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DOES VERTICAL ASYMMETRIC PRICE TRANSMISSION EXIST IN THE RICE MARKETS?

Purpose. *This study aims to empirically measure and analyze the long-run relationship and asymmetric price transmission of the rice market in Aceh Province, Indonesia. It also attempts to empirically examine and analyze the existence of the vertical price trends along the rice distribution channels both in the short term and long term.*

Methodology / approach. *Monthly data from January 2009 to December 2019 on the prices of dry harvested rice (known as Milled Dry Grain – MDG in Indonesia) at the farm level, the prices of MDG at the rice mill level, and the retail prices of the medium- and premium-quality rice were gathered from the report of Statistics Indonesian Agency (BPS – Statistics Indonesia). The study uses a series of econometric techniques comprising cointegration, causality, and Error Correction Model (ECM) to investigate the research objectives.*

Results. *The study found price integration between the upstream and downstream rice markets. The asymmetric price transmission existed in the short run along the rice distribution chain, including the prices of medium-quality rice and premium-quality rice. In the long term, the price of MDG at the huller level is transmitted asymmetrically to the premium-quality rice at the consumer level. A positive asymmetric price transmission is found along the rice supply chain, indicating an increase in price in the upstream market has transmitted faster to the downstream markets than the price decreases.*

Originality / scientific novelty. *Unlike previous studies that analyzed only price integration in the rice market and the direction of price transmission separately, this study empirically investigates both price integration, price transmission, and the direction and magnitude of asymmetric price transmission in the Indonesian rice market. Specifically, this study explores the existence of price integration from upstream to downstream markets and the existence of asymmetric price transmission, as well as measures the magnitude and direction of asymmetric price transmission in the rice market in Indonesia. The findings of the study enrich the existing literature and contribute insights into enhancing rice price policy from the perspective of Indonesia, the fourth largest populous country in the world.*

Practical value / implications. *These findings show the importance for the local government to maintain symmetrical market conditions to ensure efficient rice markets in the long term. Rice traders that control the premium-quality rice market by reprocessing medium-quality rice into premium-quality rice should be closely monitored. An inefficient rice market has caused consumers to spend a large proportion of their income on rice, leaving only a little to afford other needs.*

Key words: *rice market integration, asymmetric price transmission, ECM, Indonesia.*

Introduction and review of literature. Agricultural economists have long been concerned with the types of price transmission, symmetrical or asymmetrical, in agricultural commodity markets. In this context, price transmission refers to the effects of a price change in the upstream market that is transmitted to the prices in the downstream markets in the agricultural sector. To date, there is still no consensus among the studies on the nature of price transmission of agricultural products (Kamaruddin et al., 2021a; Kamaruddin et al., 2021b), which consequently generates a debate. However, there have been several studies on agricultural economics that successfully identified the symmetric price and asymmetric price transmission in the vertical marketing chain from the upstream to the downstream markets of agricultural products (Meyer & von Cramon-Taubadel, 2004; Santeramo & von Cramon-Taubadel, 2016).

Some previous researchers, such as Goodwin & Harper (2000), Goodwin & Piggott (2001), Makbul & Ratnaningtyas (2017), Sitepu et al. (2018), Mai et al. (2018), Bahmani-Oskooee et al. (2018), Elalaoui (2019), and Makbul (2019) have found a symmetric price transmission in the agricultural commodity market. Meanwhile, some other researchers have found an asymmetric price transmission in agricultural products from upstream to downstream markets (Acharya et al., 2011; Zewdie, 2017; Tsiboe et al., 2016; Rezitis & Tsionas, 2019; Jaramillo-Villanueva & Palacios-Orozco, 2019; Chaudhary et al., 2019; Darbandi, 2018; Bakucs et al., 2019; Deb et al., 2020; Lekešová & Blažková, 2022). These mixed findings show the disagreement of previous researchers on market structure-price adjustment relationship patterns along the marketing chain in the agricultural market.

With the presence of symmetric (asymmetric) price transmission, the market structure of agricultural products can be categorized into an imperfect market (a perfect market). Thus, asymmetric price transmission is often viewed as evidence of market failure. A marketing chain is said to be efficient and vertically integrated if price changes in one marketing agency will be proportionally transformed into other marketing institutions. According to Deb et al. (2020), vertical integration in the grain market plays an important role in improving a country's food security and, consequently, affecting the welfare of poor people (consumers). The degree and nature of price integration also determine the level of intervention required by the government to correct market inefficiency (Kim & Seok, 2022). Therefore, the higher the market is integrated, the less intervention to correct the market is required by the government.

According to Meyer & von Cramon-Taubadel (2004), price transmission is said to be asymmetric if there is a difference in price response between the time of a price increase (a positive price shock) and a price decline (a negative price shock) in terms of speed of time (price shocks in one market are not immediately transmitted by other markets) and the magnitude of price adjustments (price shocks in one market are not fully transmitted by other markets). The integration of prices that follow the law of one price has also been adopted by several studies to assess price transmission (Makbul, 2019; Ohen & Abang, 2011). For this purpose, previous studies have adopted an Error Correction Model (ECM) as it allows them to find evidence of price integration and the existence of a long-term relationship in the market (Asche et al., 2007; Ahn & Lee, 2015).

Previous studies on price transmission in the agricultural market that documented mixed findings of symmetric and asymmetric price transmissions have provided more motivation for this study to empirically re-assess the type of price transmission for the case of the rice market in Aceh province, Indonesia. Unlike previous studies that analyzed only price integration in the rice market, the speed of adjustment, and the direction of price transmission separately, this study intends to fill the gaps in the previous literature by empirically investigating price integration, price transmission, the speed of adjustment, and the direction of asymmetric price transmission in the rice market of Aceh, Indonesia. Specifically, this study explores the existence of price integration and price transmission from upstream to downstream markets and the existence of asymmetric price transmission as well as measures the magnitude and direction of asymmetric price transmission in the rice market of Aceh, Indonesia. Different natures and characteristics of the rice market of Indonesia to other world rice markets might contribute to different empirical evidence that needs further investigation.

Indonesia is the fourth most populous country in the world, with a total population of around 260 million in 2021 (BPS – Statistics Indonesia, 2022). Indonesia is one of the largest per capita rice consumption worldwide. In 2021, Indonesia recorded about 150 kilograms of rice consumption per capita. Even though Indonesia is the third largest country that produces the most rice in the world, the country still imports rice almost every year (although usually only for maintaining the level of rice reserves). Traditional agricultural techniques combined with high per capita consumption of rice have worsened rice production in the country. Rice production in Indonesia is dominated by small farmers, while the large private and state-owned companies have contributed only a small portion. Small farmers contribute about 90 % of the total rice production in Indonesia, while only the rest 10 % is contributed by the large private farming companies in the country. Each farmer owns an average paddy land of fewer than 0.8 hectares (Business Directory of the Indonesian Investment, 2022).

On average, per capita, rice consumption in Indonesia was very high. It is reported that poor people spend 70 % of their income on rice (Zeigler, 2005). A 10 % increase in rice prices in Indonesia has caused an increase in the poverty rate by 4 %, whereas a 30 % increase has exacerbated the poverty rate to increase by 14 % (Peiffer, 2013). Warr & Yusuf (2014) and McCulloch (2008) documented that an increase in rice prices has led to an increase in poverty rates in urban and rural areas, especially among small-scale rice farmers. As one of the 34 provinces in Indonesia, Aceh is ranked as the sixth poorest province nationwide and has the highest percentage of poor people (15.5 %) out of 10 provinces on the similar Island of Sumatra as of September 2021 (BPS – Statistics Indonesia, 2022). An increase in per capita rice consumption in the province would be detrimental to the government policy aimed at further eradication of poverty. Thus, investigating the rice marketing chain from the downstream to the upstream markets, especially in Aceh Province, Indonesia becomes more important because a change in rice price has a great impact on the people's welfare who regards rice as an irreplaceable staple food. A long-term increase in rice prices would consequently worsen the poverty level since the income of the poor would mostly be spent on rice.

Geographically, the majority of Aceh people are living in rural areas and work as farmers. They cultivate rice fields once or twice a year with a small land area of less than one hectare. During the rice harvest season, they become rice producers, while during the rice planting and dry seasons, they become rice consumers who buy rice from traders in the market. A high degree of dependence of rural communities on rice consumption was evident in 2020, in which their spending on rice reached 21.1 % of the total spending on food of 77.3 % (BPS – Statistics Indonesia, 2022). They expect the rice price to remain stable and the rice markets to remain efficient, showing the symmetrical condition of rice price transmission from the upstream to the downstream markets.

The rice supply chain in Aceh Province, Indonesia begins with farmers to intermediary traders (rice collectors). The dry harvested rice (Milled Dry Grain – MDG) is sold to the rice mill owners to go through the de-husking process. After the rice is free of husks, it is sold to intermediary traders who then sell it to consumers. Most of the rice mill owners in the province play dual roles either as intermediary traders or wholesalers who sell rice to consumers. Rice milling units produce rice with two different qualities, namely medium and premium. Premium rice quality has a maximum broken rate of 15.0 %, whereas medium rice quality has a broken rate between 15.0 % to 25.0 % (BPS – Statistics Indonesia, 2022).

Against the above research backdrop, the present study addresses the following issues in the case of the rice market in Aceh Province, Indonesia:

1. Is there price integration along the rice market supply chain?
2. What kinds of price transmission exist in the rice market supply chain: symmetric or asymmetric?
3. If there was an asymmetric price transmission in the rice market, how long would it take to return to the state of equilibrium?
4. What is the direction of asymmetric price transmission: positive or negative?

The purpose of the article. To explore the above-mentioned research questions, this study aims to empirically measure and analyze the long-run relationship and asymmetric price transmission of the rice market in Aceh Province, Indonesia. It also attempts to empirically examine the existence of the vertical price trends along the rice distribution channels both in the short term and long term.

It is expected that the results of this study will shed light on relevant government agencies in designing a proper rice policy to maintain the efficiency of the rice market by ensuring symmetrical price transmission both in the short term and in the long term. It is also expected that the results of the study will be used as a policy guide by local governments in order to regulate the rice market so that it is efficient and control market power so as not to be monopolized by a group of traders, ensuring the transmission of rice prices from upstream to downstream markets remain symmetrical. Additionally, our findings are hoped to enrich the existing empirical evidence on rice price transmission from the perspective of the largest developing market in Indonesia.

Material and methods. The study utilizes the secondary data gathered from the publications of a government agency, namely the Central Bureau of Statistics of the Republic of Indonesia (BPS – Statistics Indonesia). The data comprised the prices of dry harvested rice (Milled Dry Grain) at the farm level, the prices of MDG at the huller level, and the retail prices of medium-quality rice and premium-quality rice in Aceh Province, Indonesia. The data on the market price of different types of rice are measured in the form of the local currency of the Indonesian Rupiah (IDR) per kilogram (IDR/kg). The monthly data from January 2009 to December 2019 were used.

The analysis of unidirectional vertical price transmission was examined in the study by assessing the changes and price transmission in the downstream market (i.e., retail prices of rice at the consumer level) caused by the price shocks in the upstream market (i.e., the prices at the farm level and huller level). In other words, price transmission was analyzed from upstream to downstream markets, considering the trade characteristics of rice as a seasonal staple food. Rice price is mostly determined by the supply (producers) rather than by the demand (consumers). Price transmission is said to be asymmetric when a certain level in the rice marketing channel gives a different response to the price shocks (price increase or decrease) in another level. In this study, the asymmetric vertical price transmission approach was applied, focusing on the price trends of medium-quality rice and premium-quality rice at the consumer level, and the price trends of MDG at the farm level and the huller level.

Econometric model. To analyze the integration and asymmetric price transmission in the rice markets of Aceh Province, Indonesia, the study adopts the Meyer & von Cramon-Taubadel (2004) approach to the transmission of output prices and input prices assuming that price adjustment is linear and symmetrical. This study also follows the Frey & Manera (2007) technique by introducing a dummy variable in the analysis to divide the price into two, namely an increasing input price and a decreasing input price decreases.

The Error Correction Model was applied in the analysis. All data representing the price changes occurring between the t and t-1 period were required to determine the stationary data. The analytical model used in the study consists of several steps. The first step is a visual analysis of the prices to determine price fluctuations. The second step involves the analysis of stationary data. When the results display stationary data, the cointegration analysis to assess the long-term relationship of the variables is performed in the third step. Each significant long-term relationship found is then analyzed using the ECM to determine its effects on the MDG prices and rice prices both in the short term and long term. Briefly, the data analysis is conducted using the following steps.

Firstly, the stationarity test. The data series stationarity test or unit root test is carried out to determine whether the time series data used is stationary or not. The tests are carried out to ensure the consistency of the movement of time series data and to prevent spurious regression. In this study, the stationarity test was performed using the Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests. The following equations are used to estimate the respective tests:

$$\Delta P_t = c + \alpha P_{t-1} + \beta_t + \sum_{j=1}^{t} d_j \,\Delta P_{t-j} + e_t, \quad (1)$$

$$\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + e_t, \quad (2)$$

$$\Delta P_t = rt + \beta t + e_t, \quad (3)$$

where P is the price series;
P_t is the current price;
P_{t-1} is the previous price;
Δ is the first difference of price ($P_t - P_{t-1}$);
c, α and rt are the constant term;
e is the notation for error terms.

For the ADF (Equation 1) and the PP (Equation 2) tests, the null hypothesis of a non-stationarity of data is tested against the alternate hypothesis of stationary data. Meanwhile, for the KPSS (Equation 3), the null hypothesis of data stationarity is tested against the alternate hypothesis of data non-stationarity.

Secondly, the cointegration test. The movements of data between two or more variables are said to be cointegrated if the data move together in the long term, although in the short term, the movement seems distant (Enders, 2015). In this study, the cointegration test uses the Johansen-Juselius (1990) technique, namely by comparing the value of the trace statistic to the value of the t-statistic at the 5 % level. Based on the Johansen-Juselius (1990) method, the cointegration test begins with the traditional Vector Autoregressive (VAR) model to determine the optimal amount of lag based on the Akaike Information Criteria (AIC). The optimal lag is then used to estimate Vector Error Correction Model (VECM) and determine the rank and matrix parameter. The cointegration equation for the VECM model is estimated using the following equation:

$$\Delta P_t = \Pi P_{t-1} + \Gamma_1 \Delta P_{t-1} + \ldots + \Gamma_{k-1} \Delta P_{t-k} + \varepsilon_t, \quad (4)$$

where $P_t = (P_{1t} - P_{2t})$ is the price variable of integrated one;
$I(1)$, ε_t is the error terms;
Γi is the short-term dynamics and price data.

The matrix Π shows the information on the cointegration relationship between the non-stationary P_t variable. Based on the Johansen-Juselius (1990) method, the VECM is estimated using the maximum likelihood λ_{max} (r), which is a function and rank of cointegration r. To test the existence of a long-term relationship, the study performs two different tests, namely the trace (λ_{trace}) and the maximum Eigen-value (λ_{max}). If the value of Trace Statistics (TS) and Maximal Eigen Value (ME) exceeds the value of t-statistics, the null hypothesis is rejected, indicating the existence of a long-term relationship between the analyzed variables. The TS and ME tests are estimated using the following equation:

$$\lambda_{trace} = -T\ln(1-\lambda^2_i), \quad (5)$$

$$\lambda_{max} = -T\ln(1-\lambda_{r+1}), \quad (6)$$

where T is the number of observations;

i is the characteristic value of the unit root.

The null hypothesis used in the TS test is the rank is less than or equal to r against the alternate hypothesis being the rank is more than or equal to r. Meanwhile, the null hypothesis being tested in the ME is the rank (r) against the alternate hypothesis of the rank ($r + 1$).

Thirdly, the causality test. This test is performed to identify the direction of price transmission in the agricultural commodity markets. In the case of vertical price transmission, the price shocks caused by changes in supply (price transmission from upstream to downstream markets) would have a different effect on price transmission from shocks due to changes in demand (consumers). In this study, the Granger causality test is adopted.

Finally, the estimation of the Error Correction Model. The ECM has been identified as a valid estimation model for measuring price transmission. For example, the ECM used by Mayer and von Cramon-Taubadel (2004) in the analysis of price transmission was valid by Hassouneh et al. (2015) when comparing several econometric models in the analysis of price transmission since the model takes into account the presence of unit roots and cointegration in time-series data. The ECM is a valid model to identify price transmission patterns under non-stationary but cointegrated data conditions (Deb et al., 2020).

In this study, the price asymmetric analysis is conducted to investigate if the price from the producers or wholesalers was transmitted properly to consumers. The ECM model that separates the prices into two categories (short-term and long-term) was employed in the study. In this model, the asymmetric condition is not only tested for positive and negative shocks on the independent variables, but it is also tested on the coefficients of positive or negative Error Correction Terms (ECT). The ECT is used to measure the deviation from the long-term equilibrium between the prices. The use of the ECT allows the estimated price to respond to price changes and correct deviations from the long-term balance.

A short-term relationship was analyzed through each independent variable. Significant variables affecting the price in the upstream market can be identified by looking at the probability value. Different coefficient values of the variables indicate different responses to a price shock (i.e., an increasing price or a decreasing price). The more identical the variables' coefficient values, the more similar the responses given to price shocks, indicating the presence of symmetrical price transmission in the two markets. However, to confirm this price asymmetry, the Wald test is further performed. Meanwhile, a long-term relationship was analyzed using the ECT of each market. Positive ECT refers to a condition where the price is above the equilibrium level. This means that a price decline in the upstream market does not lead to a price decline in the downstream market. In contrast, the negative ECT is a condition where the price is below the equilibrium level. This suggests that an increased price in the upstream market does not raise the prices in the downstream market. The coefficient value of the ECT shows the time required by the downstream market to adjust the price (increase or decrease) as a result of the price increase in the upstream market to reach the equilibrium state. The adjustment time can be identified by multiplying the ECT coefficient by the number of months in a year (since our study uses monthly data).

The identification of asymmetric transmission of rice prices for the cases of the price of medium-quality rice and the price of premium-quality rice at the farm and huller levels are estimated using the following ECM equations:

• The price of medium-quality rice is influenced by the price of MDG at the farm level:

$$\Delta HMK_t = \alpha_0 + \sum_{i=1}^{n} \beta^+ \Delta HMK_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HMK_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HP_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HP_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HP_t^+ + \sum_{i=1}^{n} \beta^- \Delta HP_t^- + ect_{t-1}^- + ect_{t-1}^+ + e_t; \quad (7)$$

• The price of medium-quality rice is influenced by the price of MDG at the huller level:

$$\Delta HMK_t = \alpha_0 + \sum_{i=1}^{n} \beta^+ \Delta HMK_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HMK_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HH_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HH_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HH_t^+ + \sum_{i=1}^{n} \beta^- \Delta HH_t^- + ect_{t-1}^- + ect_{t-1}^+ + e_t; \quad (8)$$

• The price of premium-quality rice is influenced by the price of MDG at the farm level:

$$\Delta HPK_t = \alpha_0 + \sum_{i=1}^{n} \beta^+ \Delta HPK_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HPK_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HP_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HP_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HP_t^+ + \sum_{i=1}^{n} \beta^- \Delta HP_t^- + ect_{t-1}^- + ect_{t-1}^+ + e_t; \quad (9)$$

• The price of premium-quality rice is influenced by the price of MDG at the huller level:

$$\Delta HPK_t = \alpha_0 + \sum_{i=1}^{n} \beta^+ \Delta HPK_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HPK_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HH_{t-1}^+ + \sum_{i=1}^{n} \beta^- \Delta HH_{t-1}^- + \sum_{i=1}^{n} \beta^+ \Delta HH_t^+ + \sum_{i=1}^{n} \beta^- \Delta HH_t^- + ect_{t-1}^- + ect_{t-1}^+ + e_t, \quad (10)$$

where HMK_t is the price of medium-quality rice at the consumer level in the t period;

HPK_t is the price of premium-quality rice at the consumer level in the *t* period;

HMK_{t-1} is the price of medium-quality rice at the consumer level in the previous period;

HPK_{t-1} is the price of premium-quality rice at the consumer level in the previous period;

HP_t is the price of grain at the farm level in the *t* period;

HH_t is the price of grain at the huller level in the *t* period;

α_0 is the intercept;

β is the lag length coefficient;

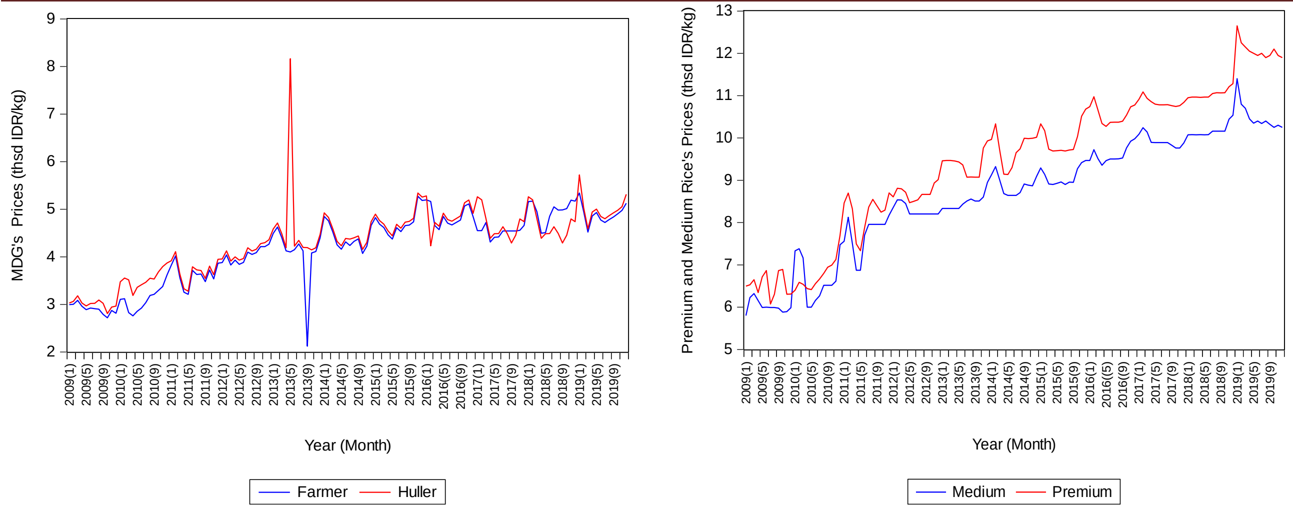
ect is the error correction term, and e_t is error term in the *t* period.

To identify the presence of a price transmission that runs asymmetrically through the coefficient identity test, the study uses the Wald test. In this case, the hypothesis testing is carried out using the F-test, with the following hypotheses: $H0: \sum_{i=1}^{n}\beta^{-} = \sum_{i=1}^{n}\beta^{\mp}$ (symmetrical in the short term) against the $H1: \sum_{i=1}^{n}\beta^{-} \neq \sum_{i=1}^{n}\beta^{\mp}$ and $H0: ect_1 = ect_2$ (symmetrical in the long run) against the $H1: ect_1 \neq ect_2$.

Results and discussion. Marketing performance plays a central role in the development of agricultural commodities in Indonesia. The pattern of marketing of grain across 34 provinces in Indonesia varies, with the various numbers of agents that make up the length of the marketing chain. In Aceh province, Indonesia, rice typically passes several points in the rice marketing channel before it reaches consumers. This leads to high prices of rice that are not enjoyed by farmers. The channel begins with farmers who sell their MDG to collectors across the villages. Then, the collectors trade it to the village rice millers. After the MDG is de-husked, it is sold to large-scale wholesalers who own warehouses of the rice. Next, the large-scale wholesalers sell it to small-scale wholesalers. Retailers buy the rice from small-scale wholesalers and, then, sell it to the end consumers. The owners of rice mills generally serve as wholesalers and middlemen at the same time who sell rice to consumers.

Figure 1(a) shows the comparison of MDG prices at the farm level and the huller level in Aceh Province from 2009 to 2019. The two had nearly the same price fluctuation. However, a difference appeared from the 50th month to the 60th month, in which the prices of MDG at the huller level decreased significantly, followed by a considerable price decline at the farm level. However, in the following months, the price moved to a similar level. At the time, the very sharp difference between the price of grain at the huller and the price at the farm level occurred during the harvest season, where the price of grain at the farm level was on average 2,123.14 IDR/kg, which was much lower than the average price of grain in the huller level, 4,194.57 IDR/kg. Generally, farmers sell all or part of the paddy at harvest for financing farming and their daily needs. They usually buy rice during the rice growing season from September to December annually.

During the harvest period, the government usually intervened in the agricultural market to ensure the stability of the purchase price of grain at the farmer level.



(a) (b)

Figure 1. The prices of MDG at the farm level and the huller level (a) and the prices of medium-quality rice and premium-quality rice at the consumer level (b)

Source: secondary data, processed (2022) using the E-Views statistical software.

However, prices at the huller level are left to follow the market mechanism. Based on an interview with the Association of Rice Milling Entrepreneurs (*Persatuan Pengusaha Penggilingan Padi dan Beras Indonesia* – PERPADI) of Aceh Province, a lot of paddies produced in the province were sold to outside province, dominantly to the nearest neighbouring Province of North Sumatera. This phenomenon has caused the huller to experience the problem of lacking paddy supply to be processed and resold to consumers in the form of rice.

Meanwhile, Figure 1(b) shows that the price of premium-quality rice was generally higher than the price of medium-quality rice. This is reasonable due to the higher quality of the premium-quality rice. Overall, they have similar fluctuation trends. However, in the 15th month, a noticeable difference appeared, in which the price of premium-quality rice dropped below the price of medium-quality rice. In the following months, the price of premium-quality rice became normal or stable, which was above the price of medium-quality rice.

Stationarity tests were performed on time-series data of price at the farm level, huller level, and consumer level to ensure the suitability of data for analyzing the price asymmetry of the rice commodity markets. Table 1 provides the findings of data stationarity using the Augmented Dickey-Fuller (ADF), Phillips-Peron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests.

As observed from Table 1, based on the ADF test at the level, except for the MDG price at the huller that is found to be stationary, all other variables of the price of MDG at the farm level, the price of medium-quality rice, and the price of premium-quality rice at the consumer level are found to be non-stationary. However, all data were stationarity at the first difference using the ADF test. The study also conducted the PP and KPSS tests to ensure the stationarity of the data. Based on these tests, all data were found to be non-stationarity at the level and all of them become stationarity at the first difference.

Table 1

Data stationarity test results

Price	Level			First difference		
	ADF test	PP test	KPSS test	ADF test	PP tests	KPSS test
MDG at the farm level	-2.109 (0.242)	-2.186 (0.212)	65.286*** (0.001)	-14.622*** (0.000)	-42.206*** (0.001)	0.593 (0.554)
MDG at the huller level	-3.071** (0.031)	-1.334 (0.613)	66.178*** (0.000)	-10.117*** (0.000)	-13.661*** (0.000)	1.556 (0.123)
Medium-quality rice	-1.603 (0.478)	-2.055 (0.263)	71.441*** (0.000)	-10.568*** (0.000)	-15.388*** (0.000)	1.502 (0.135)
Premium-quality rice	-1.289 (0.634)	-0.961 (0.766)	63.798*** (0.000)	-8.282*** (0.000)	-14.442*** (0.000)	1.650 (0.113)

Note. ***P<0.01, 1%, and ***P<0.05. Figures in parentheses (.) are the p-values.

Source: secondary data, processed (2022) using the E-Views statistical software.

Since the Phillips-Perron (PP) test has greater power and corrects for any serial correlation and heteroscedasticity in the error terms contains in the ADF test (Arltová & Fedorová, 2016), thus, the findings from the PP test are viewed as more robust and superior to the findings from the ADF test. Similarly, the KPSS is known to be among the most powerful tests for data stationarity with time trends (Genc et al., 2011). Anticipating our data to have time trends, thus KPSS results are more reliable in examining the presence of a unit root in the data. Given that ADF tests suffer from low power in distinguishing between the null hypothesis and alternative hypothesis with a trend in data and the superiority of the ADF and KPSS test, we safely conclude that our data were stationary at the first difference, *I*(1). Thus, these findings fulfil the necessary condition for further testing the cointegrating relationship among the variables.

In the next step, the study performed the cointegration test using the Johansen-Juselius (1990) technique and its findings are reported in Table 2. As observed from Table 2, it is found that the trace statistics and max-Eigen value at a cointegrating vector of 1 were greater than the critical values with a significance level of 5 %, indicating the rejection of the null hypothesis. The results revealed that there was a significant long-term relationship among the variables, with no deterministic trend and a lag length of one. These findings demonstrated that rice markets from the upstream to the downstream levels in Aceh Province were integrated. Thus, the changes in prices in the upstream market affected the prices at the downstream market (consumer level).

The findings of cointegration among the variables fulfil a sufficient condition for the study to estimate the long-run relationship and asymmetric price transmission using the VECM analysis. However, before estimating the VECM, the study conducted first the Granger causality between the variables.

The results of the causality test are presented in Table 3. The majority of the rice production in Aceh Province depends on the rainy season and its price is dominantly determined by the supply side (producers) rather than by its demand side (consumers).

Table 2

Johansen cointegration test results

Price variables	Null hypothesis	Trace statistics	Critical value (5%)	Max-Eigen value	Critical value (5%)
Medium-quality rice					
MDG at the farmer level → Rice at the consumer level	None** At most 1	24.700 0.884	12.321 4.130	23.816 0.884	11.225 4.130
MDG at the huller Level → Rice at the consumer level	None** At most 1	27.243 0.866	12.321 4.130	26.377 0.866	11.225 4.130
Premium-quality rice					
MDG at the farmer level → Rice at the consumer level	None** At most 1	23.372 1.537	12.321 4.130	21.835 1.537	11.225 4.130
MDG at the huller Level → Rice at the consumer level	None** At most 1	24.678 1.512	12.321 4.130	23.166 1.512	11.225 4.130

Note. **$P<0.05$.
Source: secondary data, processed (2022) using the E-Views statistical software.

The latter suggests that rice prices move from the upstream to the downstream level. This is proven by the estimation result of the Granger causality test at a significant level of 5 %, as shown in Table 3. In other words, price changes in the upstream market lead to price changes in the downstream market (consumer level).

Table 3

Granger causality of the rice marketing channel

Relationship	Lag-Length	t-stat.	Prob.
MDG at the farm level → Rice at the consumer level (Medium quality)***	1	17.949	0.000
MDG at the huller level → Rice at the consumer level (Medium quality)***	1	38.394	0.000
MDG at the farm level → Rice at the consumer level (Premium quality)***	1	22.502	0.000
MDG at the huller level → Rice at the consumer level (Premium quality)***	1	42.414	0.000

Note. ***$P<0.01$.
Source: secondary data, processed (2022) using the E-Views statistical software.

Furthermore, Table 3 shows that the prices of MDG at the farm level and the huller level significantly affected the prices of medium-quality rice and premium-quality rice at the consumer level in Aceh. This causality test provides certainty that the price of rice in the downstream market, both medium-quality rice and premium-quality rice were influenced by the price of rice in the upstream market. In Aceh Province, the growth of rice production has been more volatile than the growth of rice consumption. Rice production depends on the season as it is planted in paddy fields that require a lot of water. In the dry season, irrigation is not able to meet the water needs for rice to grow. These results are supported by previous studies, such as Alam et al. (2016) and Deb et al. (2020) who found that the price of rice is mainly driven by supply-side movements rather than demand-side changes.

Next, the study tested the price asymmetry model to determine whether price transmission occurred symmetrically or asymmetrically along the grain market at the farmer level, at the huller (who is a wholesaler), and at the retail market at the consumer level. This model separated between positive shocks and negative shocks of price transmission in the short-term and long-term. A positive shock is a condition in which the price of the independent variable increases, whereas a negative shock indicates that the price of the independent variable decreases. The ECT coefficient primarily describes the price condition at a certain market level that does not match the equilibrium condition (Makbul, 2019). Price reaches the equilibrium state if its increase at the producer level is followed by an increase at the wholesale level. A price drop at the producer level is usually followed by a price decrease at the wholesale level. The findings of asymmetrical price transmission estimations are reported in Table 4.

The first column of Table 4 illustrates the results of the transmission of the MDG price at the farm level to the medium-quality rice at the consumer level in Aceh Province, Indonesia. The study found that, in the short term, the price of medium-quality rice at the consumer level is determined by the increase in the MDG price at the farm level in the current period and the previous period. In the long term, both ECT+ and ECT- showed significant values with coefficients of -0.139 and -0.142, respectively. Based on the estimated value of ECT+, it showed that the time required by the downstream market to decline in the price of medium-quality rice as a response to the decline in MDG price at the farm level took 51 days or about 1.7 months to restore to the equilibrium condition. Meanwhile, based on the estimated value of the ECT-, an increase in the price of medium-quality rice took 52 days or about 1.7 months to respond to the increase in MDG price at the farm level. These two conditions suggest that the price of medium-quality rice is adjusted within a nearly similar time period to respond to price shocks of MDG at the farm level.

Table 4 of the second column reports the results of the transmission of MDG price at the huller level to the price of medium-quality rice at the consumer level. In the short term, the price of medium-quality rice at the consumer level is influenced by an increase in the MDG price at the huller level in the current period and the price of medium-quality rice in the previous period. In the long term, both ECT+ and ECT- showed significant values with coefficients of -0.127 and -0.134, respectively. The estimated ECT+ coefficient indicated that the time for the price of medium-quality rice to be adjusted to respond to the decline in the MDG price at the huller level was 46 days or about 1.5 months. Meanwhile, from the estimated value of ECT-, we can identify that it took 49 days or about 1.6 months for the price of medium-quality rice to be adjusted to its equilibrium condition as a result of an increase in the MDG price at the huller level. Both conditions indicate a similar amount of time needed to adjust the price of medium-quality rice to changes (increase or decrease) in the MDG prices at the huller level.

Table 4

Estimation results of the asymmetric price transmission model

Medium-quality rice				Premium-quality rice			
Farm level		Huller level		Farm level		Huller level	
Constant	113.847 (0.0127)	Constant	117.330 (0.011)	Constant	26.331 (0.604)	Constant	39.983 (0.441)
ΔHMK^{+}_{t-1}	-0.101 (0.357)	ΔHMK^{+}_{t-1}	-0.110 (0.380)	ΔHPK^{+}_{t-1}	-0.036 (0.759)	ΔHPK^{+}_{t-1}	0.028 (0.823)
ΔHMK^{-}_{t-1}	0.164 (0.247)	ΔHMK^{-}_{t-1}	0.354 (0.018)**	ΔHPK^{-}_{t-1}	0.166 (0.278)	ΔHPK^{-}_{t-1}	0.251 (0.102)
ΔHP^{+}	0.760 (0.000)***	ΔHH^{+}	0.121 (0.036)**	ΔHP^{+}	0.558 (0.000)***	ΔHH^{+}	0.112 (0.065)*
ΔHP^{-}	0.150 (0.132)	ΔHH^{-}	0.361 (0.003)***	ΔHP^{-}	0.171 (0.118)	ΔHH^{-}	0.344 (0.005)***
ΔHP^{+}_{t-1}	-0.007 (0.946)	ΔHH^{+}_{t-1}	0.131 (0.311)	ΔHP^{+}_{t-1}	0.253 (0.020)**	ΔHH^{+}_{t-1}	0.006 (0.961)
ΔHP^{-}_{t-1}	0.438 (0.004)***	ΔHH^{-}_{t-1}	0.019 (0.749)	ΔHP^{-}_{t-1}	0.237 (0.145)	ΔHH^{-}_{t-1}	0.112 (0.068)*
ECT^{+}	-0.139 (0.004)***	ECT^{+}	-0.127 (0.010)**	ECT^{+}	-0.134 (0.003)***	ECT^{+}	-0.148 (0.001)***
ECT^{-}	-0.142 (0.004)***	ECT^{-}	-0.134 (0.011)**	ECT^{-}	-0.137 (0.003)***	ECT^{-}	-0.157 (0.001)***
R-Adj	0.325	R-Adj	0.190	R-Adj	0.264	R-Adj	0.205
F-stat.	7.280 (0.000)***	F-stat.	3.556 (0.001) ***	F-stat.	5.411 (0.000) ***	F-stat.	3.889 (0.000)***

Notes. HP is the price of rice at the farm level; HMK is the price of medium-quality rice at the retail / consumer level; HH is the price of rice at the huller level; HPK is the price of premium-quality rice at the retail/consumer level, ECT is error correction term. ***P<0.01, **P<0.05, 1%, and *P<0.10.

Source: secondary data, processed (2022) using the E-Views statistical software.

Moreover, Table 4 of the third column provides the results of MDG price transmission at the farm level to the price of premium-quality rice at the consumer level. In the short term, the price of premium-rice quality at the consumer level is influenced by the increase in MDG price at the farmer level in the current period and previous period. In the long term, both ECT+ and ECT- showed significant values with coefficients of -0.134 and -0.137, respectively. The estimated value of the ECT+ coefficient showed the time required to adjust the price of premium-quality rice based on the decline in the MDG price at the farm level was 49 days or about 1.6 months. Meanwhile, the estimated value of ECT- showed that the time needed to increase the price of premium-quality rice due to an increase in the MDG price at the farm level was 50 days or about 1.7 months. These two conditions indicate that the adjustment time of the premium-quality rice price to respond to the decrease or increase in the MDG price at the farm level is almost similar.

Finally, the last column of Table 4 reports the results of the transmission of the MDG price at the huller level to the price of premium-quality rice at the consumer level. In the short term, the premium-quality rice price is determined by the increase in the MDG price at the huller level in the current period and previous periods. In the long term, both ECT+ and ECT- showed significant values with coefficients of -0.148 and -0.157, respectively. The estimated ECT+ coefficient showed that the time required to adjust the premium-quality rice price in response to the decline in the MDG price at the huller level was 54 days or about 1.8 months. Meanwhile, from the estimated value of the ECT- coefficient, the time needed to increase the price of premium-quality rice to respond to an increase in the MDG price at the huller level was 57 days or about 1.9 months. These conditions suggest that the prices of premium-quality rice are adjusted almost within a similar time period in responding to the decrease or increase in the MDG price at the huller level.

After estimating the Granger causality between prices in the agricultural commodity market, the study proceeds to estimate the asymmetric price transmission in the market using the VECM estimation. The Wald test is conducted to identify the nature of price transmission (symmetric or asymmetric) in the rice market in Aceh Province, Indonesia. Asymmetric price transmission in the short term was analyzed by separating the positive and negative values of the variables. In contrast, the asymmetric price transmission analysis in the long term was conducted by separating the ECT variables into ECT+ and ECT-. The identical values of the two coefficients were then compared. The results of the Wald test on price transmission along the rice marketing chain of the agricultural market in the province are presented in Table 5.

Table 5

Wald test results

Rice market	Null hypothesis	F-stat.	Prob.	Null hypothesis	F-stat.	Prob.
	Medium-quality rice			Premium-quality rice		
Farm level	$\Delta HMK^{+}_{t-1} = \Delta HMK^{-}_{t-1}$	2.004	0.159	$\Delta HPK^{+}_{t-1} = \Delta HPK^{-}_{t-1}$	0.007	0.935
	$\Delta HP^{+} = \Delta HP^{-}$	10.392	0.002***	$\Delta HP^{+} = \Delta HP^{-}$	3.506	0.064*
	$\Delta HP^{+}_{t-1} = \Delta HP^{-}_{t-1}$	5.813	0.017**	$\Delta HP^{+}_{t-1} = \Delta HP^{-}_{t-1}$	0.923	0.339
	$ECT^{+} = ECT^{-}$	0.447	0.505	$ECT^{+} = ECT^{-}$	1.115	0.293
Huller level	$\Delta HMK^{+}_{t-1} = \Delta HMK^{-}_{t-1}$	5.132	0.025**	$\Delta HPK^{+}_{t-1} = \Delta HPK^{-}_{t-1}$	1.038	0.310
	$\Delta HH^{+} = \Delta HH^{-}$	3.106	0.081*	$\Delta HH^{+} = \Delta HH^{-}$	2.878	0.092*
	$\Delta HH^{+}_{t-1} = \Delta HH^{-}_{t-1}$	0.583	0.447	$\Delta HH^{+}_{t-1} = \Delta HH^{-}_{t-1}$	0.526	0.470
	$ECT^{+} = ECT^{-}$	2.040	0.156	$ECT^{+} = ECT^{-}$	5.419	0.022**

Notes. ***P<0.01, **P<0.05, and *P<0.10.

Source: secondary data, processed (2022) using the E-Views statistical software.

As illustrated in Table 5, the results of the Wald test revealed that the MDG price at the farm level is asymmetrically transmitted to the price of medium-quality rice at the consumer level. Our findings showed the existence of an asymmetric relationship in the short term, while a symmetrical relationship existed in the long term. Besides, the prices of MDG at the huller level are transmitted to the price of the medium-quality rice, MDG at the farm level, and premium-quality rice at the consumer level, indicating the presence of the asymmetric relationship in the short term and the symmetrical relationship in the long term. The finding of the price transmission of MDG at the huller level to the premium-quality rice at the consumer level further suggested the presence of the asymmetric relationship between the two, both in the short and long term.

Our empirical findings provided evidence of the asymmetric transmission of grain prices to rice prices from upstream to downstream markets in Aceh Province, Indonesia in the short term both at the farm level and huller level for the cases of medium-quality rice and premium-quality rice. The asymmetric rice price transmission from upstream to downstream market in the short term would return to be symmetrical in the long term. Meanwhile, in the long term, the rice price asymmetric transmission only existed at the huller level for premium-quality rice. Overall, the study found a mixed finding of the price transmission for premium-quality rice and medium-quality rice at the farm level and huller level in the rice market in Aceh Province, Indonesia.

Our finding of symmetric price transmission in the rice market in Aceh Province, Indonesia are supported by several previous studies (Goodwin & Harper, 2000; Goodwin & Piggott, 2001; Makbul & Ratnaningtyas, 2017; Sitepu et al., 2018; Mai et al., 2018; Bahmani-Oskooee et al., 2018; Elalaoui, 2019; Makbul, 2019). On contrary, our empirical finding of the existence of asymmetric rice price transmission in the province is also in harmony with previous studies' findings (Acharya et al., 2011; Tsiboe et al., 2016; Rezitis & Tsionas, 2019; Jaramillo-Villanueva & Palacios-Orozco, 2019; Chaudhary et al., 2019; Darbandi, 2018; Bakucs et al., 2019; Deb et al., 2020; Lekešová & Blažková, 2022).

As for the premium quality rice market, the asymmetric price transmission both in the short-term and long-term occurred from the wholesalers – in this case, hullers – to the premium rice retail market at the consumer level. The asymmetric price transmission in the premium quality rice market was found to be positive, a condition in which a positive shock (price increase) responded faster as compared to a negative shock (price decline). These findings are in harmony with the Rocket and Feather pattern theory of Bacon (1991) documented by Peltzman (2000) where product prices rise faster than they fall. The findings of the different nature of asymmetric rice prices at the farm and huller levels for medium-quality rice and premium-quality rice in the short-term and long-term are viewed as new empirical evidence and the novelty of our study, specifically in the context of the agricultural commodity market in Indonesia. Overall, the findings of asymmetric rice price transmission are summarized in Table 6.

The finding of the existence of asymmetric price transmission in the rice market in Aceh Province, Indonesia is due to the monopsonistic nature of the market. A large number of farmers sold their crops to a few middlemen or hullers, thus the price determination is dominated by traders in the huller. Premium-quality rice that has been packed in the huller was sold at higher prices by traders. An increase in the price of un-hulled rice caused the price of premium-quality rice to rise faster compared to the situation of a decreasing price of grain at the huller level. Even though the government has set a floor price for farmers' grain, the huller could still control the price based on the grain quality they bought from farmers. Huller could also process farmers' grain becoming premium-quality rice. An increase in the price of premium rice caused losses to consumers, especially when the huller processed the medium-quality rice into the premium-quality rice.

Table 6

Summary of asymmetric price transmission analysis

Price asymmetry	Short-term		Long-term	
	Medium-quality rice	Premium-quality rice	Medium-quality rice	Premium-quality rice
Farm level	Yes	Yes	No	No
Huller level	Yes	Yes	No	Yes

Source: authors' own elaboration.

Policy implications. The existence of asymmetric rice price transmission has caused the marketing system of the rice market to become inefficient as it could harm both producers and consumers. Producers could not benefit from an increased price at the consumer level, while consumers could not also benefit from a decreasing price at the producer level (Deb et al., 2020). The inefficient rice market has led consumers to lose more of their income from buying rice. Additionally, the presence of asymmetric rice price transmission in Aceh Province, Indonesia confirmed the existence of practices of market power abuse (Meyer & von Cramon-Taubadel, 2004). Thus, our empirical findings provide important policy implications for the provincial government of Aceh to regulate the premium rice market to be free from monopolistic practices. The practices of traders to control the premium-quality rice market have also led to an increase in the price of medium-quality rice by reprocessing it into premium-quality rice (Arifin, 2020).

At the same time, the regional government of Aceh Province should monitor the price of rice in the agricultural commodity market. The government should set up a ceiling rice price for the traders who have control over the rice market. The price regulation on the rice market is important since all people in the province consume rice as their primary staple food, which has no substitution. If the price of rice is too high, Aceh as the poorest province on Sumatra Island would get poorer because most of the people's income is spent buying rice.

The finding of the asymmetric price of the premium rice market at the huller level both in the short-term and long-term shows the importance of government intervention by designing several policies that are beneficial to consumers, but it does not cause losses to traders. The government could continuously implement the floor price policy if the MDG price is too low-priced during the harvest season. The government might perform a market operation policy in the season of crop failure to ensure the stability of rice prices either in the short-term or in the long term. Local governments through the National Logistics Affairs Agency (*Badan Urusan Logistik* – BULOG) need to ensure sufficient food stocks for society by buying MDGs from farmers during the harvest season. Thus, it would help farmers from selling their rice production at a lower price. This provides more incentives for farmers to supply adequate rice stocks and ensures food security in the Aceh region.

Conclusions. This study empirically measured and analyzed the presence of price integration and asymmetric price transmission from the upstream to the downstream rice markets in Aceh Province, Indonesia over the period from January 2009 to December 2019. Using the Error Correction Model, the study found that, in a short term, the rice price at the consumer level is influenced by the rice prices at the farm and trader levels. Rice mill owners in this case also act as wholesalers. Meanwhile, the price of medium-quality rice at the consumer level is affected by the increase in the Milled Dry Grain price at the farm level in the current period and the previous period, the MDG price at the huller level in the current period, and the price of medium-quality rice in the previous period. The price of premium-quality rice is determined by the increase in the MDG price at the farm level and the wholesaler/huller level in the current period and previous periods.

Vertical price movement along the rice marketing channel in Aceh Province indicated that there has been asymmetric price transmission for premium-quality rice from the upstream to the downstream level in the short-term and long-term periods. The asymmetric price transmission found in the rice supply chain of Aceh Province, Indonesia showed a positive direction, indicating an increase in rice price at the upstream marketing level has affected the downstream level faster than when the price falls.

Our findings imply that the local government of Aceh Province, Indonesia is expected to continue monitoring rice prices in the region, especially the price of premium-quality rice with asymmetric price transmission that indicates an inefficient premium-quality rice market. A rising price at the huller level is immediately transmitted to the consumer level, whereas a falling price is not. Traders who control the premium-quality rice market can also increase the price of medium-quality rice by reprocessing it into the premium one. An inefficient rice market may force many consumers to spend a large proportion of their income on rice, leaving only a little to afford other needs. The asymmetry price transmission analysis carried out in this study is only focused on grain and rice price data.

This study only focuses its analysis on price integration and asymmetrical price transmission in the rice markets in Aceh, Indonesia. It does not specifically identify the causes of asymmetric price transmission that occurred from the huller to the price of premium-quality rice at the consumer level in the short- and long term. In order to provide more comprehensive findings on the topic, future studies might explore in-depth the causes of asymmetric price transmission in the rice markets across 34 provinces in Indonesia nationwide. Future studies could also explore the rice market structure and its effect on price asymmetric transmissions to enrich the existing empirical findings.

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