{-1}$. Although it is a t-statistic, the hypothesis is not distributed in the same way as the student-t. The ratio is contrasted to the fundamental values of Fuller (1976). Meanwhile for Phillips-Perron, the test can be calculated using the equation:

$$P_t=\beta_0+\rho\beta_{t-1}+\eta_t \qquad \textbf{(2)}$$

Where, ρ is a corrected form of T-test which corrects serial correlation and heteroskedasticity in error term η_t non-parametrically by modifying the Dickey-Fuller statistics. The test uses the same asymptotic distribution as the ADF t-statistic.

The PP test does not use specified lags and it is robust to the general forms of heteroskedasticity compared to the ADF test.

For Kwiatkowski–Phillips–Schmidt–Shin, the equation has three components that are deterministic trend, random walk, and stationary error term. The test can be calculated using the equation:

$$P_t = r_t + \beta t + \varepsilon_t \quad (3)$$

where r_t is a random walk, βt is a deterministic trend and ε_t is a stationary error.
The null hypothesis for the ADF and PP are in the same direction where H_o is non-stationary. While KPSS has a contradictory null hypothesis to ADF and PP, where H_o is stationary.
The optimal lag length for the overall series was selected using the Hannan-Quinn criterion (HQC), Schwartz Bayesian Information Criterion (SBIC) and Akaike Information Criterion (AIC) for accuracy.
The Multivariate Johansen Cointegration Test was used to investigate the existence of a long-term equilibrium after performing unit root tests on the analysed time series and confirming that all time-series are integrated in the same order.

Johansen (1988) introduced the Maximum Likelihood (ML) method, which was later extended by Johansen and Juselius (1990). In contrast to the Engle-Granger test, which can only evaluate two variables, the ML technique allows for several cointegration vectors in a multivariate structure.

The Johansen cointegration test has no endogeneity since it is based on a simplified version of the Vector Autoregression (VAR) model. As a consequence, the number of variables chosen for normalization in regression remains constant. As a result, Johansen's Cointegration Test is the best option.

In a nonstationary VAR (vector autoregression) with restrictions imposed, known as a VECM (vector error correction model), the Johansen approach implies a maximum likelihood system that identifies a number of cointegrating vectors in a nonstationary VAR (vector autoregression) with restrictions imposed. The estimation model of Johansen can be written as follows:

$$\Delta \boldsymbol{P_t} = \sum_{i=1}^{k-1} \boldsymbol{r_i} \Delta \boldsymbol{P_{t-i}} + \prod \boldsymbol{P_{t-k}} + \boldsymbol{\mu} + \boldsymbol{\alpha\beta t} + \boldsymbol{\varepsilon_t} \quad (4)$$

Where, $P_t = (P_{1t}, P_{2t}, \ldots, P_{nt})$ is a n*1 vector of the n-cointegrated variables, which are meant to be integrated of order I(n); $\mu = (\mu_1, \mu_2, \ldots, \mu_n)$ is a n*1 vector of intercepts; $\beta' = (\beta(1), \beta(2), \ldots, \beta(r))$ is the n*r cointegrating matrix made of the r-cointegrating vectors. β' constitutes a long-run cointegrating relationship between variables; α represents the matrix n*r of the r-adjustment coefficient for each n variables. Hence r is the number of cointegrating relationship among the variables, where $0 < r < n$. α estimates the speed of adjustment of the equilibrium; r_i represents n*n matrixes of the autoregressive coefficient; $\sum_{i=1}^{k-1} \boldsymbol{r_i} \Delta \boldsymbol{P_{t-i}}$ is a short-run integrant or a vector autoregression; $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{nt})$ is a vector which implies uncorrelated white noise disturbances of $(0, \Sigma)$.

If the cointegration among the markets are confirmed, then VECM model is used to explore dynamic (short run) cointegration relationship among three or more variables.
Johansen (1991) proposes two probability ratio tests: The Trace test and Maximum eigenvalue test. The trace statistics is often used compared to Maximum eigenvalue since there is yet to be a solution to the multiple-testing problem (Kuzmenko, Smutka, Strielkowski, Štreimikis, & Štreimikienė, 2020). The Trace statistic is used to evaluate the null hypothesis of at most r cointegrating vectors against a general alternative hypothesis of than r cointegrating vectors. The remaining (K – r) eigenvalues are zero if the number of cointegrating equations is limited to r or less. Johansen (1995) derives the trace statistic's distribution as follows:

$$(\lambda \text{ - trace}) = - T \Sigma \ln (1 - \lambda_i) \qquad (5)$$

where T denotes the number of observations and λ_i is the approximate eigenvalues.
Large values of the trace statistic for any given value of *r* are proof against the null hypothesis that the VECM contains r or less cointegrating relations.

The variables were normalized, resulting cointegrating relationship such that the coefficient is equal to one. Any variable could be selected to normalize the data, as Juselius (2006) states that, the ratios among coefficients in cointegrating relationships are the same regardless of which variable is used. In this analysis, the largest producers, and exporters of each type of pepper product will be selected for normalization.

The validity and the strength of the model is tested after performing cointegration. Normality disturbance (Jarque-Bera Test), Heteroskedasticity (Breusch-Pagan- Godfrey Heteroskedasticity Test and Autoregressive Conditional Heteroskedasticity (ARCH) Test), serial correlation (Breusch-Godfrey Serial Correlation LM Test) and specification error (Ramsey's Regression Equation Specification Error Test) are tested as post-estimation analysis.

All tests are performed using E-views 10 statistical software (IHS Markit Ltd, London, England).

Results and discussion

Graphical Illustration for the Time Series

Prior to carrying out further analysis for the time series, the stationarity of the four different series is being predicted by plotting the graphs in the linear form, as can be seen in Figure 1. All the plotted time series suggested that there are stochastic and random walk trends in the series. Hence, it is predicted to be non-stationary at level. All the time series indicates similar movement and trend, yet their relationships are vague and equivocal.

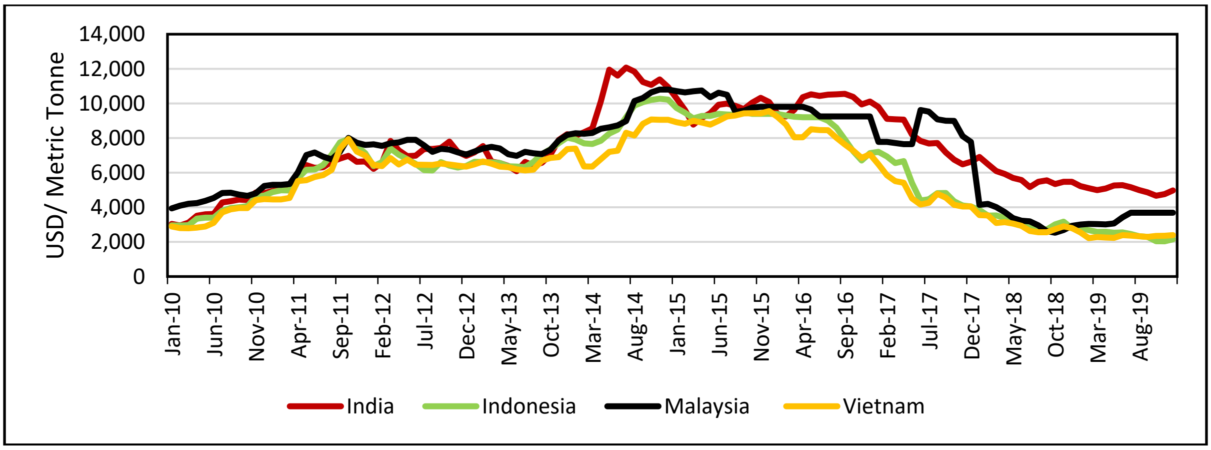

Figure 1. Black Pepper Export Price for India, Indonesia, Malaysia & Vietnam in USD/Metric Tonne for the year 2010 to 2019.

Testing for Unit Root

The series in log form have been tested for unit root using the augmented Dickey–Fuller (ADF) test, Phillips–Perron (PP) test and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. The

Schwarz Information Criterion was used for the ADF test lag selection and Newey-West Bandwidth was used for PP and KPSS Bandwidth selection.
All the series has proven to have a unit root at level. Meanwhile, at first difference all the series has indicated to be stationary at 1 percent significance of the critical value as shown in Table 1. Hence, the cointegration test can be carried out, furthering with Vector Error Correction Model (VECM).

Table 1. Unit Root Test for Export Black Pepper Price Series.

		ADF		PP		KPSS
Series		Probability	Statistics	Probability	Statistics	LM Statistic
Vietnam	Level	0.766	−1.651	0.769	−1.643	0.304 ***
	First Difference	0.000	−9.034 ***	0.000	−8.932 ***	0.091
India	Level	0.691	−1.815	0.690	−1.816	0.303 ***
	First Difference	0.000	−9.286 ***	0.000	−9.286 ***	0.061
Indonesia	Level	0.767	−1.649	0.860	−1.385	0.311 ***
	First Difference	0.000	−8.689 ***	0.000	−8.027 ***	0.077
Malaysia	Level	0.816	−1.523	0.766	−1.651	0.277 ***
	First Difference	0.000	−9.431 ***	0.000	−9.565 ***	0.060

Notes: ADF and PP H_o: The series is non-stationary; KPSS H_o: The series is stationary. *** statistically significant at 1 per cent level. For Unit Root Test for 120 observations: From Fuller (1976): −4.038 at 1%, −3.448 at 5%, −3.149 at 10%; From Philip-Perron (1988): −3.486 at 1%, −2.885 at 5%, −2.579 at 10%; From Kwiatkowski–Phillips–Schmidt–Shin (1992): 0.216 at 1%, 0.146 at 5%, 0.119 at 10%.

Multivariate Cointegration Interpretation

In order to test the presence of cointegration of the vectors, the Johansen maximum likelihood has been implemented as described in the methodology section. The Trace test was selected for the analysis in conjunction with multivariate cointegration testing across all of the studied sequences. The test results are displayed in the Table 2.

Table 2. Cointegration Test for Export Black Pepper Price Series.

Series	Test Specification	Null Hypothesis (Trace Test)
Vietnam/Indonesia/India/	None	Fail to Reject
Malaysia	Restricted Constant	Fail to Reject
	Linear Trend	Rejected (r = 1)
	Restricted Linear Trend	Rejected (r = 2)
	Quadratic Trend	Rejected (r = 1)

Note: H_o: Trace test indicates no cointegrating equation at 0.05 level (r = 0); H_1: Trace test indicates 1 cointegrating equation at 0.05 level (r = 1); H_2: Trace test indicates 2 cointegrating equation at 0.05 level (r =2).

Based on the results in the Table 2, it can be concluded that all the series has at least one or two cointegrating vectors. Yet only the target variable, which is the main producer and exporter (key players) will be focused on as described in the methodology. Hence only H_1 will be normalized and interpreted into cointegrating equation.
The VECM dynamics of long-run and short-run coefficient are stated in the Table 3 for each series.

Table 3. VECM for Export Black Pepper Price Series.

Series	Long-Run Relationship	Short-Run Relationship	
	Normalized Cointegrating Coefficients	Error Correction Term (ECT)	*p*-Value
ECT Coefficient (CoInt.Eq)	-	−0.187 ***	0.004
Vietnam	1.000	0.253 *	0.062
Indonesia	−1.280	−0.027	0.853
India	0.360	0.064	0.574
Malaysia	0.098	−0.031	0.672
Intercept	−0.685	−0.000	0.820

Notes: *** statistically significant at 1 per cent level, * statistically significant at 10 per cent level.

Multivariate Vector Error Correction Model Result

As described by Juselius (2006), any variables can be selected to form a cointegrating equation as the ratio of the coefficients are the same disregard of the variables chosen. Hence, Vietnam was chosen due to its role as the key producer and exporter of black pepper. This is based according to the data provided by International Pepper Community (International Pepper Community, 2019).

Following is the cointegrating equations and their interpretations:
Table 3—Export black pepper price series:
Cointegrating equation:

$$1.000 \times \text{Vietnam} - 1.280 \times \text{Indonesia} + 0.360 \times \text{India} + 0.098 \times \text{Malaysia}$$

- $\hat{\alpha} = (0.253; -0.027; 0.064; -0.031)$
- $\widehat{B}' = (1;\ -1.280; 0.360; 0.098)$

  Coefficient Interpretation:
- 1% increase in Indonesia's export price resulted in an increase of 1.280% in Vietnam's export price.
- 1% increase in India's export price resulted in a decrease of 0.360% in Vietnam's export price.
- 1% increase in Malaysia's export price resulted in downward movement of 0.098% in Vietnam's export price.
-

In the long-run connections of black pepper export prices series, Indonesia-Vietnam has the strongest relationship. While India-Vietnam is more than three times weaker compared to Indonesia-Vietnam. The link between Malaysia-Vietnam has the weakest connection, where it is thirteen times weaker compared to Indonesia-Vietnam's. Meanwhile, the short-run ECT coefficient indicates an adjustment of 18.7 percent each period. The negative and statistically significant value shows that there is a long-run causality diverted from the independent variables to the dependent variable. The speed of adjustment for the variables ranged from 2.7 to 25.3 percent, with only with Vietnam being statistically significant.

Post-Estimation Diagnostic Analysis

The validity of each model has been tested using the residuals. Post estimation of the series includes test for serial correlation, heteroskedasticity, normality of disturbance and specification error. The results of the tests for the series are shown in Table 4.

Table 4. Post-Estimation Analysis for Black Pepper Export Price.

Diagnostic Test	Null	*p*-Value	Conclusion
Breusch-Godfrey Serial Correlation LM Test Chi-Square Probability	No serial correlation	0.7934	Null Accepted
Autoregressive Conditional Heteroskedasticity (ARCH) Test	No conditional heteroskedasticity	0.2901	Null Accepted
Jarque–Bera Normality Test Probability	Disturbance is normally distributed	0.0012	Null Rejected
Ramsey's Regression Equation Specification Error Test	No specification error	0.0511	Null Accepted

Breusch–Godfrey serial correlation LM test was employed to examine whether correlation existed inside the model. Since the null hypothesis for the series was unable to be rejected, the test findings demonstrated that there is no serial correlation.

The estimation for heteroskedasticity was implemented using the Breusch-Pagan-Godfrey Heteroskedasticity Test. The result for the series has shown that there is no heteroskedasticity for each series as the null hypothesise is failed to be rejected.

Jarque–Bera normality test were used to estimate the normality disturbance. According to the outcome of the test, export price series has rejected the null hypothesise at 1 percent statistical significance. These indicates that the residuals are not normally distributed.

In fact, the residuals are most likely not natural because the time series under analysis represent pricing; this suggests that the data originated from a process with "heavy tails" (Kuzmenko et al., 2020). It may occur from significant shifts in the state of the world economy, which would make achieving a regular distribution very difficult. Concurrently, theoretically, a failure of the Jarque–Bera test would point to an inadequate number of delays selected for the model—a possibility unrelated to our model. Generally speaking, it should be mentioned that a failed Jarque–Bera test is a reasonably typical event that won't materially affect the results, especially when dealing with tiny data sets (Sukati, 2013).

For a number of reasons, pepper markets—one of the fastest-growing developing markets—are definitely worthwhile researching. Some of the issues include large regional differences in the market, noticeable price volatility, ongoing changes in consumer behaviour, quick supply and stock expansion due to increased speculative trading activity, the significant influence of protectionist measures, and more.

When there is spatial integration, the price shock due to change in demand or supply in a market will be transmitted to another market, inferring that all markets integrated will have an equal impact.

As was already established, a wide range of protective and supportive mechanisms that are used unevenly in various nations define the food market, including the pepper market, as do significant price disparities between particular countries (and even markets within a single area). Preserving food safety, market stability, and rural livelihoods are the main drivers for government intervention. These interventions usually lead to a limitation or absence of price transmission between markets, which is the opposite of free market dynamics. Stated differently, poor transmission and pricing obfuscation are linked to market fragmentation in the expansion of pepper markets.

Lack of integration amongst market due to protectionism leads to autarky price in domestic markets, which leads to deadweight loss and inefficient economy, which consequently suffocates the freedom of the producers and consumers. Autarky price annihilates opportunities for spatial arbitrage, leading to prices moving independently in the same or opposite direction in each market.

Market integration through free trade leads to an efficient and functional market system, which ensures food safety through the responds of market's demand and supply movement internationally. Producers, such as farmers, will be able to control and schedule production and storage by predicting excess demand and supply. Free trade enables better price which gives producers an opportunity to obtain higher income through competitive price. Besides that, it also enables agriculture diversification and improve nutrition.

All of these factors piqued the curiosity to explore the degree of interconnection between major producing countries (represented by Vietnam, Indonesia, India, and Malaysia). The export market price were studied to analyse the presence of long-run equilibrium.

From the analysis conducted, the price series have revealed that there is presence of mutual interaction among the selected pepper markets despite an obvious diversification in prices among them. The co-movement amongst the market have proved that the goal or hypothesis of 'cointegrated market' has been achieved.

The findings of this study supports the previous study by Sinharoy and Nair (1994) on international trade and pepper price variation, which stated that the movement of prices of pepper have been synchronized indicating an integration in the world pepper market. Hema et al. (2007), whom studied the same relationship, also indicated that prices have quick to move towards equilibrium in the long run in this period of time frame compared to pre-liberalization period.

The study conducted by Sabu et al. (2019), on price variability of pepper markets in the state of Kerala, India, indicated that the price variability was insignificant when related to the net income of the farmers. This shows that the price transmission of the pepper markets is symmetric.

The extent of the strength of the co-movement amongst the markets has significantly bolstered the understanding of the current industry trend. All series has proven that the market system is converging to equilibrium and the models estimated are stable.

For further study, panel data analysis as described by Taasim, Pinjaman, and Albani (2021) and Akhyar, Ilham, and Subhan (2023) can be conducted to obtain information on individual markets behaviours across time. Whereas, for future study on market asymmetries, the non-linear autoregressive distributed lag (NARDL) model as described by Taasim (2021), Chowdhury, Meo, Uddin, and Haque (2021), and Kashif et al (2023) could be employed for robust statistical analysis.

Conclusion

The study has found that there are co-movement amongst the market, despite the obvious price difference and frequent fluctuations. The short-run ECT coefficient indicates an adjustment of 18.7 percent for export price for each period. The speed of adjustment of the variables indicates that only Vietnam was statistically significant in terms of the speed of adjustment for the variables, which ranged from 2.7 percent to 25.3 percent. This suggests that the bodies involved in the trade of pepper could help in enhancing the efficiency of the marketing system and reduce market distortion, in terms of speed of adjustment.

Overall, this study inferred that, the price movement in a market is reflected on the other markets. Hence, the market system is at unison supporting the previous study conducted by Sivasankari and Vasanthi (2015). For the market to remain competitive and integrated, studies on market frictions and free trade policy are essential to mitigate large deviation from LOOP (Froot, Kim, & Rogoff, 1995; Steinwender, 2014). Comprehending the types of frictions that impede cross-market arbitrage is a fundamental goal in global commerce (Anderson & Van Wincoop, 2004; Steinwender, 2014).

References

Akhyar, C., Ilham, R. N., & Subhan, M. (2023). The Effect Of Leverage, Systematic Risk, Firm Size, Growth Opportunity And Roa On Earning Response Coefficient In Pharmaceutical Companies On The Indonesia Stock Exchange. *Journal of Accounting Research, Utility Finance and Digital Assets*, *1*(3), 233–243.

Birge, J. R., T. Chan, M. Pavlin, and I. Y. Zhu. 2020. Spatial Price Integration in Commodity Markets with Capacitated Transportation Networks. *SSRN Electronic Journal* 1–40. https://doi.org/10.2139/ssrn.3544530.

Chowdhury, M. A. F., Meo, M. S., Uddin, A., & Haque, M. M. (2021). Asymmetric effect of energy price on commodity price: New evidence from NARDL and time frequency wavelet approaches. *Energy*, *231*, 120934.

Conforti, P. 2004. Price Transmission in Selected Agricultural Markets. FAO Commodity and Trade Policy Research Working Paper. Available online: http://www.fao.org/3/j2730e/j2730e05.htm (accessed on 16 September 2021).

Dickey, D.A. and Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, *74*(366a), pp.427-431.

Engle, R. F., and C. W. J. Granger. 1987. Co-integration and error correction: Representation, estimation, and testing. *Econometrica: Journal of the Econometric Society* 55: 251–76.

Fuller, W.A. 1976. Introduction to Statistical Time Series. Wiley: New York, United States of America.

Hema, M., R. Kumar, and N. P. Singh. 2007. Volatile price and declining profitability of black pepper in India: Disquieting future. *Agricultural Economics Research Review* 20: 61–76.

International Pepper Community. 2019. *Pepper Statistical Yearbook 2019*. International Pepper Community: Jakarta, Indonesia.

Johansen, Søren. 1988. Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* 12: 231–54.

Johansen, S. 1991. Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica* 59: 1551–80.

Johansen, S. 1995. Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press: Oxford, United Kingdom.

Johansen, Søren. 1997. Likelihood analysis of the I (2) model. *Scandinavian Journal of Statistics* 24: 433–62.

Johansen, Soren, and K. Juselius. 1990. Maximum likelihood estimation and inference on cointegration—with appucations to the demand for money. *Oxford Bulletin of Economics and Statistics* 52: 169–210.

Juselius, K. 2006. *The Cointegrated VAR Model: Methodology and Applications*. Oxford University Press: Oxford, United Kingdom.

Kashif, U., Shi, J., Naseem, S., Ayaz, M., Butt, R. S., Khan, W. A., & Al-Faryan, M. A. S. (2023). Do agricultural commodity prices asymmetrically affect the performance of value-added agriculture? Evidence from Pakistan using a NARDL model. *Humanities and Social Sciences Communications*, *10*(1), 1–9.

Kuzmenko, E., L. Smutka, W. Strielkowski, J. Štreimikis, and D. Štreimikienė. 2020. Cointegration analysis of the world's sugar market: The existence of the long-term equilibrium. *EaM: Ekonomie a Management* 23: 23–38. https://doi.org/10.15240/tul/001/2020-4-002.

Kwiatkowski, D., Phillips, P.C., Schmidt, P. and Shin, Y., 1992. Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?. *Journal of econometrics*, *54*(1-3), pp.159-178.

Nair, K. P. 2020. *The Geography of Black Pepper (Piper nigrum)*. Berlin/Heidelberg: Springer, vol. 1. https://doi.org/10.1007/978-3-030-52865-2.

Phillips, P.C. and Perron, P., 1988. Testing for a unit root in time series regression. Biometrika, 75(2), pp.335-346.

Rashid, S., N. Minot, and B. Behute. 2010. Are Staple Food Markets in Africa Efficient? Spatial Price Analyses and Beyond with Assistance from Solomon Lemma in Maputo, Mozambique under the Comesa-MSU-IFPRI African Agricultural Markets Project (AAMP) Spatial Price Variation in Sub-Saharan Africa. Available online: https://ageconsearch.umn.edu/bitstream/58562/2/AAMP_Maputo_12_spatial_price_variation.pdf (accessed on 21 April 2021).

Ravindran, P. N., and J. A. Kallupurackal. 2012. Black pepper. In *Handbook of Herbs and Spices*. Amsterdam: Elsevier, pp. 86–115

Sabu, S. S., A. Kuruvila, and K. Manojkumar. 2019. Price behaviour of black pepper in Indian and International markets: A comparative analysis. *Journal of Spices and Aromatic Crops* 28: 27–33.

Schrimper, R. A. 2001. *Economics of Agricultural Markets*. Prentice Hall: New Jersey, United States of America.

Sinharoy, S., and S. R. Nair. 1994. International trade and pepper price variations: A cointegration approach. *Indian Journal of Agricultural Economics* 49: 417–25.

Sivaraman, K., K. Kandiannan, V. K. Peter, and C. K. Thankamani. 1999. Agronomy of black pepper (*Piper nigrum* L.)—A review. *Journal of Spices and Aromatic Crops* 8: 1–18. https://doi.org/10.1017/CBO9781107415324.004.

Sukati, M. A. 2013. Cointegration Analysis of Oil Prices and Consumer Price Index in South Africa Using STATA Software. Available online: http://mpra.ub.uni-muenchen.de/49797/ (accessed on 12 March 2021).

Taasim, S. I. (2021). Nonlinear Effects of Remittances Paid on Macroeconomics in Malaysia. *The Journal of Asian Finance, Economics and Business*, *8*(2), 783–790.

Taasim, S. I., Pinjaman, S., & Albani, A. (2021). Does energy consumption and trade openness contribute to economic growth in the East Asian growth area? *International Journal of Energy Economics and Policy*, *11*(2), 23–29.