Uncertain Supply Chain Management 11 (2023) 1735–1744

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

The fluctuation linkages and price volatility risk on agricultural commodity market: Evidence from Vietnamese coffee

Nguyen Thi Thu Hoai[a], Dang Trung Tuyen[a], Nguyen Duy Nhien[b*] and Nguyen Thi Hong[c]

[a]*VNU University of Economics and Business, 144 Xuan Thuy, Hanoi, Vietnam*
[b]*Hanoi National University of Education, Vietnam*
[c]*International Training and Cooperation Institute, East Asia University of Technology, Hanoi, Vietnam*

A B S T R A C T

Article history:
Received April 18, 2023
Received in revised format May 29, 2023
Accepted June 20 2023
Available online
June 20 2023
Keywords:
Coffee price
DCC-GRACH model
Price volatility
VaR model
Risk management

This paper uses the DCC-GARCH and Value at Risk (VaR) model to analyze the fluctuation, linkage, and price volatility risk among coffee price series in the period of 2004 - 2020. In terms of the fluctuation, the study points out, the volatility of Vietnamese coffee price and the price of Robusta coffee in two markets were affected by two ARCH terms and GARCH terms at 1 percent level. Meanwhile, the coffee price of Brazil and Colombia is only impacted by the ARCH term. The linkage between Brazil and Colombia is the biggest. The average coefficient linkage among Vietnam with two main competitors is relatively small. In terms of price volatility risk, the price volatility risk of Vietnamese coffee is the smallest and the biggest risk is belonging to Brazilian coffee price. The results obtained would be a valuable reference for stakeholders, policymakers, coffee processing and exporting enterprises, and coffee farmers to clearly understand the fluctuation and linkage among coffee export price series, and thereby have appropriate and effective solutions and strategies in price volatility risk management to sustainable development.

1. Introduction

Price transmission refers to the effect of prices in one market on the prices of another market. Meanwhile, price volatility spillover is defined as the transmission of instability from market to market. It occurs when volatility price change in one market causes a lagged impact on volatility price in another market above the local market effects. Both details show the fluctuation linkages in price among commodities or countries. There are several large studies which research this problem with some popular agricultural and non-agricultural commodities such as: Oil, silver, gold, coin, wheat, soybean, and so on. However, coffee is also a very popular agricultural commodity with huge output and transaction value, only few scholars pay attention to study.

Coffee, one of the World's most valuable export commodities, is produced in more than 70 developing countries and consumed mainly in developed countries with over US $30.4 billion of total trade value ((OEC), 2017). During the fourteen-year period of 2004 - 2020, like many commodities, coffee prices always fluctuate, and it is very difficult to forecast. Vietnamese coffee price (PVN) was almost parallel with the World's Robusta coffee price in the American market (PRB-US) and European market (PRB-EU). After a long period of steadily climbing from 40 US cents/lb in 2004 to 111 cents/lb in 2008, Vietnamese coffee export price had a period of adjustment in the three years from 2008 to early 2011 and the transaction price was adjusted about only 70 US cents/lb. The price peaked at 110.16 US cents/lb in May 2011 before hitting the lowest point of 74.71 US cents/lb in April 2016. Recently, although it has been impacted by COVID-19, the Vietnamese coffee and World's Robusta

* Corresponding author
E-mail address nhiennd@hnue.edu.vn (N. D. Nhien)

doi: 10.5267/j.uscm.2023.6.017

coffee price are relatively suitable. Currently, they are being traded at approximately 70 US cents/lb. Meanwhile, the coffee prices of two Arabica coffee production and exporting (Brazil and Colombia) countries were also parallel together. The fluctuation of them is stronger than the Vietnamese coffee and World's Robusta coffee price. From January 2004 to May 2011, this is an increasing period of the coffee price of two countries. Brazilian coffee prices climbed from 60.36 US cent/lb to 269.68 US cent/lb, approximately 4.5 times. While Colombian coffee prices also increased from 71.62 US cent/lb to 299 US cent/lb, approximately 4.17 times. After a long rising period, the coffee price of two countries moved to the next period, an adjusting period. In this period, the fluctuation of the two countries' coffee prices is not settled. Currently, they are being traded at approximately 168.43 US cents/lb with Colombian coffee and 112.59 US cent/lb with Brazilian coffee.

Obviously, there is a linkage between the coffee price of Colombia and Brazil as well as between Vietnamese coffee price and two market prices of World Robusta coffee. In addition, Arabica coffee and Robusta coffee are substitute products for each other. There may also be a linkage among the five coffee price series.

It is against this background that a profound understanding of the fluctuation and linkage among the coffee prices series as well as calculation coffee price volatility risk of them are of importance to coffee farmers, coffee producing and exporting companies, and Governments, as it helps better characterize volatility spillovers and linkage among countries, markets, and accurately forecast future volatilities, calculate value at risk of the coffee prices, which are critical inputs to the risk management of price volatility. Significantly, the price transmission, volatility spillovers, and linkage among commodities or markets have been studied by many authors. Acosta et al. (2014 separately used several popular models and methods as Cointegration test, Granger causality test, multiple linear regression model, VAR, TVAR, ARCH types of model and GARCH types model. While few studies such as Ceballos et al. (2017), Song et al. (2019), Canh et al. (2019) have addressed price volatility and used the combination of models including VAR/VECM – DCC-GARCH, VAR/VECM – BEKK- GARCH model to deeply analyze the price transmission, volatility spillovers and the correlation of energy commodities and some main agricultural commodities like corn, soybean, milk, grain, and wheat. However, the outcomes of these studies are mixed. In addition, the studies rarely used to combine models such as DCC-GARCH and Value at Risk to analyze the linkage among the commodities price and calculate the value at risk of commodities price volatility.

To address the limitations of the previous studies, the objective of this study is to identify the price transmission, volatility spillover, and linkage among five coffee price series in two periods. In the first period, this study uses Dynamic conditional correlation - Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model to find out the trend, equation, and level of the volatility transmission of each coffee price. The Value at Risk (VaR) model is used in the second period to calculate the level of risk based on the forecasted value of the DCC-GARCH model above.

2. Literature review

As explained above, an enormous amount of literature has normally used some models such as multiple linear regression model, VAR model, VEC model, ARCH-family, and GARCH-family models to find the linkages among time series variables. Especially, the volatility spillovers and the linkage among time series price variables including the price transmission between futures market and spot market, between the international market and domestic market, and among commodities have been studied by some researchers. Most of these works have found the price transmission, volatility spillover, or equilibrium relationship among markets, or commodities in the long-run and short-run.

Some of the recent studies that evaluate market interactions between agricultural commodities or between markets have used some advanced MGARCH models or combined VAR, VEC model with GARCH models, including (Lee & Valera, 2016; Ceballos et al., 2017; Tuyến et al., 2020; Tuyen et al., 2020; Dang et al., 2021) and so on. Lee and Valera (2016) used panel GARCH framework to examine World rice price transmission and volatility spillovers across six major Asian rice markets from 2005 to 2013. The results suggested that changes in the World rice price affected not only the level of domestic market rice price but also their conditional variances. Moreover, interdependence across rice markets contributed to a strong spillover of price shock from one country to another within the region. Ceballos et al. (2017) also used a multivariate GARCH approach to examine the short-term price and volatility transmission from major grain commodities to 41 domestic food products across 27 countries in Africa, Latin America, and South Asia from 2000 to 2013. The authors only observed significant interactions from international to domestic markets in a few cases. The transmission of volatility is statistically significant in just one-quarter of the maize markets tested, more than half of rice markets tested, and all wheat markets tested.

When studying Indonesian coffee, Rahayu et al. (2015) discovered that only international coffee prices affect Indonesia's return coffee price, while the domestic market was not efficient. By using ARCH types and GARCH types model, when studying Ethiopia coffee, Worako et al. (2011) found that the fluctuation of coffee price in Ethiopia was more volatile than in Brazil, and producer's prices were found to be the most volatile, followed by wholesale prices and export prices, respectively. Apparently, there is already a large empirical literature on the dynamics of price transmissions, volatility spillovers, and linkage among price series. However, the conclusions of the literature appear to be mixed. The differences were probably arising from different periods, datasets, frequencies, methodologies, models utilized, and commodity lines. Furthermore, although there is some evidence on the calculation value of price volatility, it is still not clear and detailed, especially in literature research about coffee prices.

To overcome the limitations about the research subject and the lack of multiple regression model, this paper attempts to fill the gap in the literature regarding the price transmission, volatility spillovers, and linkage on the coffee market by applying DCC-MGARCH (1,1) model. In addition, this paper also combines the DCC-MGARCH model and VaR model to calculate the value of coffee price volatility risk.

3. Research methodology

3.1. DCC-GARCH model

The Dynamic Conditional Correlation (DCC-) GARCH belongs to the class "Models of conditional variances and correlations". It was introduced by Engle in 2002 (Engle, 2002). The idea of the models in this class is that the covariance matrix, H_t, can be decomposed into conditional standard deviations, D_t, and a correlation matrix, R_t. In the DCC-GARCH model both D_t and R_t are designed to be time-varying.

Suppose we have returned, a_t, from n assets with expected value 0 and covariance matrix H_t. Then the Dynamic Conditional Correlation (DCC-) GARCH model is defined as:

$$r_t = \mu_t + a_t$$
$$a_t = H_t^{1/2} z_t$$
$$H_t = D_t R_t D_t$$

Notation:

$\mathbf{r}_t$: $n \times 1$ vector of log-returns of n assets at time t.
$\boldsymbol{\alpha}_t$: $n \times 1$ vector of mean-corrected returns of n assets at time t, i.e. E[$\boldsymbol{a}_t$]=0. Cov[$\boldsymbol{a}_t$] = $\boldsymbol{H}_t$.
$\boldsymbol{\mu}_t$: $n \times 1$ vector of the expected value of the conditional $\boldsymbol{r}_t$.
$\boldsymbol{H}_t$: $n \times n$ matrix of conditional variances of $\boldsymbol{\alpha}_t$ at time t.
$H_t^{1/2}$: Any $n \times n$ matrix at time t such that $\boldsymbol{H}_t$ is the conditional variance matrix of $\boldsymbol{\alpha}t$. $H_t^{1/2}$ may be obtained by a Cholesky factorization of $\boldsymbol{H}_t$.
$\boldsymbol{D}_t$: $n \times n$, the diagonal matrix of conditional standard deviations of $\boldsymbol{a}_t$ at time t.
$\boldsymbol{R}_t$: $n \times n$ conditional correlation matrix of $\mathbf{a}_t$ at time t.
z_t: $n \times 1$ vector of iid errors such that E[z_t]=0 and E[$z_t\, z_t^T$] = I.
$\boldsymbol{\mu}_t$ in (1) may be modeled as a constant vector or a time series model. The elements in the diagonal matrix $\boldsymbol{D}_t$ are standard deviations from univariate GARCH models.

$$\boldsymbol{D}_t = diag(h_{1,t}^{1/2}, \dots, h_{n,t}^{1/2})$$

where

$$h_{it} = \alpha_{i0} + \sum_{q=1}^{Q_i} \alpha_{iq}\, \alpha_{i,t-q}^2 + \sum_{p=1}^{P_i} \beta_{ip}\, h_{i,t-p}$$

Note that the univariate GARCH models can have different orders. Often the simplest model, GARCH(1,1), is adequate. The specification of the univariate GARCH models is not limited to the standard univariate GARCH(p,q), but can include any GARCH process with Gaussian-distributed errors that satisfy appropriate stationarity conditions that ensures the unconditional variance to exist. In this thesis, however, only the standard univariate GARCH will be considered.

$\boldsymbol{R}_t$ is the conditional correlation matrix of the standardized disturbances ε_t, i.e:

$$\varepsilon_t = D_t^{-1}\, \alpha_t \sim N(0, R_t)$$

Since $\boldsymbol{R}_t$ is a correlation matrix it is symmetric.

$$R_t = \begin{bmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \cdots & \rho_{1n,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \cdots & \rho_{2n,t} \\ \rho_{13,t} & \rho_{22,t} & 1 & \ddots & \vdots \\ \vdots & \vdots & \ddots & \ddots & \rho_{n-1,n,t} \\ \rho_{1n,t} & \rho_{2n,t} & \cdots & \rho_{n-1,n,t} & 1 \end{bmatrix}$$

The elements of $\boldsymbol{H}_t = \boldsymbol{D}_t\boldsymbol{R}_t\boldsymbol{D}_t$ is:

$$[\mathbf{H}_t]_{ij} = \sqrt{h_{it} h_{jt} \rho_{ij}}$$

where $\rho_{ij} = 1$.

There are different forms of R_t. When specifying a form of R_t two requirements must be considered:

H_t must be positive definite because it is a covariance matrix. To ensure H_t to be positive definite, R_t must be positive definite (D_t is positive definite since all the diagonal elements are positive).

All the elements in the correlation matrix R_t must be equal to or less than one by definition.

To ensure both requirements in the DCC-GARCH model, R_t is decomposed into:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}$$

$$Q_t = (1 - a - b)\underline{Q} + \alpha \varepsilon_{t-1} \varepsilon_{t-1}^T + bQ_{t-1}$$

where $\underline{Q} = Cov[\varepsilon_t \epsilon_t^T] = E[\varepsilon_t \epsilon_t^T]$ is the unconditional covariance matrix of the standardized error ε_t. $\underline{Q}$ can be estimated as:

$$\underline{Q} = \frac{1}{T} \sum_{t=1}^{T} \varepsilon_t \, \varepsilon_t^T$$

The parameters *a* and *b* are scalars, and Q_t^* is a diagonal matrix with the square root of the diagonal elements of $Q_t$at the diagonal:

$$Q_t = \begin{bmatrix} \sqrt{q_{11t}} & 0 & \cdots & 0 \\ 0 & \sqrt{q_{22t}} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sqrt{q_{nnt}} \end{bmatrix}$$

Q_t^* rescales the elements in Q_t to ensure the second requirement; $|\rho_{ij}| = \left| \frac{q_{ijt}}{\sqrt{q_{iit} q_{jjt}}} \right| \leq 1$. Further Q_t has to be positive definite to ensure R_t to be positive definite.

There are imposed some conditions on parameters *a* and *b* to guarantee H_t to be positive definite. In addition to the conditions for the univariate GARCH model to ensure positive unconditional variances, the scalars *a* and *b* must satisfy:

$$a \geq 0, b \geq 0 \text{ and } a + b < 1$$

In addition, Q_0, the starting value of Q_t must be positive definite to guarantee H_t to be positive definite. To simplify, this study will use the DCC-MGARCH (1,1) model to analyze and compare the fluctuation and the linkage of the five coffee price series. The mean equation of the model is five functions of five dependent variables: Representing the main product area includes Vietnamese coffee beans export price, Brazilian coffee price, Colombian coffee price. Representing mainly consumption areas includes Robusta coffee price has been trading on LIFE and Robusta coffee price has been trading on NYBOT.

3.2 VaR model

VaR, which is short for Value at Risk, is one of the most popular techniques used in risk management to estimate the worst expected loss at a given probability level. It was introduced by J.P Morgan in 1994 in a risk control methodology known as Risk Metrics.

Let *H* is holding period and confidence level $\alpha \in (0,1]$. Then the VaR of a portfolio is defined as the smallest number *l,* such that the probability of a future portfolio loss L exceeds *l* is no larger than 1- α. It measures the risk of future losses from a specific financial asset for a certain holding period. Formally,

$$VaR_\alpha(L) = inf\{l \in R{:}Pr\ Pr\ (L > 1)\ \leq 1 - \alpha\} = inf\{l \in R{:}\, F_l(l) \geq \alpha\}$$

In the equation, *inf* is short for *infimum* and *inf(S)* represents the greatest lower bound of a subset *S,* i.e. the biggest number that is smaller than or equal to every number in *S*.

VaR involves two arbitrarily chosen parameters, confidence level (α), and holding period (*H*). The confidence level indicates the probability that we will get a future outcome no worse than estimated VaR. The holding period determines the length of the interval within which the loss is calculated.

There are three primary methods used for calculating Value at Risk (VaR). To simplify and take advantage of the DCC-MGARCH model, this study will use the Variance - Covariance methods to calculate and analyze the price volatility risk of five coffee price series in the next step.

This method assumes that the price returns for a given position follow a normal distribution. From the distribution of daily returns calculated from the price series, we estimate the standard deviation. The Value at Risk (VaR) is simply a function of the standard deviation and the desired confidence level.

The method starts by calculating the standard deviation and correlation. It then uses these values to calculate the standard deviations and correlation for the changes in the value of the individual securities that contribute to the position. If price, variance, and correlation data is available for individual securities then use this information directly. Then use the values to calculate the standard deviation of the portfolio by matrix multiplication. Calculate Value at Risk (VaR) for a specific confidence interval by multiplying the standard deviation by the appropriate normal distribution factor.

$$VaR = V_0 * (\mu_p - \alpha * \sigma_p)$$

where: V_0 is the net present value of an asset or a portfolio;
μ_p is expected profitability ratio of an asset or a portfolio;
α = 1.65 if the confidence level is 95 percent, α = 2.33 if the confidence level is 99 percent;
σ_p is the expected profitability ratio standard deviation of an asset or a portfolio.

4. Empirical analysis

4.1. Data description

This study used monthly data converted the period from January 2004 to December 2020, including 204 observations for five variables from some sources as Vietnamese coffee beans export price (PVN) is converted from the Government Statistics Office of Vietnam (GSO of Vietnam) of reports; Robusta coffee price has been trading on LIFE (PRB_EU) and Robusta coffee price has been trading on NYBOT (PRB_US) which are converted from the UNCTAD. Brazilian coffee price (PBR) and Colombian coffee price (PCL) are from the international coffee organization (ICO). All of the data are adjusted seasonally by using Census X-12, then, transferred to rate of return by the formula: $y_t = 100xLn\left(\frac{Y_t}{Y_{t-1}}\right)$, where y_t is the rate of return of coffee export price at time *t,* Y_t is the price of coffee at time *t*, Y_{t-1} is the price of coffee at time *t-1*.

4.2. The empirical analysis

4.2.1. Stationary and ARCH test

To analyze the fluctuation and correlation on the coffee market by applying the DCC-MGARCH model, we must test the stationary and ARCH effects of all variables.

Following the results of preliminary checking, all the series are considered to be stationary. To be more conservative, according to Schwert (2002) Pmax = 14, therefore, fourteen lagged differences are used to test stationary of variables. The stationery is tested using the Augmented Dickey-Fuller (ADF). Table 1 describes the results of the ADF test, J-B test, and ARCH test.

Table 1
Stationary and ARCH tests results

Variables	ADF test (C,T,L)	ADF test T – statistic value	Skewness	Kurtosis	J-B test	ARCH effect test
PVN	(0,0,14)	-13.0752***	0.215351	6.292501	93.26218***	39.11526***
PRB_US	(0,0,14)	-12.16948***	0.443286	3.317239	4.746233**	11.03972***
PRB_EU	(0,0,14)	-11.2281***	0.827551	4.798254	50.52229***	16.96609***
PCL	(0,0,14)	-12.03383***	0.950098	5.081601	67.19127***	17.85662***
PBR	(0,0,14)	-12.7827***	0.287664	5.245895	45.46394***	10.35439***

Note: C is constant or intercept, T is trend and L is lag selection. D represents the first-order difference to the time series; the ARCH effect test used lag 1 to calculate F-statistic with **, *** is significant at 5 percent and 1 percent level, respectively.
Sources: Calculated by author by using Stata

Table 1 shows that, according to the ADF test, all the variables are stationary at a 1 percent level. In addition, based on the results of the J-B test, we cannot accept the null hypothesis, it means all the variables are not a normal distribution. Furthermore, the F-statistic values of ARCH effect testing also show the paper can apply a multivariate GARCH model.

Therefore, the paper can apply the DCC-MGARCH model for further analysis.

4.2.2. DCC-MGARCH model regression and verification

In this part, the paper applies the DCC-MGARCH(1,1) model to analyze the fluctuation and correlation among countries and among between two main markets. The conditional means of the returns as a first-order vector autoregressive process and the conditional covariances as a DCC-MGARCH process in which the variance of each disturbance term follows a GARCH(1,1) process. Table 2 shows the estimate results of the DCC-MGARCH(1,1) model with μ is the intercept, α is the ARCH term of coefficient and β is GARCH term of coefficient, requiring $\mu > 0$, $\alpha > 0$, $\beta > 0$, and $\alpha + \beta<1$. In addition, the sum of two coefficients also showed the speed of price volatility, the sum of two coefficients is more closely 1 the speed of volatility is more slowly. Two parameters *a* and *b* govern the dynamics of conditional quasicorrelations, *a* and *b* are nonnegative and satisfy $a + b \leq 1$.

Table 2
The estimation results of the DCC-MGARCH(1,1) model

Variables	Parameters	Coefficient	Std. Error	t-Statistic	Prob.
PVN	α	0.6755	0.1493	4.52	0.000
	β	0.3958	0.0695	5.7	0.000
	μ	3.0306	1.096	2.77	0.006
PRB_EU	α	0.4406	0.091	4.84	0.000
	β	0.1733	0.0841	2.06	0.039
	μ	11.5637	2.4685	4.468	0.000
PRB_US	α	0.4719	0.1025	4.61	0.000
	β	0.2663	0.0805	3.31	0.001
	μ	8.5358	1.8236	4.68	0.000
PCL	α	0.5376	0.1326	4.05	0.000
	β	-0.0233	0.0616	-0.38	**0.705**
	μ	24.3369	3.7518	6.49	0.000
PBR	α	0.6386	0.1222	5.23	0.000
	β	-0.0014	0.0356	-0.04	**0.968**
	μ	28.8166	3.9122	7.37	0.000
	a	0.0912	0.0216	4.21	0.000
	b	0.7794	0.0463	16.82	0.000

Source: Calculated by author by using Stata

From Table 2 two parameters *a* and *b* are positive and satisfy $a + b \leq 1$. In addition, all of the values of parameters in the model satisfy every restriction of the model. The DCC-MGARCH model reduces to the CCC-MGARCH model when $a = b = 0$. The output shows that a Wald test rejects the null hypothesis that $a = b = 0$ at all conventional levels because the value of Chi-square is 750.51 and the value of Probability is very small (approximately zero). Therefore, the paper applied to the DCC-MGARCH model is very suitable.

(1) Analyzing the linkages among countries. The volatility of Vietnamese coffee beans export price returns was affected by two ARCH term and GARCH term with coefficients are 0.6755 and 0.3958, respectively at 1 percent level. It means both the previous month’s squared residual and the previous month’s variance influent on the fluctuation of Vietnamese coffee beans export price return at the same time. Meanwhile, the price of two countries is only impacted by the ARCH term, the GARCH term totally does not affect at 5 percent level.

(2) Analyzing the linkage between two main markets. All of the volatility of the returns of coffee price two main markets are affected by both ARCH term and GARCH term at 1 percent level. While two coefficients the returns Robusta coffee spot price in Europe market are 0.4406 and 0.1733, respectively, the returns Robusta coffee spot price in America market are 0.4719 and 0.2663, respectively. Based on the sum of two coefficients, it can see that the speed volatility of the two main market price returns is slower than Vietnamese coffee export price returns. Combining with the analysis above, Vietnamese coffee beans export price returns volatility is smaller but faster than two competitors. This situation makes the risk management of coffee price volatility more difficult. Because when the price of coffee fluctuates, almost immediately, farmers and exporters have solutions as well as risk management strategies. This is a relatively difficult requirement for factors in Vietnam's coffee export supply chain today.

(3) Analysis the linkages among coffee price returns. After comparison the fluctuation price returns of Vietnamese coffee beans export with two markets' price and two competitors' price returns, in this part, the paper will analyze the linkage among them. The results of the linkage are shown in Table 3 and from Fig. 1 to Fig. 10.

Firstly, the linkage between markets and countries is different. The linkage between Brazil and Colombia (representing produce area) is the biggest with an average coefficient of 0.9691 and then the linkage between two markets USA and Europe (representing consumption area) with an average coefficient of 0.9551. This is very suitable because Brazil and Colombia are the two main producers and exporters of Arabica coffee (supplementary and replacement product of Robusta coffee) while the USA and Europe are two main markets where they trade Robusta coffee in the World. Almost all Robusta coffee export prices of countries are based on the price of these two markets – Vietnam is an example. Because almost the coffee export of Vietnam is Robusta coffee, the linkage among Vietnam with two main markets is relatively high. The average coefficient linkage between Vietnam and the European market is higher than the USA market, 0.6267, and 0.6071 respectively. Meanwhile, the average coefficient linkage among Vietnam with two main competitors is relatively small, only 0.3349 with Brazil and 0.3305 with Colombia. The difference is due to Brazil being not only the largest Arabica coffee exporter in the World accounting for 45 percent of market share but also the second Robusta coffee exporter in the World accounting for 28 percent of market share after Vietnam with 39 percent market share. Therefore, the linkage among Brazilian coffee prices with the two main consumed Robusta coffee markets is bigger than the linkage among Colombian coffee prices with coefficients are 0.5416 compared to 0.5132 and 0.5519 compared to 0.5314, respectively.

Table 3
Average relevance value of other coffee prices

	PVN	PBR	PCL	PRBEU	PRBUS
PVN	-	0.3349	0.3305	0.6267	0.6071
PBR	0.3349	-	0.9691	0.5416	0.5519
PCL	0.3305	0.9691	-	0.5132	0.5314
PRBEU	0.6267	0.5416	0.5132	-	0.9551
PRBUS	0.6071	0.5519	0.5314	0.9551	-

Source: Calculated by author by using Stata

Secondly, the linkage among markets is not stationery and changes over time, details see from Fig. 1 to Fig. 10. The linkage among Vietnam with two areas (product and consumption) is different, but in each area, the linkage between Vietnam with each market is not distinct (see Fig. 1 to Fig. 4). The linkage among the remaining markets can be distributed in two periods. From 2004 to 2008 is the increasing period and from 2008 to 2020 is the adjusting period with coefficient linkage relatively stable, especially, the linkage between Brazil with Colombia and between the USA market with Europe market accept the linkage among Colombia with consumption area (see Fig. 5 to Fig. 10).

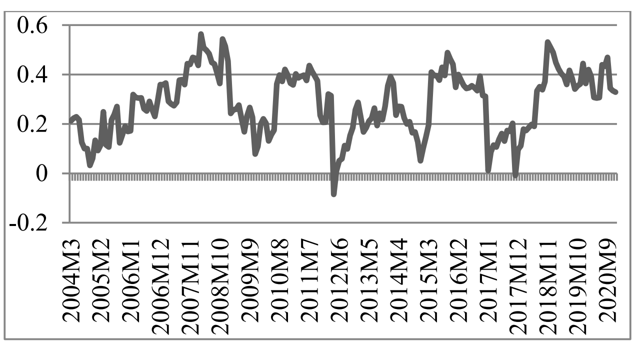

Fig. 1. The correlation between PVN and PBR

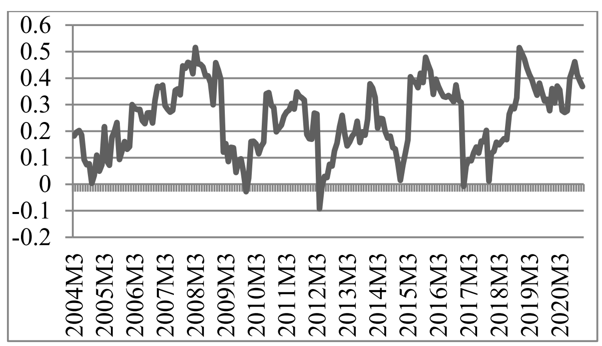

Fig. 2. The correlation between PVN and PCL

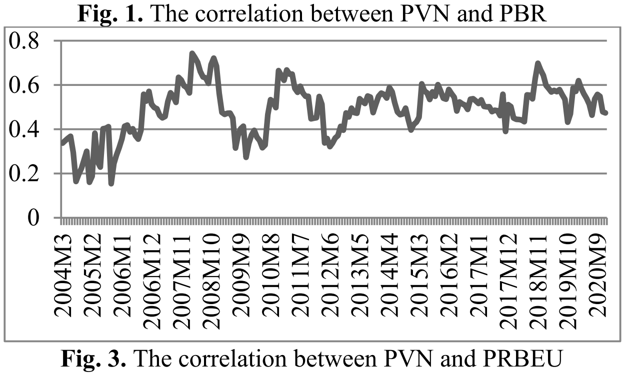

Fig. 3. The correlation between PVN and PRBEU

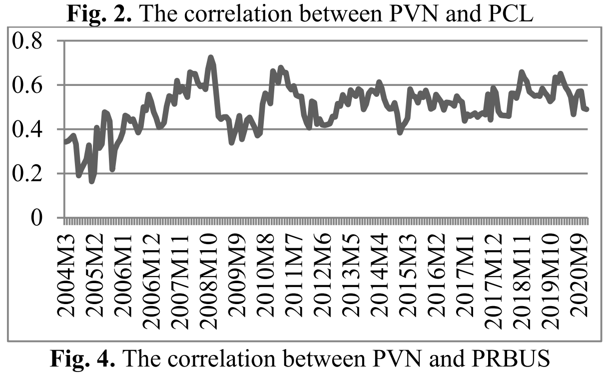

Fig. 4. The correlation between PVN and PRBUS

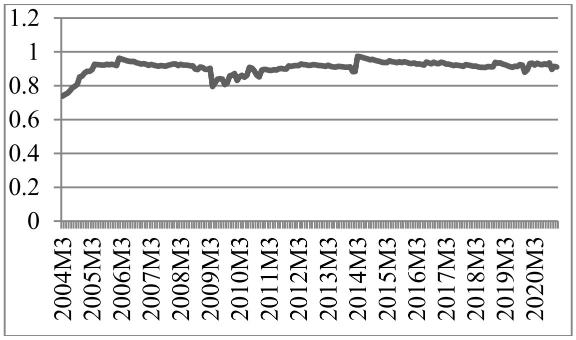

Fig. 5. The correlation between PBR and PCL

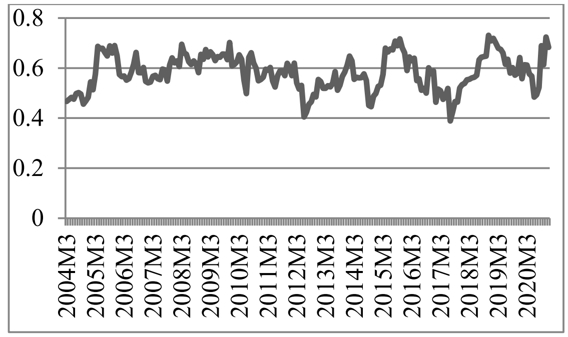

Fig. 6. The correlation between PBR and PRBEU

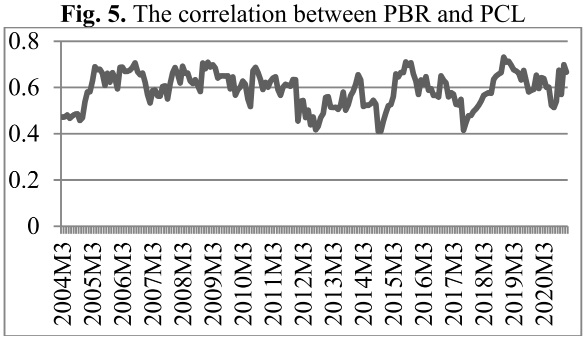

Fig. 7. The correlation between PBR and PRBUS

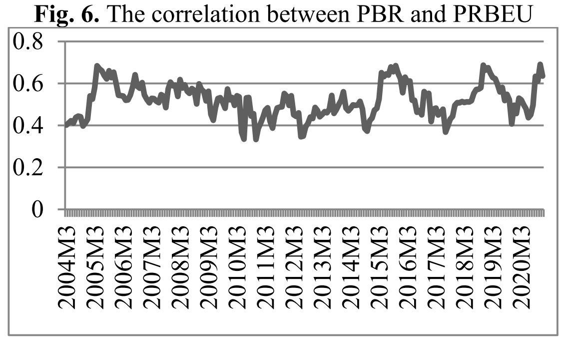

Fig. 8. The correlation between PCL and PRBEU

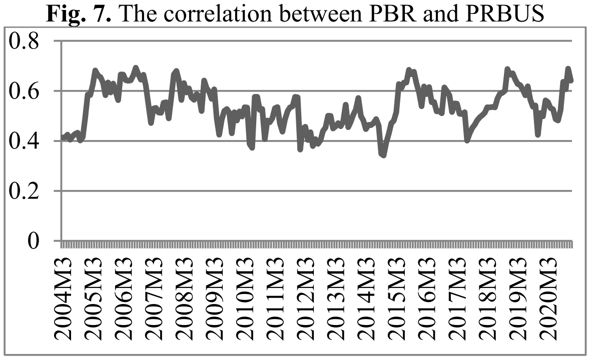

Fig. 9. The correlation between PCL and PRBUS

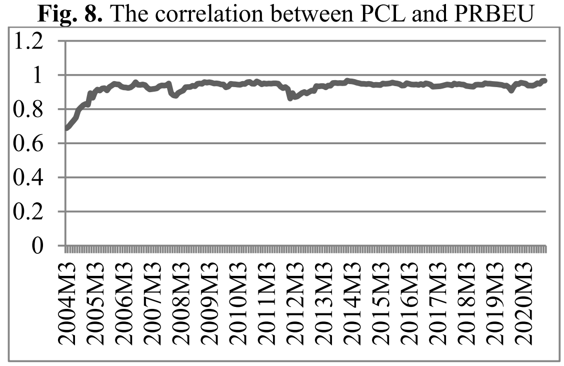

Fig. 10. The correlation between PRBEU and PRBUS

4.2.3. Calculate the Value at Risk

In this part, the paper uses the DCC-GARCH model, which is estimated above to forecast the value of variance in the future then using the Variance - Covariance method to calculate the Value at Risk of five coffee price series. After calculating the Value at Risk of assets, the paper will analyze the Value at Risk of the coffee price series. The results are shown in Table 4.

Table 4
Value at Risk of five coffee price series based on Variance - Covariance method

Confidence level	PVN	PCL	PBR	PRB-EU	PRB-US
5%	-0.0169	-0.096	-0.1182	-0.085	-0.1111
1%	-0.0254	-0.1373	-0.1682	-0.1213	-0.1583

Source: Author's calculation

From Table 4, the probability of speculators holding Vietnamese coffee will suffer a loss of 1.69 percent of the investment value in the next month is 5 percent, and the probability of a loss of 2.54 percent investment value is 1 percent. Meanwhile, at the same probability level, if speculators hold on Colombian coffee, the loss value will be 9.6 percent and 13.73 percent of the investment value, respectively. The loss value will be 11.82 percent and 16.82 percent of the investment value, respectively, if speculators hold on Brazilian coffee. In the two main markets, Europe and America, at a probability level of 5 percent, the loss will be 8.5 percent and 11.11 percent, respectively. At a probability level of 1 percent, the loss will be 12.13 percent and 15.83 percent. To summarize, based on the Variance – Covariance method, the price volatility risk of Vietnamese coffee is the smallest at the same percent and the biggest is Brazilian coffee. While the value at risk of the coffee price volatility in two markets is relatively high. Especially the risk of the fluctuation of Robusta coffee in the American market, which is only smaller than Brazilian coffee.

5. Conclusion

The fluctuation of commodities price and risk is always a big issue for countries with underdeveloped agriculture like Vietnam. Coffee export price as an example, it always fluctuates unpredictably. Moreover, the price volatility risk directly affects the export turnover and many farmer's income. Using time-series data from January 2004 to December 2020, and applying DCC-MGARCH(1,1) model and VaR model, the paper analyzed the volatility, the linkage of five coffee price series includes the coffee price of the three biggest production and exporting coffee countries and Robusta coffee price in the two main markets (America and Europe), and calculate the risk value for holding, speculating on this property. The empirical study points out, firstly, the volatility of Vietnamese coffee price returns and the price of Robusta coffee in two markets were affected by two ARCH term and GARCH term at 1 percent level. Meanwhile, the coffee price of the two countries is only impacted by the ARCH term, the GARCH term totally does not affect at 5 percent level. Based on the sum of two coefficients, the speed volatility of the two main market price returns is slower than Vietnamese coffee price returns. Combining with the analysis above, Vietnamese coffee price returns volatility is smaller but faster than other coffee prices. Secondly, the linkage between markets and countries is different. The linkage between Brazil and Colombia (representing produce area) is the biggest with an average coefficient of 0.9691 and then the linkage between two markets USA and Europe (representing consumption area) with an average coefficient of 0.9551. Because almost the coffee export of Vietnam is Robusta coffee, the linkage among Vietnam with two main markets is relatively high. Meanwhile, the average coefficient linkage among Vietnam with two main competitors is relatively small. The difference is due to Brazil being not only the largest Arabica coffee exporter in the World accounting for 45 percent of market share but also the second Robusta coffee exporter in the World accounting for 28 percent of market share after Vietnam with 39 percent of market share. Therefore, the linkage among Brazilian coffee prices with two main consumed Robusta coffee markets is bigger than the linkage among Colombian coffee prices. Thirdly, the price volatility risk of Vietnamese coffee is smaller than other coffee prices at the same percent. The biggest risk is Brazilian coffee. This means that, if a speculator holds on Vietnamese coffee will be able to bear a lower percentage of losses than the holding, speculation coffee of two competitors at the same probability level.

In summary, the new findings of this article hopefully make a significant contribution to further improving the studies of price volatility and price volatility risk management in the use of time-series data practically and theoretically. About theoretical values, this paper combined the DCC-MGARCH(1,1) model and VaR model to study a new research subject (coffee price), and provide more evidence confirming the existence of the linkage among the coffee prices of different countries and different markets. About practical value, the result obtained from this literature would be a valuable reference for stakeholders, policymakers, coffee processing and exporting enterprises, and coffee farmers to clearly understand the fluctuation and linkage coffee export price series. Based on the coffee price on these markets to calculate or predict the fluctuation of Vietnamese coffee as well as value at risk. Thereby have appropriate and effective solutions and strategies in price volatility risk management.

References

Acosta, A., Ihle, R., & Robles, M. (2014). Spatial price transmission of soaring milk prices from global to domestic markets. *Agribusiness, 30*(1), 64-73.

Canh, N. P., Wongchoti, U., Thanh, S. D., & Thong, N. T. (2019). Systematic risk in cryptocurrency market: Evidence from DCC-MGARCH model. *Finance Research Letters, 29*, 90-100.

Ceballos, F., Hernandez, M. A., Minot, N., & Robles, M. (2017). Grain price and volatility transmission from international to domestic markets in developing countries. *World development, 94*, 305-320.

Dang, T., Caihong, Z., Nguyen, T., Nguyen, N. and Tran, C. (2021), "The volatility characteristics of Vietnamese coffee export price and transmission mechanism of influencing factors: a Markov switching approach", *Journal of Asia Business Studies*, Vol. 15 No. 5, pp. 784-803. https://doi.org/10.1108/JABS-04-2019-0134

Engle, R. (2002). Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics*, 20: 339-350.

Morgan, J. P. (1994). Introduction to riskmetrics. *New York: JP Morgan*.

OEC, M. s. O. o. E. C. (2017). from https://oec.world/en/profile/hs92/0901/

Lee, J., & Valera, H. G. A. (2016). Price transmission and volatility spillovers in Asian rice markets: Evidence from MGARCH and panel GARCH models. *The International Trade Journal, 30*(1), 14-32.

Rahayu, M. F., Chang, W.-I., & Anindita, R. (2015). Volatility Analysis and Volatility Spillover Analysis of Indonesia's Coffee Price Using Arch/Garch, and Egarch Model. *Journal of Agricultural Studies, 3*(2), 37-48.

Schwert, G. W. (2002). Tests for unit roots: A Monte Carlo investigation. *Journal of Business & Economic Statistics, 20*(1), 5-17.

Song, M., Fang, K., Zhang, J., & Wu, J. (2019). The co-movement between Chinese oil market and other main international oil markets: a DCC-MGARCH approach. *Computational Economics, 54*(4), 1303-1318.

Tuyen, D. T., Caihong, Z., Hong, N. T., Akhtar, R., & Elamin, K. M. (2020). Assessing the effect of factors on agricultural commodity export price volatility: evidence from Vietnamese coffee. *Fresenius environmental bulletin*, *29*(12 A), 11151-

11164.

Tuyến, Đ. T., Caihong, Z., & Hồng, N. T. (2020). ASSESSING THE RELATIONSHIP BETWEEN INTERNATIONAL MARKET AND AGRICULTURAL COMMODITY EXPORT PRICES: EVIDENCE FROM VIETNAMESE COFFEE. *Dalat University Journal of Science*, 57-73.

Worako, T., Jordaan, H., & Van Schalkwyk, H. (2011). Investigating volatility in coffee prices along the Ethiopian coffee value chain. *Agrekon, 50*(3), 90-108.