Vector Error Correction Model to Forecasting Spot Prices for Coffee Commodities During Covid-19 Pandemic

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Abstract. Forecasting time series commonly shows non-stationer behavior and involves interrelated variables, so a method that able to obtain a good forecasting result from a non-stationary multivariate time series data is needed. Vector Error Correction Model (VECM) as one of multivariate time series model is a vector form of restricted Vector Autoregressive (VAR) for non-stationary data which has Cointegrity relationship. Prices of agricultural commodities futures usually show variability and unsystematic behavior, especially in times of facing the Covid-19 pandemic as it is today, so getting complete information about data requires data handling while still considering the concept data-driven. Coffee, as one of agricultural commodity data, is often not known for its stationarity. The purpose of this study is to identify the reliability of VECM to predict the spot price of commodities futures coffee during the Covid-19 pandemic in Indonesia. The used data is several observed variables, there are: spot price of Robusta Coffee, futures prices of Robusta Coffee, exchange rates and daily case positive Covid-19 in Indonesia.

The results of this study described the Robusta Coffee data in Indonesia as non-stationary and there is a long-term cointegration relationship to the Robusta Coffee futures price movement due to the influence of the Covid-19 pandemic.

1. Introduction

Today, the futures market has a very strategic role in economic development, especially as a medium of pricing and hedge implementer. The prolonged experience of the economic crisis proves that only agribusiness sector able to survived, so it is only natural that agribusiness is become top priority now. Business in the agricultural commodities, except physical market, has developed into derivatives market which is familiar with the risk. Futures contract is one of the forms of price risk management activity [2]. The presence of the exchange is expected to be able to meet the needs of users from the futures trading industry, create an acknowledgment from all parties that the futures exchange is a provider of price risk management tools and transparent price formation, as well as providing information on commodity prices as reference prices [2]. One of the futures exchange market in Indonesia is PT Bursa Berjangka Jakarta or known as the Jakarta Futures Exchange (JFX).

The rapid spread of the COVID-19 outbreak in Indonesia has given a major impact on the Indonesian economy. The high increasing of patient with high Fatality Rate in the last seven months, accumulated from March 2, 2020 to September 2, 2020, as many as 180,646 positive cases and 7,616 cases died (Indonesian Ministry of Health), very worrying and causing panic, both among the government, society, society and the business world. As a response, government and local community implement prevention
efforts, such as: closing schools, Work From Home for formal sector workers, postponing and canceling various government and private events, stopping several modes of public transportation, and enforcing PSBB in various regions, as well as prohibiting homecoming, which has slow down the economic rate.

Panic caused by Covid-19 also hit Indonesia's financial markets. However, the volume and value of commodity futures trading transactions was relatively stable, even though Indonesia and world globally were hit by the Covid-19 pandemic. The outbreak has not yet affected investor's interest to continue trading. It can be seen that several contracts bound at JFX and cleared through a clearing house Kliring Berjangka Indonesia (KBI) have increased, such as Loco London, Oil and Forex contracts. Only a few types of contracts experienced a slight decline, especially in some agricultural commodities, namely coffee and olein (vegetable oil) [9]. Coffee transactions declined as investors switched to safe heaven asset contracts such as Loco London gold, Oil and Forex.

According to Refinitiv 2020 data, since end of June 2020 until now, the price of robusta coffee traded on the Intercontinental Exchange (ICE) has increased by more than 26%, on a year-to-date basis (ytd) it has increased by more than 8%. Meanwhile, the price of gold since the end of June 2020 to date has strengthened by more than 9%, much lower than the increasing in coffee prices. However, since the beginning of the year, gold has been far superior, increasing by more than 28%. This means that the price of coffee has just accelerated in the last 3 months, while gold has started to rise since the beginning of 2020. Gold in the conditions of the Covid-19 pandemic experienced an increase in demand, while other commodities experienced a decline due to quarantine (lockdown) policies and social restrictions that limited public activities in all around the world.

The commodity market is a dynamic market, because the price that occurs will always change as the effect of reflected by changes in supply demand [5]. Agricultural commodity prices are substantially more volatile than non-agricultural commodities and service commodities, also the time series data on agricultural commodity prices show systematic variabilities and behaviours. Coffee is an agricultural commodity which is already known to be diverse and often tend to non-stationary [9]. Indonesian coffee production does not only rely on natural factors such as climatic/weather conditions, pests and diseases, but also on socio-economic factors, such as applied technology on cultivation process and post-harvest process. In general, coffee farmers and producers do not face production risks but also market risks, such as, price fluctuations and market uncertainty. In general, coffee market players who are exposed to price risk are not only farmers but also sellers, exporter, also processing and producing coffee products companies [1]. Price risk relies not only on supply and demand at every level in the marketing chain, but also by market mechanism at each level.

Spot price is current delivery price for commodities traded on the spot market or also known as cash prices. Spot price is influenced by the existence of supply and demand [7]. Referring to this research, the analysis is carried out by using regression analysis because of its ability to predict or predict long-term futures prices based on spot prices, which are the best predictors [3]. Spot prices have a positive correlation and significant to the Futures Price prediction. The spot price can be used as a reference price and as a basis for determining the decisions related to commodities. The exchange rate affects the volatility of Robusta coffee’s spot price, while the volatility of domestic futures prices is influenced by the volatility of foreign futures contract prices [12].

The choice of model / research method is adjusted to the research data, which in the form of time series data, using the Vector Error Correction Model (VECM) model. VECM is a multivariate form of the Error Correction Model (ECM). ECM is a technique for correcting short-term imbalances towards long-term equilibrium, and able to explain the relationship between variables in the present and past times. This study focused on several variables (multivariate) time series, so ECM was inappropriate to use.

VECM analysis is an analysis developed by [5] to reconcile short-term economic behaviour with long-term economic variables [6]. An Important concept in VECM is long-term balance of time series data which is often called cointegration. Cointegration is a linear combination of variables that are not stationary and integrated on the same order. Cointegration aims to determine the long-term equilibrium
A relationship between the observed variables [4]. VECM analysis is also referred as VAR-Restricted model with non-stationary data but has a cointegration relationship. This research is focused on the VECM model to analyze the cointegration relationship between the Robusta coffee’s spot price, Robusta coffee’s futures price, exchange rate of Rupiah against Dollar, and the positive case of Covid-19 in Indonesia. The purpose of this study is to model the cointegration relationship in providing clarity on the long-term relationship of the influence of the Covid-19 pandemic on the price movement of coffee futures and to predict the modeling of coffee futures commodity spot price predictions.

2. Literature Review

2.1. Vector Error Correction Model
In general, the timeseries econometric model is a structural model because it based on existing economic theory. In 1980, Christopher A. Sims introduced the VAR model as an alternative in macroeconomic analysis. The VAR model is a non-structural model because it is theoretical. The VAR model has a simpler model structure with a minimalist number of variables where all variables are assumed to be endogenous variables with lag as independent variable. The VAR model is designed for stationary variables that does not contain a trend. Stochastic trends in the data indicate that there are long-run (long-term) and short-run (short-term) components in the time series data. Research on stochastic trends in economic variables continues to grow, so that in 1981, Granger developed the concept of cointegration. In 1987, Engle and Granger developed the concept of cointegration and error correction. Then, in 1990, Johansen and Juselius developed the concept of VECM (Vector Error Correction Model). VECM offers a simple working procedure to separate the long-run and short-run components of the data generation process. Thus, VECM is different with VAR, which VECM can be used to model co-integrated and non-stationary time series data. VECM is often referred to as the restricted form of VAR [11]. In general, the VAR model is unrestricted and has p-lags as shown in equation (2.1).

\[ y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + \epsilon_t \]  \hspace{1cm} (2.1)

where
\[ Y_t \]: a vector with k variable
\[ A \]: matrix parameters
\[ \epsilon_t \]: error vector

Because of the linear cointegration relationship, VAR model in equation (2.1) will change to the VECM model using \( y_{t-1} \) \text{(first difference)} as shown in equation (2.2).

\[ \Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta y_{t-i} + \epsilon_t \]  \hspace{1cm} (2.2)

with
\[ \Pi = -(1_K - A_1 - \cdots - A_p), \text{ dan } \Gamma_i = (A_{i+1} + \cdots + A_p), i = 1, \ldots, p - 1 \]

where
\[ \Gamma_j \]: matrix coefficient \((p \times p), j = 1, \ldots, k \)
\[ \Pi \]: matrix \((p \times r), 0 < r < p\) and \( r \) is the number of linear combinations of \( y_t \) elements which is only affected by the shock transistor.
\[ \mu \]: error correction vector
\[ t \]: number of observations

2.2. Cointegration Johansen
The existence of cointegration can be determined by conducting a cointegration test which is known as the Johansen cointegration test. If it is known that the \( VAR (p) \) model in equation (2.1) where \( y_t \) is a
vector with \( k \) non-stationary variable I (1), \( A \) is the parameter matrix and \( \epsilon t \) is error vector, then equation \( VAR (p) \) can be written as equation (2.3).

\[
\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \ldots + \Gamma_k \Delta Y_{t-k+1} + \Pi Y_{t-k} + \epsilon t
\]

(2.3)

To test the hypothesis, trace statistics can be used, i.e.:

\[
LR_{tr}(r|k) = -T \Sigma \log(1-\lambda_i)k_i=r+1
\]

and the maximum eigenvalue test statistics, i.e.:

\[
LR_{max}(r|r+1) = -T \log(1-\lambda r+1) = LR_{tr}(r|k) - LR_{tr}(r+1|k)
\]

For \( r=0,1, \ldots, k-1 \) with the hypothesis used are as follows:

\( H_0 \): there is \( r \) cointegration equation
versus

\( H_1 \): there is none \( r \) cointegration equation

At the significance level \( (1-\alpha) \) of 100%, \( H_0 \) is accepted if the trace test statistic and maximum eigenvalues are less than the critical value \( \alpha \), or \( p-value \) is greater than the significance value \( \alpha \) [10].

2.3. Procedure
The time series data used in this research is the daily data on the spot price of Robusta Coffee, futures prices of Robusta Coffee, exchange rates and daily case positive Covid-19 Indonesia in 2 March 2020-30 September 2020, which is 213 observations. The data is a non-stationary time series data.

The steps in this study are:
Step 1. Test the stationary of data using a ADF unit root test proposed. If the data is not stationary, then the difference is done so that the data is stationary.
Step 2. Determining the optimum p order or lag
Step 3. Johansen cointegration test to see the cointegration between variables.
Step 4. Estimating and Examining the VECM Model
Step 5. Forecasting and Structural Analysis

3. Result and Discussion
In this research, the VECM is applied to daily data on the spot price of Robusta Coffee, futures prices of Robusta Coffee, exchange rates and daily case positive Covid-19 Indonesia in 2 March 2020-30 September 2020, which is 213 observations. Description is used to determine the general description of the data, namely how much the mean value, distribution of data, maximum and minimum values, and the amount of data used in this research is shown as Table 1.

| Variable       | N   | Mean   | Std Deviation | Minimum | Maximum |
|----------------|-----|--------|---------------|---------|---------|
| Positif Covid-19 | 213 | 1347   | 1234,2020     | 0       | 4823    |
| Robusta        | 213 | 19183  | 2286,6093     | 16158   | 24159   |
| Futures        | 213 | 1268   | 130,4633      | 1084    | 1554    |
| Kurs           | 213 | 14918  | 635,4925      | 13956   | 16741   |

Based on Table 1, it shown that the amount of data on each variable is 213 observations. The mean of Positive Covid-19 patients during the 213 observation periods was 1347 with a standard deviation of 1234.20. as for spot price of Robusta coffee during 213 observation periods, it has an average price 19183 per kilogram with a standard deviation of 2286.6093, spot price of Robusta coffee during 213 observation periods had minimum price and the maximum price 16158 and 24159, respectively.
average futures price for Robusta coffee was 1268 with a standard deviation of 130.463. The minimum and maximum futures prices are 1084 and 1554, respectively. For the exchange rate, had an average 14918 with a standard deviation of 635.4925 and the minimum and maximum values are 13956 and 16741, respectively.

The next step after descriptive statistics is to test the data stationarity. The data stationarity test can use the Augmented Dickey-Fuller unit root test (ADF) with the decision criteria at the \((1 - \alpha)100\%\) significance level, where \(H_0\) is rejected if the \(p\)-value is smaller than the significance value \(\alpha\). The results of the stationarity test are as shown in Table 2.

| Data       | P-value before differencing | P-value after differencing | Conclusion                      |
|------------|-----------------------------|----------------------------|---------------------------------|
| Positif Covid-19 | 0.9594                       | 0.01                       | Stationary after differencing to 1 |
| Robusta    | 0.7823                       | 0.01                       | Stationary after differencing to 1 |
| Futures    | 0.7186                       | 0.01                       | Stationary after differencing to 1 |
| Kurs       | 0.2721                       | 0.01                       | Stationary after differencing to 1 |

Based on Table 2, it is known that after the first differencing, the \(p\)-value for each variable was obtained 0.01 and is smaller than \(\alpha = 5\%\). This means that stationarity is achieved after the first differencing.

Furthermore, before estimating the VECM model it is necessary to determine the length of the lag, so determining the optimal lag is one of the important procedures that must be carried out in the formation of a VECM model [4]. The result of determining the optimum lag length are shown in Table 3.

| Kriteria | Lag   |
|----------|-------|
|          | 1     | 2     | 3     | 4     | 5     | 6     |
| AIC      | 3.69E+01 | 3.68E+01* | 3.69E+01 | 3.70E+01 | 3.70E+01 | 3.70E+01 |
| HQ       | 3.71E+01* | 3.71E+01 | 3.73E+01 | 3.74E+01 | 3.76E+01 | 3.77E+01 |
| SC       | 3.73E+01* | 3.75E+01 | 3.78E+01 | 3.82E+01 | 3.85E+01 | 3.87E+01 |
| FPE      | 1.09E+16 | 1.00E+16* | 1.08E+16 | 1.13E+16 | 1.22E+16 | 1.16E+16 |

*lag terpilih berdasarkan kriteria lag optimum
AIC: Akaike Information Criterion
HQ: Hannan-Quinn Information Criterion
SC: Schwarz Information Criterion
FPE: Final Prediction Error

Based on Table 3 It can be seen that the smallest AIC and FPE values are in the 2nd lag, while the smallest HQ and SC values are in the 1st lag, so the optimum lag for the VECM model is the VECM (1) model and the VECM (2) model.

3.1. Johansen Cointegration Test
The results of the cointegration test between variables using the Johansen test are presented in Table 1.4.

| Test Statistics trace | Critical Value | Test Statistics | Critical Value |
|-----------------------|----------------|----------------|----------------|
Based on Table 4, it can be seen that the Johansen cointegration test results show that there is cointegration between variables. This can be seen from the trace statistic value and the maximum eigenvalue at $r = 0$, which is greater than the critical value, both the critical value of 1%, 5%, and 10% and for other $r$, the critical value is greater than the trace statistic value and maximum eigenvalues. Therefore, it can be concluded that there is at least one form of cointegration equation which shows that the variables have a balanced relationship and movement similarity in the long run. The form of the cointegration equation is as follows:

$$\epsilon_t = \text{robus}ta_t - 18.572 \text{ futures}_t - 0.603 \text{kurs}_t + 0.102 \text{positif}_t$$

### 3.2. VECM estimation

The cointegration relationship between research variables has been shown and the next step is to form a VECM model. According to Enders [4], if there is a cointegration relationship between the research variables, then the estimation is done using the VECM model. If there is no cointegration between variables, the estimation is done using the VAR-d model. An important procedure in estimating the VECM model equation is selecting the optimum lag and then checking the model to select the best model between the VECM (1) model and the VECM model (2) as presented in Table 5.

| Kriteria | VECM(1) | VECM(2) |
|----------|---------|---------|
| AIC      | 13.94   | 13.91   |
| SC       | 14.10   | 14.01   |

Based on Table 5, it can be shown that the AIC value and the SC value in the VECM (2) model are smaller than the AIC value and the SC value of the VECM (1) model. This means that the VECM (2) model is better than the VECM (1) model. Thus, the form of the VECM (2) model equation for the case of Robusta Coffee in Indonesia is as follows:

$$d(\text{robus}ta) = -0.18(\text{robus}ta - 18.572 \text{ futures} - 0.603 \text{kurs} + 0.102 \text{positif})$$

$$+0.001d(\text{robus}ta(-1)) + 0.016d(\text{robus}ta(-2)) + 5.71d(\text{futures}(-1))$$

$$+0.53d(\text{futures}(-2)) - 0.03d(\text{kurs}(-1)) - 0.15d(\text{kurs}(-2))$$

$$+0.1d(\text{positif}(-1)) - 0.07d(\text{positif}(-2)) + 4.76$$

### 3.3. Forecasting and Structural Analysis

In this research, impulse response analysis can be used to see the effect of shocks. the future price of robusta coffee, the rupiah exchange rate against the US dollar, and the positive case of Covid-19 against the Robusta coffee spot price and against itself for the next 10 days. Meanwhile, variance decomposition is used to analyze which variable has the most dominant influence on the Robusta coffee spot price.
3.3.1. Impulse Respone. The following shows a graph of the impulse response in Figure 1.

![Orthogonal Impulse Response from robusta](image)

**Figure 1.** Impulse-Response Analysis

Based on Figure 1, it can be seen that the response of the Robusta coffee spot price variable due to a shock or shock to this commodity and the exchange rate variable shows a positive response but tends to decline for the Robusta coffee spot price and an increase in the exchange rate variable. The response shown by the Robusta coffee futures price variable does not show any significant movement and remains close to the value 0. Furthermore, the response due to the Covid-19 case variable shows a negative response and tends to fluctuate but the movement still shows a negative response to the Robusta coffee spot price.

3.3.2. Variance Decomposition. The following is the variance decomposition output in Table 6.

| Period | S.E.    | ROBUSTA | FUTURES | KURS | POSITIF |
|--------|---------|---------|---------|------|---------|
| 1      | 252.4884| 100.0000| 0.000000| 0.000000| 0.000000|
| 2      | 373.4070| 82.02179| 17.67466| 0.042547| 0.261000|
| 3      | 468.3705| 70.33020| 29.43483| 0.069076| 0.165895|
| 4      | 544.6172| 62.57342| 36.99845| 0.242053| 0.186068|
| 5      | 612.7385| 55.56297| 43.67893| 0.575162| 0.182940|
| 6      | 676.0970| 49.36094| 49.41147| 1.049878| 0.177718|
| 7      | 735.7009| 44.02656| 54.17795| 1.609643| 0.185849|
| 8      | 792.8236| 39.39385| 58.19249| 2.216080| 0.197579|
| 9      | 848.2761| 35.36159| 61.58850| 2.841922| 0.207991|
| 10     | 902.3402| 31.86689| 64.44999| 3.464769| 0.218360|

From the output, it can be seen that in the first period, the Robusta coffee spot price variable was only influenced by itself without any fluctuation contribution from other variables. As for the following periods, the Robusta coffee futures price is a fairly dominant variable that contributes to fluctuations in GRDP compared to the rupiah exchange rate variable against the US dollar and the positive case of Covid-19, seen until the 10th-period spot price shocks due to the increase in robusta coffee futures prices. up to 64.44%. Thus, the dominance of the coffee futures price variable compared to other
variables starts from the second period to the end of the period. In general, fluctuations caused by exchange rate shocks and positive cases of Covid-19 are very small on the spot price of Robusta coffee.

3.3.3. Forecasting. The results of forecasting data for the next 10 periods based on the VECM (2) model can be seen in Table 7 with an RSME value of 174.62.

| Date       | Data Pengujuan | Data Perkiraan |
|------------|----------------|----------------|
| 1 Oktober 2020 | 20007          | 20010          |
| 2 Oktober 2020 | 19692          | 19948          |
| 3 Oktober 2020 | 19692          | 19833          |
| 4 Oktober 2020 | 19692          | 19770s         |
| 5 Oktober 2020 | 19695          | 19704          |
| 6 Oktober 2020 | 19108          | 19752          |
| 7 Oktober 2020 | 18980          | 19655          |
| 8 Oktober 2020 | 18781          | 19538          |
| 9 Oktober 2020 | 18850          | 19486          |
| 10 Oktober 2020 | 18850          | 19416          |

The results obtained in Table 7 are the results of the forecast of the Robusta coffee spot price in the period 1 October 2020 to 10 October 2020. In addition, in Table 6 testing data is the actual data for 10 days of the Robusta coffee spot price. To see the closeness of the data between the test data and the estimated data, it can be seen in Figure 2 below.

4. Conclusion
Based on the analysis, it can be concluded that the best model obtained is VECM (2) in analyzing the Robusta coffee spot price. The cointegration test between variables shows that for each variable in the short-run period relationship tends to adjust to each other to achieve its long-run equilibrium. The results of structural analysis of the model VECM (2) show that the shock variable spot price of Robusta coffee due to the variable itself tends to decrease, but significantly very influential. Another variable that also has a big influence on the spot price of Robusta coffee is the futures price of Robusta coffee. Meanwhile, shocks due to the Covid-19 case even though they experienced a positive response, the response from these variables was negative and in general, the fluctuation that occurred was very small. Thus, the Covid-19 pandemic did not significantly influence the Robusta coffee spot price movement. The results
of the forecasting obtained using VECM (2) show the results of a good forecast value for the Robusta coffee spot price for the next 10 periods by following the actual data closeness.

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