The implications of the COVID-19 pandemic on rice market performance in Java, Indonesia

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Abstract. Applying the multivariate cointegration tests with daily prices during the period August 15, 2019, to August 11, 2020 (250 data), this paper examines whether prices in the rice deficit market (Jakarta) are co-integrated with prices in surplus markets (Semarang and Surabaya). Research data is the average daily price in traditional markets in Jakarta, Semarang, and Surabaya. The main focus is on the effect of implementing various programs and policies relating to controlling the spread of COVID-19 to the integration of the rice market in Java. On March 02, 2020, the first two COVID-19 cases in Indonesia were confirmed as a dummy variable that we use regarding controlling borders between regions and restricting the movement of goods. The cointegration tests find that the domestic rice prices of Jakarta-Semarang and Jakarta-Surabaya are integrated both in short-run and long-run periods. In the short term, programs and policies relating to controlling the spread of COVID-19 do not affect the integration of Java's rice market. One reason is that during the pandemic, the rice supply chain's performance was still protected by the government to maintain the stability of rice supply for the citizens.

1. Introduction
The COVID-19 outbreak is considered to have a bad influence on the economy in various countries. The process of economic development in various countries is predicted to decline uncertainty in the future and international vigilance against the spread of the plague. The Asian Development Bank predicts that COVID-19 will affect the decline in GDP growth in Southeast Asia by around 3.40 percent by 2020 [1]. The sharp decline in GDP growth is predicted to increase the poverty rate, which has implications for increasing food insecurity in various countries.

The COVID-19 outbreak in Indonesia has reached around 3,469 deaths from a total of 72,347 confirmed cases of 10 July 2020 [2]. The uncertainty over the spread of COVID-19 has resulted in the central and regional governments implementing social restrictions by encouraging residents to stay-at-home, work from home, and avoid large gatherings. Besides, controlling the spread of COVID-19 has significantly disrupted the balance of supply and demand for food in various regions as an economic implication of controlling borders between regions, restricting the movement of goods and implementing health controls. The COVID-19 outbreak has reduced the number of workers in the...
production sector, thereby reducing the volume of goods and services supply [3]. On the other hand, there is an increase in the volume of demand for goods due to panic buying by consumers to secure their food needs during the pandemic period [4].

In this study, we will analyze the economic impact of the COVID-19 outbreak on the integration of the rice market in Java Island. We focus on this research on the price of rice because rice is one of the staple foodstuffs of most Indonesians. The rice market's performance was affected by the pandemic, which was caused by the nature of rice production, which was only concentrated in certain areas so that the need for rice in deficit areas was highly dependent on the supply of rice from surplus areas. Market integration is one of the concepts considered capable of providing price balance between regions due to the spatial dispersion in the production aspect. The concept of spatial integration of the rice market also plays a significant role in terms of maintaining economic performance between regions, especially during certain conditions, such as a pandemic.

The determination of Java Island as the research location was due to the most significant national deficit in rice production in Java Island, namely DKI Jakarta Province. On the other hand, the eastern part of Java Island is one of the largest surplus rice production areas nationwide, namely Central Java and East Java Provinces [5]. On the other hand, the most substantial proportion of confirmed COVID-19 cases in Indonesia until July 10, 2020, were in the Provinces of East Java, DKI Jakarta and Central Java, which reached around 15,730 cases, 13,739 cases and 5,303 cases [2]. This condition has implications for the existence of various social restrictions to control the spread of COVID-19 in Java Island, which could affect the integration of the rice market in Java Island. This study aims to determine how the COVID-19 outbreak affects the integration of the rice market in Java Island.

In the second session of this paper, we presented various studies on the effect of implementing various policies related to controlling the spread of COVID-19 on the performance of the agricultural commodity market. In the third session, various researches related to the integration of agricultural commodity markets were presented. In the fourth session, the methodology concept and the data used were explained. The fifth session discusses our empirical results, and in the last session, we present the major conclusions.

1.1. The COVID-19 outbreak and agricultural commodities market

Controlling the spread of the COVID-19 outbreak through restrictions on social activities in the form of stay-at-home in several countries in Europe has affected the supply and demand for foodstuffs. In March 2020, there was an increase in food prices by 1 percent compared to January and February 2020. Prices for these foods continued to increase until April and were stable in May 2020 [6]. Government policies related to handling the COVID-19 outbreak can significantly disrupt the global trade system, supply chains, and trade flows, which have implications for increasing product prices and threatening a country's food security [7].

The government's social restrictions to deal with the spread of the COVID-19 outbreak have led to panic buying and increased household consumption, thus affecting the volume of transportation and cargo capacity in German food retail logistics. On the other hand, the increase in cargo volume for dry products in German food retail logistics does not depend on the COVID-19 epidemic period but is influenced by the number of new confirmed cases of infection every day [8]. On the other hand, trade restrictions during the COVID-19 outbreak to prevent cross-regional spread can also harm the region's food system [9].

Substantially, the implementation of activity restriction policies can also reduce the level of market competition. Foodstuff traders are interested in gaining profits from the fragmentation of economic activity to increase the market power they have against consumers and producers. During the COVID-19 pandemic, wholesale-retail and farm-retail in Europe were able to increase their marketing margins [10].
1.2. Agricultural market integration

Broadly, the cointegration method has been applied in various studies related to the integration of agricultural commodity markets. [11] investigated the integration of rice and wheat markets in India using the cointegration method [12,13]. Market integration is carried out spatially in Bihar, Orissa, Uttar Pradesh, and West Bengal, with the number of markets studied reaching 17 markets. Based on the analysis results, it is recommended that there be restrictions on government intervention and provide full access for private actors to contribute to integrated markets.

The cointegration approach and vector error correction model are used to investigate price transmission in the wheat market and the rice market in Pakistan [14]. The research was conducted in January 2006 to June 2014 using monthly prices at the retail level. It is known that long distances between markets, different geographic conditions, and poor transportation infrastructure cause the transmission of prices between markets to occur slowly. This statement is based on the finding that there is price integration between markets, but with a low-price transmission rate.

The vector error correction model (VECM) and the threshold vector error correction model (TVECM) were applied to study the integration of the wheat market in Pakistan in 2014 to 2015 [15]. This research was conducted spatially on five wheat wholesale markets in Hyderabad, Lahore, Multan, Rawalpindi, and Peshawar. The results show that the entire wheat market in Pakistan is well integrated so that the government is advised to provide greater access to the private sector in the wheat trade in the domestic market and increase investment in the storage and transportation sector.

Multivariate time series analysis was applied to determine the relationship between international sugar prices [16]. The study was conducted using daily data on sugar prices of the seven most crucial sugar stock exchanges (New York, London, New Delhi, Sao Paolo, Tokyo, Russia, and Beijing) from August 2012 to August 2017. The results showed that there were only a few sugar stocks exchange that has long-term and short-term relationships. Meanwhile, the integration between wheat markets in Turkey was studied using a vector error correction model [17]. The results show that there is a long-term relationship between wheat prices and markets so that in the future it is necessary to liberalize the wheat market in Turkey.

2. Methods

2.1. Samples and data collection

In this study, we used daily data on rice prices for the period August 15, 2019, to August 11, 2020 (250 data), at the merchant level in three different cities, namely Central Jakarta City as a representation of the Jakarta Special Capital Region Province, which is the largest rice production deficit area in Java Island. The cities of Semarang and Surabaya are defined as the representation of Central Java and East Java Provinces as the largest surplus rice production areas in Java Island. The price of rice is the trader level in traditional markets based on the data collected by the Food Price Information Center <https://hargapangan.id/> . In this study, rice in Central Jakarta City is the average price of rice in Jatinegara Market, Kramatjati Market, and Minggu Market. The price of rice in Semarang City comes from two markets, namely Johar Market and Peterongan Market. The price of rice in the city of Surabaya is represented by the average daily prices at the Tambah Rejo Market and the Wonokromo Market.

2.2. Measurement

This research begins with unit root testing to determine the level of price series stationarity. Cointegration occurs when each variable is $I(1)$ and has a linear combination $I(0)$. Unit root testing is carried out through the Augmented Dickey-Fuller Test (ADF) approach to determine the stationarity of each price series variable individually [18]. Mathematically, the ADF equation is as follows:

$$\Delta y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-i} + \varepsilon_t$$

(1)
In equation 1, the value of the lag of $\Delta y_t$ can accumulate each dynamic structure in the dependent variable to ensure that $e_t$ is uncorrelated [19].

In this study, the lag length is determined based on the lowest information criterion value of the Schwarz Bayesian Information Criterion (SBIC) and Akaike Information Criterion (AIC). Mathematically, the SBIC and AIC equations are:

$$
SBIC = \ln(\hat{\sigma}^2) + \frac{k}{T}\ln{T} 
$$

(2)

$$
AIC = \ln(\hat{\sigma}^2) + \frac{2k}{T} 
$$

(3)

where $\hat{\sigma}^2$ is the residual variance, $k$ is the number of parameters estimated, and $T$ is the sample size.

If each price series individually is integrated of order one, $I(1)$, then it is continued with cointegration testing through multivariate cointegration tests. In this study, the cointegration test was carried out using the [20] method, namely through the trace test and maximum eigenvalue test.

$$
\lambda_{\text{trace}}(r) = -T \sum_{i=r+1}^{g} \ln(1 - \hat{\lambda}_i) 
$$

(4)

$\lambda_{\text{trace}}$ is a joint test with the following hypothesis:

$H_0 : r = g - 1$

$H_1 : r = g$

$$
\lambda_{\text{max}}(r, r + 1) = -T \ln(1 - \hat{\lambda}_{r+1}) 
$$

(5)

$\lambda_{\text{max}}$ tests separately for each eigenvalue, with the following hypothesis:

$H_0 : r = 0$

$H_1 : r \geq 1$

The error correction equation determines the cointegration relationship between rice prices. Based on this equation, it can be seen that the long-term and short-term relationship between the price series in each market. On the other hand, if a short-run adjustment for each price series can correct a deviation from the equilibrium position, then the speed of adjustment can be measured through the error correction term (ECT). The long-term relationship between the price series can be determined by changing the equation into the least-squares estimation form, formulated as follows:

$$
ECT_{t-1} = \beta_1 \Delta LnJakarta_{t-1} + \phi_j \Delta LnSemarang_{t-1} + \varphi_m \Delta LnSurabaya_{t-1} + u_t 
$$

(6)

where $u_t$ is stationary equilibrium error.

The implications of various policies to control the spread of the COVID-19 outbreak on rice market integration is explained as a dummy variable in the short-term equation. The dummy variable is determined based on the period when the COVID-19 case was first confirmed in Indonesia, namely on March 02, 2020. Mathematically, the short-term dynamic equations between the price series are presented in the following equation:

\[
\begin{align*}
\Delta LnJakarta_t &= a_0 + \sum_{i=1}^{k-1} \beta_i \Delta LnJakarta_{t-i} + \sum_{j=1}^{k-1} \phi_j \Delta LnSemarang_{t-j} + \sum_{m=1}^{k-1} \varphi_m \Delta LnSurabaya_{t-m} + \omega_r \text{ Dummy } + \lambda_1 \text{ECT}_{t-1} + u_t \\
\Delta LnSemarang_t &= a_0 + \sum_{i=1}^{k-1} \beta_i \Delta LnJakarta_{t-i} + \sum_{j=1}^{k-1} \phi_j \Delta LnSemarang_{t-j} + \sum_{m=1}^{k-1} \varphi_m \Delta LnSurabaya_{t-m} + \omega_r \text{ Dummy } + \lambda_1 \text{ECT}_{t-1} + u_t \\
\Delta LnSurabaya_t &= a_0 + \sum_{i=1}^{k-1} \beta_i \Delta LnJakarta_{t-i} + \sum_{j=1}^{k-1} \phi_j \Delta LnSemarang_{t-j} + \sum_{m=1}^{k-1} \varphi_m \Delta LnSurabaya_{t-m} + \omega_r \text{ Dummy } + \lambda_1 \text{ECT}_{t-1} + u_t
\end{align*}
\]

(7)

(8)

(9)

3. Results and discussion

In the period from August 15, 2019, to August 11, 2020, it is known that the price of rice in Jakarta is around IDR 12,897 per kilogram or higher than the price of rice in Surabaya (IDR 11,867 / kg) and Semarang (IDR 11,338 / kg). The price of rice in Jakarta is higher than in other regions due to Jakarta’s status as a rice production deficit area so that meeting domestic rice demand is highly
dependent on supplies from surplus production areas such as Surabaya and Semarang. Meanwhile, the movement of rice prices in Jakarta during the study period tended to be more volatile than in Surabaya and Semarang, which tended to be stable. Since the period of confirmation of the first COVID-19 case in Indonesia (as on March 02, 2020), the price of rice in Jakarta has continued to increase until April 06, 2020, with the highest price reaching IDR 13,375 / kg, and is in a stable position starting April 22, 2020. On the other hand, the COVID-19 case is considered not to affect the stability of rice prices in Surabaya and Semarang.

![Figure 1. The development of rice prices for the period from August 15, 2019, to August 11, 2020.](image)

### Table 1. Statistical description of rice prices for the period from August 15, 2019, to August 11, 2020.

| City      | Mean  | StDev | Min  | Max  |
|-----------|-------|-------|------|------|
| Jakarta   | 12,897| 400   | 12,400| 13,375|
| Semarang  | 11,338| 48    | 11,250| 11,375|
| Surabaya  | 11,867| 50    | 11,800| 11,925|

The Augmented Dickey-Fuller test results show that all price series at the log level is nonstationary at 10%, 5%, and 1% significance levels. Meanwhile, the unit root test in the form of the first difference shows that the null hypothesis can be rejected at a 1% level of significance, indicating that the entire price series is integrated of order 1, \( I(1) \). Based on the results of the unit root testing, the cointegration test can be continued on the rice price series in Java Island.

The cointegration relationship between the price series is determined through The Johansen maximum-likelihood multivariate cointegration model. The optimal lag in the model is determined to be two lags based on the Schwarz criterion (SC). The cointegration test results show that the model has two cointegrating equations at the 5% significance level, which are confirmed based on the results of the trace test and the maximum eigenvalue test.

The long-term relationship between the price series in the error correction model is presented in equation 10, where the target variable is the price of rice in Jakarta, which is the most significant deficit in rice production in Java.
Table 2. Testing natural log of rice price series for a unit root.

| City       | Intercept | Augmented Dickey-Fuller | Trend and intercept | None |
|------------|-----------|-------------------------|---------------------|------|
| Jakarta    | -0.70     | -1.47                   | 2.17                |      |
| ΔJakarta   | -8.34***  | -8.33***                | -7.99***            |      |
| Semarang   | -1.35     | -1.81                   | 0.94                |      |
| ΔSemarang  | -8.34***  | -16.63***               | -16.62***           |      |
| Surabaya   | -1.22     | -1.93                   | -0.94               |      |
| ΔSurabaya  | -16.65*** | -16.62***               | -16.62***           |      |

Note: Intercept critical values: ***(Pr ≤ 0.01) = -3.46; **(Pr ≤ 0.05) = -2.87; *(Pr ≤ 0.1) = -2.57. Trend and intercept critical values: ***(Pr ≤ 0.01) = -4.00; **(Pr ≤ 0.05) = -3.43; *(Pr ≤ 0.1) = -3.14. None critical values: ***(Pr ≤ 0.01) = -2.57; **(Pr ≤ 0.05) = -1.94; *(Pr ≤ 0.1) = -1.62.

Table 3. Johansen’s test for cointegration.

| Null | Alternative | Trace | 5% Critical Value | Maximum Eigenvalue | 5% Critical Value |
|------|-------------|-------|-------------------|--------------------|-------------------|
| r = 0| r ≥ 1       | 65.10** 29.80 | 47.30** | 21.13 |
| r ≤ 1| r ≥ 2       | 17.80** 15.49 | 17.05** | 14.26 |
| r ≤ 2| r ≥ 3       | 0.75 3.84 | 0.75 | 3.84 |

Note: ** denotes rejection of the null hypothesis at 5% significance level.

\[
l_{\ln Jakarta} = -839.16 + 47.99 l_{\ln Semarang} + 42.70 l_{\ln Surabaya} \]
\[(-7.71) \quad (-6.05)\]  

(10)

The t-statistics values are presented in the () brackets, and the t-values at the 1%, 5%, and 10% significance levels are 2.58, 1.96, and 1.65. Based on equation 10, it is known that at a significance level of 1%, an increase in rice prices in Semarang and Surabaya by 1% will increase rice prices in Jakarta by 47.99% and 42.70%. The supply of rice prices from surplus areas (Semarang and Surabaya) is crucial in determining rice prices in Jakarta, which implies that maintaining the smooth distribution of rice from the eastern to the western regions will play a significant role in the stability of rice prices in Java.

The short-term dynamics of the rice price series in Java Island are presented in Table 4, with the Lagrange Multiplier (LM (2)) test result of 0.985, which confirms that the residuals do not show a deviation from white noise at the 5% significance level. The short-term dynamic relationship between the rice market in Java Island is only found in the Jakarta and Surabaya models, shown by the significance of the error correction term coefficient. In the following section, a specific discussion of price dynamics in the short term is presented and the correction of temporary disequilibrium between rice markets in Java.

Jakarta has an ECT (-1) estimation coefficient which is significantly negative, which indicates that if there is a shock in the price of rice in Jakarta, the system will correct around 0.5% errors on the first day, around 0.5% errors on the second day, and so on until it reaches long-run equilibrium position. The coefficient of short term estimate for rice prices in Semarang is -0.253 and is significant at the 10% significance level of current price changes in the Jakarta market, which implies that a 10% change in rice prices in Semarang on the previous day would reduce the current rice price in Jakarta by 0.253%. The price of rice in Jakarta in the short term is influenced by the price of rice in Semarang (surplus area) because geographically, the distance between Jakarta - Semarang is about 477 km or closer than Jakarta - Surabaya which is about 787 km.
Table 4. Error correction model for rice price series.

| Independent Variables | Dependent Variables |
|------------------------|---------------------|
|                        | ∆lnJakarta | ∆lnSemarang | ∆lnSurabaya |
| ECT(-1)                | -0.005*** | 0.001      | 0.002***    |
| ∆lnJakarta(-1)         | 0.091      | 0.078***   | 0.047*      |
| ∆lnSemarang(-1)        | -0.253*   | -0.032     | 0.089       |
| ∆lnSurabaya(-1)        | 0.013      | 0.007      | -0.057      |
| Constant               | 2.140x10^-4 | 0.542x10^-4 | -0.445x10^-4 |
| COVID-19               | 1.490x10^-4 | -0.913x10^-4 | -0.191x10^-4 |
| LM test                | 0.985      |            |             |

Note: *, ** and *** indicated a statistical at 1%, 5% and 10% significance level, respectively

The ECT (-1) estimation coefficient in Bandung is significantly positive, which indicates that there is no correction for short-term deviations, or the model is unstable. A 10% change in the price of rice in Jakarta on the previous day will increase the rice price in Surabaya by 0.047%, which indicates that Jakarta, as the most significant deficit area in Java, can send signals that will influence price formation in Surabaya. This condition reflects a significant level of trade between the two regions. On the other hand, the absence of a short-term relationship between surplus areas (Semarang - Bandung, respectively) means that Jakarta, which acts as a center for rice demand in Java, can signal price formation in other regions.

It is known that programs and policies related to controlling the spread of the COVID-19 outbreak do not affect the integration of the rice market in Java Island that indicates that during the pandemic, movement restrictions imposed by the government did not affect the distribution of rice from surplus areas to deficit areas. Local governments do not implement a lockdown policy, but only limited to partial lockdowns carried out in certain areas because the economic cost of implementing a lockdown is considerable. During a pandemic, the government protects the food supply chain sector's performance and realizes that this sector has a vital role in maintaining the food supply and nutrition of the population.

4. Conclusion

This paper provides an empirical analysis of the integration of the rice market in Java Island between surplus areas (Semarang and Surabaya) and deficit areas (Jakarta), which are associated with controlling the COVID-19 outbreak. The main focus of this research is to determine the effect of implementing various programs and policies related to controlling the spread of COVID-19 during the period 02 March 2020 to 11 August 2020 on the cointegration between rice markets in 3 main areas in Java Island.

In theory, policies to control the spread of COVID-19, especially restrictions on various movements, will affect market integration caused by the disruption of rice's smooth supply from surplus areas to deficit areas. However, the empirical results of this study confirm that although the policy to control the spread of COVID-19 is implemented in various regions, the markets in Jakarta - Semarang, and Jakarta - Surabaya remain integrated into the short and long term, which indicates that the policy does not interfere with linkages between markets.

One of the reasons related to the absence of influence in the integration of the rice market between surplus areas and deficit areas was because, during the pandemic, the performance of the rice supply chain was still protected by the government to maintain the stability of rice supply for the population. On the other hand, the integration of the existing rice market must be maintained by improving the
quality of transportation infrastructure and giving full access to private actors to contribute to integrated markets.

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References
[1] Asian Development Bank 2020 Asian Development Bank, Metro Manila Available from: https://www.adb.org/sites/default/files/publication/575626/ado2020.pdf
[2] Ministry of Health 2020 Statistik COVID-19 Available from: https://covid-monitoring.kemkes.go.id/ (cited 2020 April 12)
[3] Cappelli A and Cini E 2020 Trends in Food Science & Technology 99 566–7
[4] Power M, Doherty B, Pybus K and Pickett K 2020 Emerald Open Research 2 11
[5] Central Bureau of Statistics (Badan Pusat Statistik) 2019 Harvested Area and Rice Production in Indonesia 2018 (Luas Panen dan Produksi Beras di Indonesia 2018) Available from: https://bps.go.id/ (cited 2020 July 4)
[6] Akter S 2020 Food Security 12 719–25
[7] Carreño I, Dolle T, Medina L and Brandenburger M 2020 European Journal of Risk Regulation 11 402–10
[8] Loske D 2020 Transportation Research Interdisciplinary Perspectives 6 100–65
[9] Chen K Z and Mao R 2020 Food Policy 12 735–8
[10] Ihle R, Rubin O D, Bar-Nahum Z and Jongeneel R 2020 Food Security 12 727–34
[11] Ghosh M 2010 The Journal of Applied Economic Research 4 495–516
[12] Johansen S 1988 Journal of Economic Dynamics and Control 12 231–54
[13] Johansen S and Juselius K 1990 Oxford Bulletin of Economics and Statistics 52 169–210
[14] Ahmed U I, Ying L, Bashir M K, Iqbal M A, Rizwan M, Iqbal M M, Qamar M R and Nazeer A 2015 Pakistan Journal of Agricultural Research 28 254–62
[15] Sahito J G M 2017 Journal of Agricultural Research 55 545–56
[16] Ruma’nkova’ L, Smutka L, Maitah M and Benes’ova I 2020 Sugar Tech. 21 853–61
[17] Eryigit K Y and Karaman S 2011 Quality & Quantity 45 1519–30
[18] Dickey D A and Fuller W A 1981 Econometrica 49 1057–72
[19] Brooks C 2014 Introductory Econometrics for Finance 3th ed (New York: Cambridge University Press)
[20] Johansen S 1991 Econometrica 59 151–8