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Multi-objective lagrange quadratic programming for rice price stability in East Java

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Abstract

Purpose — This study optimizes consumer-level rice prices across districts and cities in East Java while balancing consumer affordability and producer interests.
Method — Using monthly retail price data for medium and premium rice from the National Food Agency for January–December 2024, the study applies a multi-objective Lagrange Quadratic Programming model. Regional production and price data are incorporated through weighted contributions, subject to applicable policy constraints.
Findings — The model effectively stabilizes medium rice prices, producing an optimal average price below the initial average while remaining within policy limits. Premium rice prices exhibit greater regional variation, although their average remains within the specified constraints. Low objective-function values indicate that the model can reduce regional price disparities and fluctuations.
Implications — The findings provide a pre-2025 baseline for identifying regional price disparities and supporting targeted monitoring and distribution interventions. Because the estimates reflect the 2024 production and policy environment, the optimized prices should not be interpreted as current price recommendations.
Originality — This study applies a multi-objective Lagrange Quadratic Programming approach to district- and city-level rice prices in East Java while jointly considering consumer and producer interests.
Keywords: Rice Prices, Lagrange Quadratic Programming, Food Security, East Java, Regional Price Disparities
JEL Classification: C61; Q11; Q13; Q18

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Introduction

In the context of Indonesia's food security, rice plays a crucial role, particularly in East Java, which is one of the country's main rice-producing regions. Instability in rice prices can significantly affect both farmers' welfare and consumers' purchasing power. Rice-price fluctuations can also contribute to regional inflation and affect household welfare (Kusmutiarani et al., 2018).

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This issue is even more pressing given that approximately 70% of Indonesians still rely on rice as their staple food (Ruspayandi et al., 2023). Several studies highlight that rice price stability is influenced by multiple factors, including market policies, production levels, and global dynamics (Siswanto et al., 2018). Indonesia maintained rice availability and price stability during the COVID-19 pandemic and the Russia–Ukraine War, although national rice reserves declined (Suryana et al., 2024). Against this background, this study employs a quantitative approach to analyze and optimize rice price stability in East Java.

As one of Indonesia's main rice-producing provinces, East Java plays a strategic role in national rice availability. Production capacity is also unevenly distributed across East Java, with districts and cities forming distinct high, medium, low, and very-low production clusters (Azari et al., 2024). The latest final figures show that East Java's harvested area increased from 1.62 million hectares in 2024 to 1.84 million hectares in 2025. Paddy production also increased from 9.27 million tons of milled dry grain in 2024 to 10.44 million tons in 2025. Meanwhile, rice production for food consumption increased from 5.35 million tons to 6.03 million tons, representing growth of 12.60 percent (Badan Pusat Statistik Provinsi Jawa Timur, 2026). At the national level, rice production for food consumption reached 34.69 million tons in 2025, an increase of 13.29 percent from 2024 (BPS, 2026).

The national rice-policy environment also changed substantially in 2025. In January 2025, the Government Purchase Price for harvested dry grain at the farmer level was set at IDR 6,500 per kilogram under National Food Agency Decision No. 14 of 2025 (BAPAN, 2025a). The government subsequently revised the Highest Retail Price for Zone 1, which includes East Java, to IDR 13,500 per kilogram for medium rice and IDR 14,900 per kilogram for premium rice, effective from 22 August 2025 (BAPAN, 2025b). The government also implemented the 2025 rice-field development programme to expand the national production base (Kementerian Pertanian,2025). At the beginning of 2026, the government officially announced that Indonesia had achieved rice self-sufficiency in 2025, supported by higher production and the absence of consumer-rice imports during that year (Sekretariat Kabinet Republik Indonesia, 2026). These post-study developments demonstrate why the 2024 results should be treated as a baseline rather than as current rice-price recommendations.

Increased rice production does not necessarily ensure stable retail prices or improve farmer welfare. Kharisma and Indrawan (2023) found asymmetric rice-price transmission between farmers and consumers in West Java in both the short and long run, partly reflecting intermediary market power and price-adjustment costs. This indicates that consumer rice prices depend not only on production conditions but also on how price changes are transmitted through the supply chain. These factors highlight the need for a pricing framework that balances consumer affordability with producer interests.

Previous research on Indonesian rice prices has primarily examined stabilization policies, price transmission, and differences between rice-quality segments. A separate strand of research has focused on rice-price forecasting. Fardhani et al. (2018) applied a Backpropagation model to retail rice prices in 33 Indonesian cities. Santoso et al. (2024) used Recurrent Neural Network and Long Short-Term Memory models to predict rice prices. Ruspayandi et al. (2022) used an Autoregressive Distributed Lag model to evaluate the determinants of consumer rice prices and the role of BULOG's market participation in price stabilization. Their findings demonstrate that market participation can complement government stabilization measures.

At the local level, Sasongko (2024)found that cheap-market operations in Bandung were ineffective because market rice prices remained above HET. Meanwhile, Utami, Harianto, and Krisnamurthi (2023) applied a multivariate Vector Error Correction Model to daily wholesale prices and found strong price interdependence among premium-, medium-, and low-quality rice. Changes in premium- and low-quality rice prices had substantial effects on medium-quality rice prices, whereas the reverse effects were weaker. These studies explain national price formation and transmission but do not estimate the price adjustments required to reduce retail-price disparities across districts and cities.

Other studies have examined the broader socioeconomic and supply-side consequences of rice-price policies. Other studies have examined the broader socioeconomic and supply-side dimensions of rice markets. Fachrurrazi et al. (2023) applied Fuzzy Time Series and linear regression to analyze rice stock availability. In East Java, Zamahzari and Puryantoro (2023) used an ARIMA model to forecast paddy production and rice consumption for 2022–2027. Their results projected declining paddy production and a gradual increase in rice consumption from 2023 onward.

Fitrawaty et al. (2023) simulated how changes in domestic production, international rice prices, exchange rates, and economic conditions affect domestic rice prices and income distribution. Zega and Hakim (2024) examined the relationship between rice self-sufficiency and farmer welfare using dynamic panel data. They found that rice self-sufficiency did not significantly improve farmers' terms of trade, partly because supply-chain inefficiencies limited the benefits received by farmers. In the East Java context Shobur et al. (2025)developed a system-dynamics framework for optimizing import volumes and improving communication among rice-supply-chain actors. Their study emphasizes the importance of coordination and information exchange but does not examine district-level retail-price adjustments.

Recent studies have also demonstrated the importance of spatial differences in Indonesian food markets. Theresia et al. (2025) used a Dynamic Conditional Correlation GARCH model to examine the transmission of producer-price volatility across Indonesian regions. Their results identified Java as an important transmitter of food-price volatility and supported the use of geographically differentiated stabilization policies. Persada, Subagyo, and Wibowo (2026) similarly found that the effects of rice-price policies differed between surplus–low-price and deficit–high-price provinces. The Government Purchase Price was associated with higher retail prices only in deficit provinces, while public rice stocks were associated with lower prices only in surplus provinces. These findings demonstrate that uniform price policies may produce different outcomes across regional market structures.

Taken together, previous studies have explained the roles of BULOG, price transmission, rice quality, supply-chain coordination, farmer welfare, and regional market heterogeneity. However, limited evidence translates district-level retail-price dispersion into a constrained optimization framework for medium- and premium-quality rice in East Java. This study addresses that gap by applying separate Lagrange Quadratic Programming models to estimate the contribution of each district and city to regional price stability. The models minimize regional retail-price dispersion while incorporating the consumer price ceiling and producer-price benchmark applicable during the 2024 study period. The contribution is therefore a district-level and optimization-based assessment of retail-price stability. Because farmer income, production costs, and farm profitability are not directly measured, the producer-price constraint should be interpreted as a policy safeguard rather than evidence that the model improves farmer welfare.

This study focuses on January–December 2024 and treats the period as a baseline for rice-price conditions before the substantial changes in Indonesia's rice production and policy environment in 2025. This positioning allows the study to identify regional price disparities and evaluate the performance of the optimization model under the producer- and consumer-price policies applicable during 2024. The results therefore represent conditions within the study period and should not be interpreted as estimates of current optimal rice prices.

Accordingly, this study aims to apply Lagrange Quadratic Programming to optimize consumer-level rice-price stability across districts and cities in East Java during 2024, evaluate the extent to which the model reduces regional price disparities for medium and premium rice, and formulate policy recommendations based on the regional price conditions observed during the study period.

Methodology

The data used in this study are secondary data obtained from the National Food Agency's Food Price Panel (BAPAN, 2024). The data collected includes retail prices of medium and premium rice at the consumer level in each district/city of East Java Province from January 2024 to December 2024. The selected period represents a complete annual observation window and is used as a pre-2025 policy baseline. Accordingly, the optimization constraints and policy benchmarks employed in the model refer to the regulations and market conditions applicable during 2024. In addition, average producer-level prices for both medium and premium rice were also gathered for the same period. The data are structured in a panel format, combining time-series and cross-sectional dimensions, enabling spatio-temporal analysis to better understand price fluctuations across districts and months.

The consumer price data were obtained from the BAPANAS Panel Harga Pangan and represent retail selling prices collected from retail traders in the main traditional market monitored in each district/city. The series does not combine prices from supermarkets or other modern retail outlets. BAPANAS enumerators record rice prices from selected retail traders in each monitored market and report the observations through the Panel Harga Pangan system. Although the underlying price observations are collected daily, this study uses the monthly average prices published by BAPANAS for January–December 2024. Therefore, the unit of observation in this study is the district/city-month for each rice category.

Under the BAPANAS price-monitoring procedure, retail respondents are selected to represent different locations within the monitored market. The reported market price is calculated from the selling prices recorded from the selected retail traders. The same market and respondent structure is monitored repeatedly to maintain comparability over time.

Table 1. Operational Definition of Variables

Variable Name	Definition	Unit	Data Source
Medium Rice Price	Average consumer-level retail price of medium-quality rice in each district/city per month	IDR/kg	SIPN BAPAN
Premium Rice Price	Average consumer-level retail price of premium-quality rice in each district/city per month	IDR/kg	SIPN BAPAN

Source: Processed by Author

The stability analysis of medium rice prices at the consumer level was conducted using an optimization approach that separates the objective function from the constraint function. The primary goal of the Lagrange Quadratic Programming (LQP) model is to assess the stability of medium- and premium-rice prices across districts in East Java Province, accounting for fluctuations and deviations from the national price ceiling. The model applies objective functions to assess price stability at the consumer level, focusing on inter-district fluctuations. Mathematically, the general form of the objective function as defined by Tran et al. (2023) and modified accordingly.

$$f_{medium}(x) = \sum_{i=1}^{n} \sum_{j=1}^{m} \omega_i \omega_j \sigma_i \sigma_j \tag{1}$$

Both functions share the same mathematical structure but are applied separately to medium and premium rice to capture the unique market characteristics of each. In these functions, ω_i and ω_j represent the weights assigned to district *i* and *j*, reflecting their respective levels of price fluctuation. Regions with higher volatility receive larger weights. Meanwhile, σ_i and σ_j denote the standard deviation of prices in each district, serving as quantitative indicators of price variation.

$$f_{premium}(x) = \sum_{i=1}^{n} \sum_{j=1}^{m} \omega_i \omega_j \sigma_i \sigma_j \tag{2}$$

Constraint functions are then formulated for each rice category (premium and medium), incorporating the National Price Ceiling (HET) as well as the average producer-level price.

$$g(x_{medium}) = \frac{HET_{medium} + \overline{HP}_{medium}}{2} \tag{3}$$

Here, x medium and x premium denote consumer prices for medium and premium rice, respectively. The average HP values represent the corresponding average producer-level prices used in the model.

$$g(x_{premium}) = \frac{HET_{premium} + \overline{HP}_{premium}}{2} \tag{4}$$

These constraint functions determine the mid-value benchmark for medium- and premium-priced rice. This benchmark ensures that consumer prices do not exceed the HET (to maintain affordability and compliance with government policy), while remaining above producer prices (to safeguard profit margins for distributors, millers, and traders). Thus, the price ranges are defined below.

$$\overline{HP}_{medium} \leq x_{medium} \leq HET_{medium} \tag{5}$$

During the January–December 2024 study period, the applicable HET was IDR 12,500 per kilogram for medium rice and IDR 14,900 per kilogram for premium rice, as stipulated in the letter of the Head of the National Food Agency to rice sector stakeholders, No. 160/TS.02.02/K/5/2024 dated 31 May 2024.

This policy extends the relaxation of HET regulations for both medium and premium rice until the issuance of a revised regulation under BAPAN Regulation No. 7 of 2023. Its aim is to provide flexibility for businesses and farmers while ensuring public access to rice at reasonable, affordable prices (BAPAN, 2024b).

$$\overline{HP}_{premium} \leq x_{premium} \leq HET_{premium} \tag{6}$$

Based on equations (1), (2),(3), (4), the LQP model is formulated for both medium and premium rice to support consumer-level price stabilization, subject to upper limits (HET), lower limits (average producer price), and other optimization constraints. The general form of the LQP equations is:

$$L(f_{medium}(x)) = \sum_{i=1}^{n}\sum_{j=1}^{m} \omega_i\omega_j\sigma_i\sigma_j + \lambda_1\left(\sum_{i=1}^{n} \omega_i\bar{x}_i - g(x_{medium})\right) + \lambda_2\left(\sum_{i=1}^{n} \omega_i - 1\right) \tag{7}$$

Each function aims to minimise inter-district price deviations by adjusting the weights ω_i and ω_j. The quadratic terms σ_i and σ_j represent price variability. By solving these equations, the model seeks to produce a more stable and equitable price distribution.

$$L\left(f_{premium}(x)\right) = \sum_{i=1}^{n}\sum_{j=1}^{m} \omega_i\omega_j\sigma_i\sigma_j + \lambda_1\left(\sum_{i=1}^{n} \omega_i\bar{x}_i - g(x_{premium})\right) + \lambda_2\left(\sum_{i=1}^{n} \omega_i - 1\right) \tag{8}$$

The optimization is solved using the Karush-Kuhn-Tucker (KKT) method through partial derivatives. The Lagrangian function incorporates three key elements: the quadratic objective function as a measure of deviation, the average consumer price constraint around $g(x)$, and the normalisation constraint ensuring that the sum of weights equals one. Partial derivatives yield:

$$\frac{\partial L}{\partial \omega_i} = \sum_{j=1}^{m} 2\omega_j\sigma_i\sigma_j + \lambda_1\frac{\partial}{\partial \omega_i}\left(\sum_{i=1}^{n} \bar{x}_i - g(x)\right) + \lambda_2 \tag{9}$$

Differentiating the Lagrangian with respect to the first multiplier produces the average consumer-price constraint shown below.

$$\frac{\partial L}{\partial \lambda_1} = \sum_{i=1}^{n} \bar{x}_i - g(x) = 0 \tag{10}$$

Differentiating the Lagrangian with respect to the second multiplier produces the weight-normalisation constraint shown below.

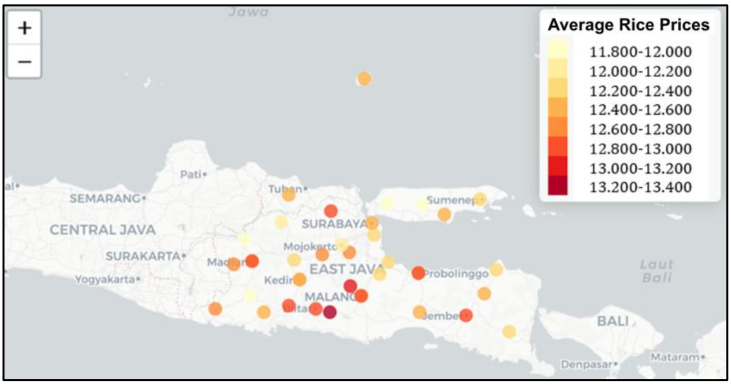
$$\frac{\partial L}{\partial \lambda_2} = \sum_{i=1}^{n} \omega_i - 1 = 0 \tag{11}$$

This system of equations is solved simultaneously to obtain the optimal values of ω_i. Model validation is conducted by comparing simulated optimal prices with observed consumer prices, evaluating whether inter-district price fluctuations have decreased, and ensuring adherence to the HET and producer price constraints. This validation confirms that the selected parameters (σ, ω, and λ values) and the model formulation are robust, providing both mathematically optimal solutions and policy-compliant price stabilization outcomes.

Results and Discussion

This subsection presents a descriptive analysis of the development of medium- and premium-level rice prices at the consumer level in East Java Province from January 1 to December 1, 2024. The purpose of this analysis is to provide an overview of the spatial distribution patterns and price fluctuations of both rice types across districts and cities. Using thematic map visualizations, the analysis highlights interregional price differences and trend tendencies, which can serve as a basis for formulating policies on price stabilization and more equitable rice distribution in East Java.

Figure 1. Average Consumer Price of Medium-Grade Rice



Source: Processed by Author

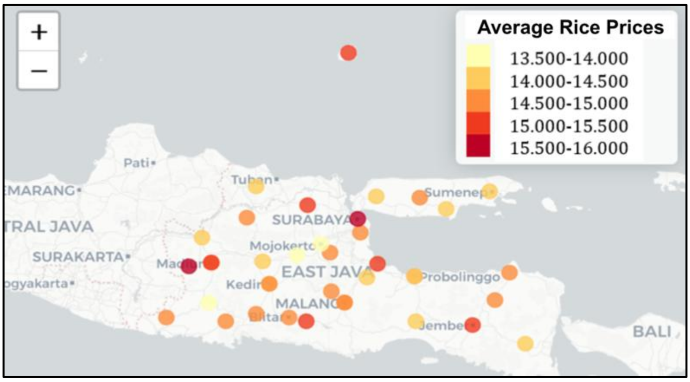
Each point on the map represents a regency or city, with colors indicating specific price ranges as shown in the legend at the top right. Dark red reflects the highest prices, while yellow indicates lower prices. Based on this visualization, areas such as Malang City, Kediri Regency, and several surrounding regions appear to have relatively high medium-grade rice prices, ranging from IDR 13.000 to IDR 13.400 per kilogram. Conversely, regions such as Sumenep, Bangkalan, and parts of the northern and eastern coastal areas display relatively lower prices, below IDR 12.200 per kilogram.

The distribution of medium-grade rice prices highlights regional disparities in East Java, likely driven by differences in geography, supply availability, demand levels, and distribution infrastructure. Higher prices in central and southern areas may be linked to greater demand in urban regions or limited distribution channels. Meanwhile, lower prices in certain coastal and inland areas may reflect stable local markets or government distribution interventions. Overall, the map provides a comprehensive overview of rice price conditions in East Java, serving as a valuable basis for regional food policy planning and price stabilization efforts.

The distribution map of average premium rice prices, where each point on the map represents a district or city, with colors indicating price ranges as shown in the legend at the top right. Yellow represents the lowest price range (Rp 13.500–14.000 per kilogram), while dark red indicates the highest (Rp 15.500–16.000 per kilogram). Based on this visualization, the highest premium rice prices are concentrated in several parts of central and northern East Java, including Surabaya City and surrounding regions. In contrast, areas in the southwest and parts of the east show relatively lower prices.

Several eastern coastal and island regions, such as Sumenep, tend to have more affordable prices, which may be linked to proximity to production centers or local rice distribution policies. This price distribution pattern highlights significant disparities in premium rice prices, potentially influenced by factors such as urbanization, high consumer demand in major cities, logistics costs, and supply from local producers. The visualization provides valuable insights for policymakers in formulating strategies for price stabilization and equitable food distribution across East Java.

Figure 2. Average Consumer Price of Premium-Grade Rice



Source: Processed by Author

The average price of medium rice in East Java in 2024 was 12.515 IDR per kilogram, while premium rice averaged 14.657 IDR per kilogram. This indicates that premium rice consistently commands a higher price than medium rice, reflecting its higher quality and market positioning. The median prices, 12.469 IDR for medium rice and 14.650 IDR for premium rice, are very close to their respective means, suggesting that the price distributions are fairly symmetric and not significantly affected by extreme values.

The standard deviation of medium rice prices is 329, indicating that price fluctuations are relatively small and that prices are generally stable around the average. In comparison, premium rice exhibits a higher standard deviation of 462, reflecting greater price variability that could result from differences in quality, brand, or distribution across districts. The observed price ranges further highlight this pattern: medium rice prices varied from 11.866 IDR to 13.221 IDR, while premium rice ranged from 13.612 IDR to 15.843 IDR, showing a wider dispersion for premium rice relative to its mean.

Table 2. Statistics Descriptive Medium and Premium Rice Price in East Java 2024

Statistics	Medium Rice Price	Premium Rice Price
Mean	12.515	14.657
Median	12.469	14.650
Standard Deviation	329	462
Minimum	11.866	13.612
Maximum	13.221	15.843

Source: Processed by Author

Overall, medium rice demonstrates greater price stability, whereas premium rice shows higher variability. The similarity between the mean and median for both rice types indicates a roughly symmetrical price distribution. These findings provide a foundational understanding of market price behavior, which is essential for informing policy measures aimed at stabilizing prices and guiding distribution strategies in East Java.

The optimization of rice prices was carried out by assigning contribution weights to identify the spatial role of districts/cities in maintaining the stability of medium- and premium-grade rice prices at the consumer level. The estimation considered both the national Highest Retail Price (HET) and producer-level prices as benchmarks. The initial step involved formulating objective functions for 38 districts/cities in East Java, based on equations (1) and (2) as follows:

$$f_{medium}(x) = \sum_{i=1}^{38} \sum_{j=1}^{38} \omega_i \omega_j \sigma_i \sigma_j \tag{12}$$

The next step in stabilizing medium- and premium-grade rice prices in East Java was formulating constraint functions under specific conditions. The assumption used was when consumer prices lie midway between producer average prices and the national HET.

$$f_{premium}(\,x) = \sum_{i=1}^{38} \sum_{j=1}^{38} \omega_i \omega_j \sigma_{ij} \tag{13}$$

These constraints were designed not only to account for producer-side efficiency but also to reflect government regulations and consumer purchasing power. This strategy ensures that optimization results remain within reasonable price ranges, acceptable to the market, and reflective of each region's contribution to price stability. The constraints, based on equations (3) and (4), are expressed as:

$$g(x_{medium}) = \frac{12{,}500 + 12{,}336}{2} = 12{,}418 \tag{14}$$

Equation (14) establishes the price constraint for medium rice at IDR 12,418, derived from the specified price parameters. The same constraint formulation is subsequently applied to premium rice, as presented in Equation (15).

$$g\left(x_{premium}\right) = \frac{14{,}900 + 13468}{2} = 14{,}184 \tag{15}$$

From the formulated objective and constraint functions, the Lagrange Quadratic Programming (LQP) model was developed to obtain stable optimal price solutions. The general form of the LQP model, based on (7) and (8), is expressed as:

$$L\left(f_{medium}(x)\right) = \sum_{i=1}^{38}\sum_{j=1}^{38} \omega_i\omega_j\sigma_i\sigma_j + \lambda_1\left(\sum_{i=1}^{38} \omega_i\bar{x}_i - 12{,}418\right) + \lambda_2\left(\sum_{i=1}^{38} \omega_i - 1\right) \quad (16)$$

Equation (16) specifies the LQP model for medium rice by incorporating the price constraint of IDR 12,418 and requiring the regional weights to sum to one. The same formulation is then applied to premium rice using its corresponding price constraint of IDR 14,184, as shown in Equation (17).

$$L\left(f_{premium}(x)\right) = \sum_{i=1}^{38}\sum_{j=1}^{38} \omega_i\omega_j\sigma_i\sigma_j + \lambda_1\left(\sum_{i=1}^{38} \omega_i\bar{x}_i - 14{,}184\right) + \lambda_2\left(\sum_{i=1}^{38} \omega_i - 1\right) \quad (17)$$

The model was then solved numerically to derive weights representing the percentage contribution proportions of each district/city in maintaining rice price stability in East Java, using equations (9), (10), and (11).

Table 3. Optimization Results of Medium-Grade Rice Prices

District/City	Initial Average Price (IDR)	Contribution (%)	Optimal Price (IDR)
Bangkalan	11,866.42	10.67%	13,132.56
Banyuwangi	12,318.08	6.76%	13,150.79
Blitar	13,221.00	-3.24%	12,792.64
Bojonegoro	12,118.58	9.91%	13,319.53
Bondowoso	12,404.25	-4.72%	11,818.77
Gresik	12,583.42	4.19%	13,110.66
Jember	12,822.08	3.85%	13,315.73
Jombang	12,688.17	6.02%	13,451.99
Kediri	12,605.92	3.09%	12,995.44
Lamongan	12,968.58	6.58%	13,821.92
Lumajang	12,568.67	-3.83%	12,087.29
Madiun	12,422.42	8.58%	13,488.26
Magetan	12,788.75	-5.61%	12,071.30
Malang	12,466.33	12.49%	14,023.38
Mojokerto	12,646.33	0.23%	12,675.42
Nganjuk	12,275.33	9.70%	13,466.04
Ngawi	11,965.25	-0.11%	11,952.09
Pacitan	12,795.67	-4.98%	12,158.44
Pamekasan	12,448.58	11.69%	13,903.82
Pasuruan	12,373.75	0.10%	12,386.12
Ponorogo	11,941.08	7.33%	12,816.36
Probolinggo	12,433.75	2.61%	12,758.27
Sampang	11,972.67	-5.89%	11,267.48
Sidoarjo	12,395.17	8.57%	13,457.43
Situbondo	12,357.75	2.13%	12,620.97
Sumenep	12,309.42	-7.79%	11,350.51
Trenggalek	12,445.08	4.43%	12,996.40
Tuban	12,471.58	-0.98%	12,349.36
Tulungagung	12,879.92	6.83%	13,759.61
Kota Batu	13,139.50	-1.35%	12,962.12
Kota Blitar	12,804.75	7.72%	13,793.28
Kota Kediri	12,572.67	9.54%	13,772.10
Kota Madiun	12,805.08	-6.60%	11,959.95

District/City	Initial Average Price (IDR)	Contribution (%)	Optimal Price (IDR)
Kota Malang	12,888.08	-5.63%	12,162.48
Kota Mojokerto	12,037.25	6.04%	12,764.30
Kota Pasuruan	12,384.08	-1.52%	12,195.85
Kota Probolinggo	12,923.25	3.31%	13,351.01
Kota Surabaya	12,475.00	-0.11%	12,461.28
Jawa Timur	12,515.36	-2.50%	12,202.69

Source: Processed by Author

Initial average price represents pre-optimization conditions, while the optimized price reflects results after weighting regional contributions using numerical methods that account for interregional price variation. The contribution percentage column indicates the extent to which each district/city contributes to provincial price stability, either positively or negatively. For example, Malang (12.49%), Pamekasan (11.69%), and Bangkalan (10.67%) contributed the most to raising provincial averages, with optimized prices of Rp14,023.38, Rp13,903.82, and Rp13,132.56, respectively, supporting aggregate stability without exceeding consumer price ceilings. Conversely, districts such as Sumenep (-7.79%), Kota Madiun (-6.60%), and Sampang (-5.89%) were adjusted downward, with optimized prices of Rp11,350.51, Rp11,959.95, and Rp11,267.48, respectively, to dampen excessive price pressures. Overall, the optimized average price of medium-grade rice in East Java was Rp12,202.69, lower than the initial average of Rp12,515.36, and remained within policy-approved limits (not exceeding HET nor falling below producer prices). This demonstrates the model's success in ensuring stable and equitable rice prices across districts while complying with national affordability regulations.

Table 4. Optimization Results of Premium-Grade Rice Prices

District/City	Initial Average Price (IDR)	% Contribution	Optimal Price (IDR)
Bangkalan	14,234.00	-3.00%	13,806.98
Banyuwangi	14,360.75	19.00%	17,089.29
Blitar	15,007.08	-10.00%	13,506.38
Bojonegoro	14,614.50	24.00%	18,121.98
Bondowoso	14,825.42	4.00%	15,418.43
Gresik	15,068.67	3.00%	15,520.73
Jember	15,163.25	-4.00%	14,556.72
Jombang	13,946.92	0.00%	13,946.92
Kediri	14,299.25	7.00%	15,300.20
Lamongan	15,113.92	10.00%	16,625.31
Lumajang	14,100.42	-4.00%	13,536.40
Madiun	14,874.33	13.00%	16,808.00
Magetan	15,632.83	10.00%	17,196.12
Malang	14,712.25	2.00%	15,006.50
Mojokerto	14,974.17	0.00%	14,974.17
Nganjuk	14,481.08	-1.00%	14,336.27
Ngawi	14,329.83	2.00%	14,616.43
Pacitan	14,978.92	3.00%	15,428.28
Pamekasan	14,167.67	-8.00%	13,034.25
Pasuruan	14,326.25	4.00%	14,899.30
Ponorogo	13,611.75	9.00%	14,836.81
Probolinggo	14,510.08	-3.00%	14,074.78
Sampang	14,544.17	-5.00%	13,816.96
Sidoarjo	14,685.08	16.00%	17,034.70
Situbondo	14,655.00	4.00%	15,241.20
Sumenep	14,434.17	10.00%	15,877.58
Trenggalek	14,862.75	7.00%	15,903.14
Tuban	14,195.58	15.00%	16,324.92

District/City	Initial Average Price (IDR)	% Contribution	Optimal Price (IDR)
Tulungagung	14,883.75	-1.00%	14,734.91
Kota Batu	14,645.17	-2.00%	14,352.26
Kota Blitar	14,523.75	-12.00%	12,780.90
Kota Kediri	14,932.67	-9.00%	13,588.73
Kota Madiun	15,222.25	-7.00%	14,156.69
Kota Malang	14,888.08	15.00%	17,121.30
Kota Mojokerto	13,804.17	15.00%	15,874.79
Kota Pasuruan	15,009.08	-5.00%	14,258.63
Kota Probolinggo	14,493.00	4.00%	15,072.72
Kota Surabaya	15,842.50	-21.00%	12,515.58
Jawa Timur	14,656.70	-2.16%	14,340.11

Source: Processed by Author

This table presents the optimization results of premium-grade rice prices at the consumer level for each district/city in East Java, covering the initial average price, optimal contribution weight, and optimized price. The results show varying regional contributions, reflected in post-weighting average price changes. Some districts/cities had significant positive contributions, reinforcing stability, while others required downward adjustments to balance distribution.

Bojonegoro recorded the highest contribution (24%), raising its optimal price to Rp18,121.98, far above the initial Rp14,614.50, highlighting its key role in regional stabilization. Banyuwangi and Sidoarjo also showed high contributions (19% and 16%), with optimal prices of Rp17,089.29 and Rp17,034.70, respectively. In contrast, Kota Blitar (-12%), Kota Kediri (-9%), and Surabaya (-21%) had negative contributions, significantly reducing optimal prices.

For example, Surabaya's price fell from Rp15,842.50 to Rp12,515.58. Neutral contributions (0%) were found in Jombang and Mojokerto, leaving prices unchanged. At the aggregate level, the optimized provincial average premium price was Rp14,340.11, within the constraint range of Rp13,468.00–14,500.00. This indicates that the LQP approach successfully distributed contributions fairly and efficiently across regions, achieving stable premium rice prices at the consumer level.

The comparison of optimization results is carried out by evaluating the optimal contribution weights for each regency/city and assessing optimization performance, one aspect of which is measured by the model's objective value. This objective value represents the variance of rice prices across regions after weighting. The smaller the objective value, the more stable the aggregated rice prices become. The comparison of objective values is presented below.

Table 5. Comparison of Objective Values

Rice Quality	Objective Value
Medium	0.01
Premium	55.93

Source: Processed by Author

This table presents the objective values from the optimization model as a measure of price stability for medium- and premium-quality rice across regencies/cities in East Java. Table 3 shows the optimization model's evaluation results, based on the objective value, for two rice quality types: medium and premium. The objective value in this model reflects the variance of rice prices across regencies/cities after weighting. A smaller objective value indicates lower price discrepancies across regions, indicating greater overall price stability.

For medium-quality rice, the objective value obtained is 0.01. This very small value indicates that the model successfully optimized the contribution weights of each regency/city, resulting in highly stable consumer prices for medium rice across regions. Meanwhile, for premium-quality rice, the objective value of 55.93 suggests a relatively higher variance across regions even after weighting. This implies that, although the model was optimized, premium rice prices still exhibit significant fluctuations compared to medium rice.

The optimal lag tests in Table 3 reveal that the three information criteria (AIC, SC, HQ) reach their minima at lag 0 (AIC=-58.08, SC=-58.02, HQ=-58.06), which technically favors a no-lag specification. However, the LR test and the correlogram pattern indicate improvement when adding lags (LR for lag 1 = 185.97, significant), and there is evidence of autocorrelation at medium/high orders. Practically, a lag = 0 specification risks omitting relevant dynamics, so a pragmatic choice is to include one lag (lag 1) in the VAR estimation.

Conclusion

The optimization of rice prices in East Java Province demonstrates that the Lagrange Quadratic Programming (LQP) approach is effective in fairly regulating the contribution of each regency/city to maintain rice price stability at the consumer level. For medium-quality rice, the provincial average price after optimization was lower than the initial price while remaining within the policy-defined range. The contributions of each region were proportionally adjusted: areas with efficient distribution received upward price adjustments, while regions with potential price pressures received downward adjustments. These results indicate the model's success in achieving price equality for medium-quality rice at the consumer level without violating established upper or lower policy limits.

The evaluation of the objective value further supports the model's effectiveness, with the very low value reflecting highly even price distribution across regions for medium-quality rice. For premium-quality rice, the LQP model also proved effective in distributing consumer-level rice prices fairly across regions, although price variations between regencies/cities were larger compared to medium-quality rice. Certain regions played a dominant role in shaping the provincial price, necessitating larger adjustments to maintain regional stability. Nevertheless, the optimized average price remained within the policy constraints. This indicates that the model not only considers numerical efficiency but also accommodates the diversity of local market structures.

Overall, this optimization approach is effective in creating a fair distribution of rice prices at the consumer level and can serve as a foundation for formulating rice price policies that are more adaptive to interregional dynamics. Based on these findings, policy recommendations can be made more practically applicable, not only for East Java Province but also for other regions in Indonesia, ensuring that regional differences in distribution efficiency and market pressures are considered while maintaining overall price stability.

AI declaration

The authors declare that artificial intelligence (AI) tools were used solely to assist in language refinement, grammar checking, and improving the clarity of writing. The use of AI did not influence research design, data collection, data analysis, interpretation of results, or the development of conclusions. All intellectual contributions, including conceptualization, methodology, analysis, and final content, remain the full responsibility of the authors.

Conflict Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. The research was conducted independently without any financial, commercial, or personal relationships that could be construed as a potential conflict of interest.

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