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# Market Equilibrium Modelling of Rice in South Kalimantan Using the Nonlinear Programming Method: Implications for Agricultural Policy

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## Abstract

Despite being a top global producer, Indonesia's rice market equilibrium is increasingly threatened by demographic pressure, land conversion, and a growing reliance on imports. This study develops a novel Computable General Equilibrium (CGE) model using General Algebraic Modelling Language (GAMS) and nonlinear programming to analyse how regional production responds to shifting policies and market dynamics. The research specifically focuses on South Kalimantan, a region that serves as a strategic food buffer for the new National Capital (IKN). The model demonstrates strong empirical reliability, with a price calibration deviation of only 1.8% and an overall production error of just -0.7%. Simulation results reveal that while overproduction creates regional surpluses, it does not necessarily lead to lower consumer prices. Conversely, government-imposed price controls were found to trigger significant supply deficits by disincentivising producer output. These findings confirm the model's utility as a robust tool for evaluating productivity, infrastructure, and stabilisation policies to ensure national food security.

## Keywords

CGE-SAM model, GAMS, rice market equilibrium, South Kalimantan, food security, price control.

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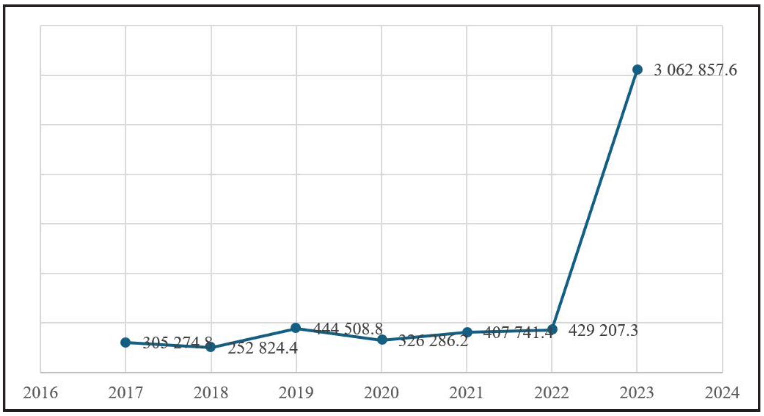
## Introduction

Indonesia has long been recognised as an agricultural country, where a large proportion of its population relies on farming for their livelihoods. The nation's diverse agroclimatic conditions, characterised by abundant rainfall, year-round sunlight, and fertile volcanic soils, create an environment highly conducive to the development of food crops and plantation commodities. These geographical advantages have positioned agriculture as the backbone of rural economic life and a crucial provider of the national food supply. Thus, it plays a strategic role in the Indonesian economy, not only as a major contributor to the Gross Domestic Product (GDP) but also in providing employment opportunities. Statistics Indonesia indicates that the agricultural sector contributes around 14.35% to the total national GDP while absorbing around 30% of the total Indonesian workforce, either directly or indirectly, while rice is the single-most-important agricultural product (Badan Pusat Statistik, 2025a, 2025b). It is a staple food and the primary source of caloric intake for most Indonesians. As a strategic commodity, rice significantly influences economic stability, political dynamics, and social vulnerability. Historical evidence shows that disruptions in food supplies, particularly rice, sparked unrest and criminal activity during the early stages of the reform era.

As a staple food, the demand for rice in Indonesia increases every year along with the increase in population. However, this rising demand, coupled with shrinking agricultural land and declining rice production, dropping by 1.8% and 1.6% annually (2010 to 2019), threatens market equilibrium (Quartina Pudjiastuti et al., 2021). To meet the demand, Indonesia relies on imports. Indonesia depends on rice imports, thereby exposing local prices to volatility and fluctuations within the global rice market. Although a major producer, Indonesia's rice imports continue to rise. Between 2017 and 2023, import volumes consistently increased (Figure 1), with a dramatic surge in 2023—over seven times higher than the previous year—making Indonesia the world's largest rice importer, accounting




Source: Statistic Indonesia (BPS), 2025

Figure 1: Indonesia rice import data.

for 5.46% of global rice imports valued at USD 32.78 billion (Darmawan et al., 2021; Kusumastuti et al., 2024). In 2024, the situation worsened, with rice imports reaching 4.52 million tons (Rachman, 2025).

Rice imports are intended to stabilise domestic supply and prevent inflation due to shortages (Sholikhah and Anjani, 2023). The various impacts of rice imports have been widely stated in many studies, including the depletion of national foreign exchange reserves and the decline in domestic rice prices, which can lead to reduced competitiveness and negatively affect farmers' welfare. This condition can reduce the motivation of farmers to increase their production, and it can threaten food sovereignty and food security and even invite political pressure from exporting nations (Kusumastuti et al., 2024; Umar, 2025). In fact, the rice market in Indonesia is currently shifted to a fully market-driven one, so the price of rice will be more volatile.

In 2024, Indonesia produced 30.62 million tons of rice from 10 million hectares, yet high per capita consumption (97,6 kg)—surpassing regional neighbours like Malaysia and Brunei—creates a significant supply challenge (Fitrawaty et al., 2023). To support over 284 million citizens, the government must prioritise stable domestic production to ensure food security and minimise import dependency. South Kalimantan is a vital rice production hub outside Java, designated as a strategic food buffer for the new National Capital (IKN). In 2024, the province generated a 28.31% surplus, producing 609,172 tons against a demand of 421,957 tons. However, with a high population growth of 1.29% in the last five years, the government must remain vigilant regarding future rice availability and the potential consequences of market imbalances, including price distortions (Badan Pusat Statistik Provinsi Kalimantan Selatan, 2025).

Rice market equilibrium is influenced not only by production and consumption but also by other factors such as price volatility, climate-induced shifts in production, and import or distribution policies. In recent years, the rice market equilibrium in South Kalimantan has faced various challenges, including price volatility, changes in production patterns due to weather factors, and import and distribution policies that affect supply and demand. Additionally, (Noviar and Affandi, 2019) highlight that government interventions—such as fertiliser subsidies, the government purchasing price, and national rice reserve programs—have been crucial in stabilising rice supply and demand. Therefore, these interrelated factors require thorough analysis.

The study aims to:

1. Analyse how rice production across different regions responds to changes in policies or market conditions.
2. Assess the impact of changes in production and demand on market prices and overall economic equilibrium.
3. Evaluate the effectiveness of government intervention, such as surplus absorption or price controls, in addressing market imbalances.
4. Identify potential regional surpluses or shortages in rice supply under various policy and market scenarios.

**Modelling the rice economy: a general equilibrium approach**

Economic analysis tools are essential in understanding and forecasting market behaviour. Among these tools, general equilibrium (GE) modelling is widely recognised for analysing interactions between supply and demand across multiple markets simultaneously, whether a stochastic model (Hassan et al., 2025; Tanaka et al., 2021; Tanaka and Guo, 2020) or a dynamic approach (Akune et al., 2015; Hossain et al., 2023; Kunimitsu, 2015; Zhang et al., 2022) or combination approaches (Gao, 2024; Javadi et al., 2022; Vellinga and Tanaka, 2025). The general equilibrium (GE) model provides a comprehensive framework for analysing the interrelationships between markets, effectively capturing the interactions between industries, resources, and institutions. This holistic approach allows for a deeper understanding of how shifts in one area of the economy propagate through other sectors (Ghaith et al., 2021; López and Méndez Segura, 2024; Malahayati and Masui, 2022; Suryadi, 2019; Valera et al., 2024a). Furthermore, Wei and Aaheim (2022) conducted a systematic review of CGE models in climate change adaptation studies, finding that CGE models apply across sectors, including transportation, energy, and investment, yet reviewed studies mainly focus on agriculture, with country-level models most widely adopted.

Numerous studies have applied GE and similar models to agricultural commodities, including rice (Balié and Valera, 2020; Bonga-Bonga and Mbanda, 2025; Hummel and Ziesemer, 2023; Kamei, 2024; Lanzara and Santacesaria, 2023; Robinson et al., 2018). In this context, CGE models systematically integrate production, distribution, and consumption activities, capturing the influence of government policies, market mechanisms, and interactions among economic agents along the supply chain, thereby providing an analytical framework to support policymakers in designing effective policies that enhance welfare outcomes for domestic farmers and consumers (Kunimitsu, 2015; Siswanto et al., 2018). The CGE model is a widely used numerical simulation framework for assessing the impacts of economic shocks and policy changes (Hossain et al., 2023; Okodua, 2018). It can be modified and extended to evaluate the implications of various economic policies, including changes in taxes, subsidies, tariffs, and technological progress, particularly in developing country contexts (Lofgren et al., 2002; Valera et al., 2024a; Widyastutik et al., 2025). Accordingly, this study employs a CGE framework to systematically analyse the structural characteristics and policy dynamics of the rice sector.

Several studies utilising CGE models have demonstrated how price policies, subsidies, distribution systems, and climate change may influence economic equilibrium, particularly within strategic sectors. For instance, Fitrawaty et al. (2023) showed that rising rice prices exacerbate income inequality, especially for smallholder households, without adequate compensation from other sectors. On the other hand, (Balié and Valera, 2020; Vellinga and Tanaka, 2025; Ouraich et al., 2019; Valera et al., 2024b) have shown that trade liberalisation—especially in rice—may reduce consumer prices but harms farmers due to uncompetitive domestic pricing. These studies underscore the importance of policy balance, including subsidies or direct transfers. Similarly, Hoang and Meyers (2015) examined rice trade liberalisation in Southeast Asia (Indonesia, Malaysia, Philippines), revealing that while state-trading enterprises (e.g. Bulog (Indonesia Logistics Bureau) can stabilise prices and enhance efficiency, they may also increase import dependency and affect the income of local farmers. CGE models are also widely employed to analyse the uncertainty of agricultural production shocks due to climate change, which will have a multiplier effect on the economy as demonstrated in studies conducted by (Belford et al., 2023; Bosello et al., 2018; Hossain and Delin, 2019; Javadi et al., 2022).

In this study, we develop a rice market model using mathematical equations within a nonlinear framework to examine how changes in production, demand, and price-related policies affect market equilibrium by integrating spatial dimensions, policies, and uncertainties into a unified quantitative structure. The proposed model is a novel synthesis of classical and modern economic theory, tailored to the characteristics of rice —such as its dependence on geographical factors, policy interventions, and production variability. It incorporates key variables, including production costs, government policy effects, dynamics, and the effects of transportation and subsidies. By employing nonlinear programming, the model better reflects real-world market behaviour by accounting for non-linear constraints and interactions among variables. Designed for use in agrarian countries with geographic diversity and strong government intervention (e.g. Indonesia or Thailand), the model supports spatial economic analysis and provides a practical tool for policymakers to promote food security and improve market efficiency.

### Novelty and comparison with previous models

The proposed rice market model introduces a significant breakthrough by integrating the spatial dimension, government policies, and production uncertainties into a single, holistic quantitative framework. This integration is demonstrated through five key aspects, each of which explicitly distinguishes the model from classical approaches while acknowledging the limitations of those earlier frameworks.

1. **Integration of spatial theory and production economics.** The model synthesises Thünen's location theory with Weber's transportation model to analyse how land productivity, market access, and transport costs collectively shape agricultural pricing and location decisions. A key novelty is the resulting Spatial-Dynamic Production Function, which determines regional output based on land area (a(r)), distribution distance (d(r)), and a stochastic component (uniform random variable). By incorporating random variation, the model introduces production uncertainty into spatial economics—a feature rarely addressed in classical literature. This represents a fundamental departure from the classical von Thünen (1966) model, which described a static, circular structure of agricultural production around a single market without multi-region dynamics, complex distance variables, or stochastic shocks. Furthermore, the present framework is scalable, allowing application at both micro-levels (villages or districts) and the national level, contingent upon spatial data availability.
2. **Hybrid production costs: labour and land.** Building upon the widely used Cobb-Douglas cost function, the model has been modified to reflect the specific characteristics of the agricultural sector. By analysing the relationship between labour and land as primary inputs, a distributed cost function (cst(r)) is obtained, combining wages (wl) and land rent (pk(r)), with parameters (β) that vary between regions to reflect differences in input use intensity. The market equilibrium condition (∑(wl·ltot) = ∑(cst(r)·y(r))) links wages directly to regional productivity, an integration that has not been fully explored in traditional Cobb-Douglas applications within spatial CGE frameworks.
3. **Market equilibrium with government intervention.** Market equilibrium in the agricultural sector is frequently distorted by government interventions such as price floors or ceilings. Drawing on Muth's (1961) partial equilibrium model, this framework explicitly incorporates two simultaneous policy instruments: (i) Surplus Purchase (ip(r)), activated when the price falls below the government-set floor price, and (ii) Producer Subsidy (sub(r) = (Price_ceiling−p)·y(r)), applied when prices are administratively controlled below market-clearing levels. This dual-policy structure is a substantial advance over the simple static minimum or maximum price policy proposed by Tweeten (1963), which treated interventions as one-off measures without feedback effects. In the present model, interventions affect not only prices but also production and transportation costs through feedback loops to y(r) and tc(r), thereby capturing the multidimensional impacts of policy on interregional trade flows and resource allocation—a mechanism not previously accommodated in the literature.
4. **Production uncertainty and policy simulation.** The incorporation of stochastic elements in agricultural production is crucial for food security analysis. A uniform random factor embedded in the production function y(r) enables the simulation of extreme climate scenarios or crop failure. This represents a clear departure from the deterministic supply models pioneered by Nerlove (1958), which assumed static production responses and ignored random exogenous shocks such as weather variability. The stochastic component allows the present model to be tested with varying policy parameters —for instance, adjusting the price floor to estimate impacts on market equilibrium, government budgets, and regional rice distribution under conditions of uncertainty.
5. **Multidimensional integration: production, transportation, and policy.** This research develops an integrated framework that synthesises five dimensions often studied separately in the economic literature: (i) spatial production that accounts for geographic location and land productivity;

(ii) Weberian transportation costs that depend on distance and accessibility. Notably, transportation costs are modelled non-linearly (tc(r) = t·d(r)·y(r)), in contrast to the linear or "iceberg" approach introduced by Samuelson (1952), thereby better representing the reality of agricultural commodity distribution where costs depend on both volume and distance; (iii) price and subsidy policies that capture government intervention; (iv) labour market equilibrium linking wages to production sector needs; and (v) production uncertainty, including climate variability and yield risk.

The integration of these five dimensions provides a robust foundation for understanding economic dynamics in a holistic and contextual manner, particularly in strategic sectors such as rice. For example, if the government raises the price floor, the model can simultaneously estimate the resulting increase in government purchases (ip(r)), the impact on subsidy costs (sub(r)), and the consequent changes in labour allocation across regions. By synthesising classical location theory, public economics, and stochastic production, the framework not only contributes to the spatial economics literature but also offers a practical empirical tool for promoting market efficiency and equitable distribution in agrarian economies with pronounced spatial disparities, such as Indonesia and Thailand. The key distinctions between the proposed model and previous classical approaches are summarised in Table 1.

## Materials and methods

### Conceptual framework

In the economic context, the equilibrium of the rice market is influenced by both supply and demand-side variables, as well as other external factors. These include regional land area and productivity; access to labour, capital, and technology; input costs (e.g. wages and land rents); transportation costs and infrastructure; government subsidies and price support. This study captures these complexities through a nonlinear programming model, which formalises these relationships into a structured system of equations. To ensure a rigorous analysis, mathematical formalisation is used to transform the conceptual economic framework into a structured set of equations for precise empirical testing and scenario simulation. Here are some key parts that are mathematically formalised:

**Objective function.** In line with the theory of general equilibrium, this model is formulated as a mixed complementarity problem (MCP) rather than a traditional optimization problem. The equilibrium is found by solving a system of inequalities that represent the optimization problems of all agents (producers and consumers). There is no single objective to be maximized (like total output or a single price); instead, the model finds a vector of prices and quantities that clears all markets.

This approach is implemented in GAMS using a nonlinear programming (NLP) formulation to find a feasible point that satisfies all constraints. The artificial objective function is set to a constant (e.g., Objective = 1) * or, in a more theoretically robust implementation, we maximize the aggregate excess demand value to drive the system toward equilibrium. This is a standard technique to solve for an equilibrium in a square system of equations, ensuring that the solution corresponds to a Walrasian equilibrium where supply equals demand in every market. This reformulation corrects the earlier, theoretically weak objective of simply maximizing a single price and aligns the model with standard CGE practice.

**Constraints.** This model has several constraints, such as cost function, production function, equilibrium of labour and commodity markets, government intervention, and market imbalances.

| Aspect | Classical Model | Classic Model References | Developed Model |
|---|---|---|---|
| Spatial | Static (single market centre) | Von Thünen (1826), *Der isolierte Staat* [Location model with a single market centre]. | Dynamic (multi-region + distance) |
| Government Intervention | Minimum or maximum price | Tweeten (1963), *Foundations of Farm Policy* [simple basic price/subsidy policy analysis]. | Two instruments + feedback effect |
| Uncertainty | Deterministic | Nerlove (1958), *The Dynamics of Supply* [deterministic agricultural offering model]. | Stochastic (*Uniform*) |
| Transportation Costs | Ignored or linear | Samuelson (1952), *Spatial Price Equilibrium* [Linear transportation costs "iceberg"]. | Non-linear (tc(r) = t·d(r)·y(r)tc(r) = t·d(r)·y(r)) |

Source: Authors' own summary based on the comparative analysis presented above

Table 1: Comparative aspects of classical vs developed models in agricultural and spatial economics.

The constraints illustrated how production, costs, and prices interact in each region, and how markets might experience shortages or surpluses.

Cost function for each region (Equation 1):

$$def\_cst(r): Ø.cst(r) + 0.002.a(r) + 0.005.d(r) + \\ + 0.0005.y(r) \geq wl.\beta + pk(r).(1\text{-}\beta) + 0.0003.ltot \quad (1)$$

- Production function for each region (Equation 2):

$$prf\_y(r): cst(r) + t.d(r) + wp \geq p\text{-}0.006.a(r) \quad (2)$$

The constants appearing in the constraint equations (e.g., 0.002, 0.005, 0.0005 in def_cst(r)) are not arbitrary. They are calibrated parameters resulting from the process of fitting the model to the empirical data presented in the Social Accounting Matrix (SAM) and regional production tables (Table 2 and 4). The calibration process uses a minimum-RMSE (Root Mean Square Error) approach to adjust these coefficients so that the model's output (prices, production, costs) replicates the base -year data (2024-2025) as closely as possible. For instance, the coefficient for a(r) in the cost function represents the marginal cost share of land, derived from the land rent and production data in the SAM.

- Market imbalance (Equation 3):

$$mkt\_imbalance(r): shortage(r) = \\ = max\left(0, \sum_h \alpha(h).ltot - y(r)\right) \quad (3)$$

Following mathematical formalisation, a simulation protocol operationalises the model through baseline calibration. This stage ensures the model replicates current market conditions by setting the price parameter to fluctuate between IDR 8,000 and IDR 20,000, reflecting historical BPS volatility. The total labour endowment (ltot) is fixed at 80, with cost and production parameters initialised to model specifications. By solving the system using standard equilibrium equations without external interventions, the model establishes baseline values for production, market prices, and shortages, providing a benchmark for subsequent scenario analysis.

Moreover, a counterfactual scenario is needed to test how a system would behave under different assumptions or interventions. Some examples of interventions or changes that can be tested are:

***Government intervention*: If the price of rice falls below the floor price set by the government, intervention will occur. Counterfactual scenarios could involve adjusting the floor price set by the government or changing the intervention mechanism (Equation 4).

$$govt\_intervention(r): ip(r) = \\ = \max\left(0, \frac{(price\_floor - p).shortage(r)}{1.2}\right) \quad (4)$$

***Price shocks:*** If the value of p (rice price) changes beyond its normal range, it simulates how the system reacts to extreme price spikes or drops

***Changes in external factors:*** by introducing changes in parameters such as the transport endowment (trns), the labour endowment (ltot), or the area (a(r)), to see how these factors affect the system.

Each scenario resolves the equilibrium equations under shifted parameters to observe how such changes perturb rice production and pricing, while identifying potential market imbalances and shortages. The primary structural components of the model are as follows:

1. The production function is to determine rice output based on maximum capacity and production factors in each region.
2. A production cost equation to measure the impact of land costs on production prices.
3. Market equilibrium equation to ensure that total production corresponds to total consumption and intervention policies.
4. The equation of government intervention determines when the government needs to buy surplus or set a maximum price.
5. Transportation costs and subsidies consider the influence of geographic distribution and economic incentives on market equilibrium.

By understanding the purpose and logic behind each equation above, it becomes possible to assess the model's capacity to replicate real-world conditions and to evaluate the implications of external interventions or shocks. A brief explanation of each equation is provided below to clarify its function and role within the overall model framework.

1. **Production function in each region.** Rice production in each region depends on the maximum production capacity and other factors such as the area and the distribution distance (EQUATION 5):

$$y(r) = \min(Y{=}Y_{maz}, \max(Y_{min}, C_1 + C_2.ord(r) + C_3.a(r) - C_4.d(r) + uniform(C_5,C_6))) \quad (5)$$

where:

$y(r)$ is rice production in the region.

$a(r)$ is the area of production.

$d(r)$ is the distribution distance.

$C_1$.. $C_6$ is a constant parameter in the production function.

$Uniform(C_5,\ C_6)$ is a random variation factor in production.

**2. Production cost function.** Production costs in each region are calculated based on labour costs and land ren (Equation 6):

$$cst(r) = \frac{wl.\beta + pk(r).(1-\beta) + C_7.ltot}{\emptyset} - C_8.a(r) - C_9.d(r) - C_{10}.y(r) \quad (6)$$

where

$cst(r)$ is the cost of production per unit in the region.

$wl$ is the wages of the farmer.

$Pk(r)$ is the land rent in the area.

$\beta$ is a factor in the distribution of labour and land costs.

$ltots$ is the total available workforce.

$\emptyset$ is the scale of the cost of production.

$C_7$, $C_8$, $C_9$, $C_{10}$ a constant parameters in the function of production cost.

**3. Market equilibrium equation.** The market must achieve an equilibrium between total production and market demand (Equation 7):

$$p.\sum_r y(r) = \sum_r ip(r) + \sum_r \sum_h \alpha(h).ltot + C_{11}.\sum_r y(r) \quad (7)$$

where:

$p$ is the market price of rice.

$ip(r)$ is a government intervention in the form of surplus purchases.

$\alpha(h)$ is the proportion of household consumption.

$\sum_r y(r)$ is the total rice production in all regions.

$C_{11}$ is a constant parameter in the market equilibrium.

**4. Government intervention when the price falls below the floor price**

(Equation 8)

$$ip(r) = \max(0,(P_{floor} - p).shortage(r)/C_{12}) \quad (8)$$

where:

$ip(r)$ is the amount of rice purchased by the government.

$shortage(r)$ is a shortage of supply in the region.

$P_{floor}$ is the minimum price set by the government.

C12 is a constant parameter in government intervention.

**5. Labour market equilibrium.** The labour market must meet the balance between available labour and that used in production (Equation 9):

$$wl.ltot = \sum_r y(r).\beta.cst(r) + C_{13}.lto \quad (9)$$

where:

$wl$ is the wages of labour.

$\sum_r y(r).\beta.cst(r)$ is the total of labour in production

$C_{13}$ is a constant parameter in the equilibrium of labour

**6. Transportation costs.** Transportation costs are calculated based on distribution distance and production quantity(Equation 10):

$$tc(r) = t.d(r).y(r) \quad (10)$$

where:

$tc(r)$ is the cost of transportation in the region.

$t$ is the cost per unit of transportation.

$d(r)$ is the distance to the distribution centre.

$y(r)$ is the amount of production.

**7. Government subsidies for producers (if price controlled).** If the government controls prices below market value, subsidies are given to the producer (Equation 11).

$$sub(r) = \max(0,(price_{ceiling} - p).y(r)) \quad (11)$$

where:

$sub(r)$ is a subsidy given to producers in the region.

$price_{ceiling}$ is the maximum price limit set by the government.

$p$ is the market price of rice.

$y(r)$ is production in the region.

## Results and discussion

### Model evaluation

The rice market model developed using GAMS successfully represented market equilibrium by integrating multiple economic factors, including regional production, price dynamics, input costs, and government intervention. The original GAMS model had been calibrated using the latest empirical data from Statistics Indonesia (2024-2025) and empirical studies, as shown in Table 2.

| Parameter | Value |
|---|---|
| Rice prod (real) | 22,150 |
| - Region 1 (r1) | 5,000 |
| - Region 2 (r2) | 5,300 |
| - Region 3 (r3) | 5,500 |
| - Region 4 (r4) | 1,670 |
| - Region 5 (r5) | 3,080 |
| - Region 6 (r6) | 1,600 |
| Price (real) | Rp 13,641 - Rp 14,000 per kg |
| Elasticity (empirical result) | |
| - price elasticity of demand for rice | -0.26 (inelastic) |
| - supply elasticity | 0.3 |
| Cost share:<br>- labour<br>- land | 60% (dominated by land preparation and planting)<br>40%<br>Calibration:<br>phi (Φ) = 0.74<br>beta (β) = 0.60<br>via minimize RMSE (y model vs real) |
| Model scale | *ltot* scaled ~4.4e6 (man-days national proportional), |
| | a(r) prop real production. |

Source: Data processing result, 2025

Table 2: Structural parameters and baseline calibration for the rice sector.

The model integrated empirical data from Statistics Indonesia (2024-2025) with calibrated parameters to replicate real-world market conditions. Total real rice production of 22,150 tons was distributed across six regions, with $r_3$ (5,500 tons) and $r_1$ (5,000 tons) serving as the primary hubs. A demand elasticity of -0.26 confirmed rice as a highly inelastic staple, while the supply elasticity was established at 0.3. The cost structure was notably labour-intensive, with labour accounting for 60% of total costs—primarily driven by land preparation and planting—while land constituted 40%. To ensure predictive accuracy, parameters $\Phi$ (0.74) and $\beta$ (0.60) were calibrated by minimising the RMSE between modelled and observed data. The model scaled labour endowment (*ltot*) to approximately 4.4 million man-days, reflecting national proportional employment levels in the agricultural sector. Meanwhile, Table 3 displayed the fully calibrated SAM model, illustrating sectoral interaction, particularly emphasis on rice (rice.mkt).

Following the IFPRI (2023) framework, the Social Accounting Matrix (SAM) in Table 3 establishes a balanced circular flow for the regional economy. The SAM is constructed to capture all transactions between activities, factors, and institutions. Key features include:

1. **Factors:** Labour and land receive income from production activities. Labour income (204 units) is endogenously determined, reflecting the labor-intensity of the sector ($\beta$ parameter).
2. **Institutions:** Households (farmers, workers, owners) receive factor incomes and allocate them to consumption (of rice and other goods) and savings. Household consumption of rice is derived from their expenditure shares ($\alpha$), which are calibrated from household survey data.

| Account | Labour Inc | Land Inc | HH Farmer | HH Worker | HH Owner | Gov IP | Savings | Rice.mkt Out | Row Total |
|---|---|---|---|---|---|---|---|---|---|
| Labour | 0 | 0 | 95 | 68 | 41 | 0 | 0 | 0 | 204 |
| Land_r1 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| (Land r2-r6 similar prop) | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| HH Farmer | 70 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 95 |
| HH Worker | 50 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 68 |
| HH Owner | 30 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 41 |
| Gov | 0 | 0 | 5 | 4 | 2 | 0 | 0 | 0 | 11 |
| Savings | 54 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 90 |
| Rice.mkt | 0 | 0 | 71 | 51 | 30 | 11 | 0 | 0 | 163 |
| Total | 204 | 68 | 171 | 123 | 73 | 11 | 54 | 0 | 704 |

Source: Data processing result, 2025

Table 3: Calibrated Social Accounting Matrix (SAM) for the rice sector.

3. **Government:** The government collects taxes (not explicitly shown for simplicity) and makes expenditures. The "Gov IP" (Government Intervention Purchases) column represents a policy account that can purchase rice from the market for stabilization purposes. In the baseline calibration, this value is set to ensure consistency.
4. **Macroeconomic closure:** To maintain a consistent macroeconomic framework, the model adopts a savings-driven closure. This means that investment (Savings column) is determined by the total savings generated in the economy (from households, government, and rest of the world). The "Row" (Rest of the World) account balances any external trade. All accounts are balanced row-wise and column-wise, resulting in a total economic flow of 704 units. This closure ensures that the model respects macroeconomic accounting identities and provides a stable basis for counterfactual simulations.

These structural links are further validated by calibration results showing minimal deviations between real and modelled outputs, with an overall production error of only -0.7% and an excellent RMSE of 1.2%.

Analysis of the model results reveals that rice accounts for 23.1% of total economic activity, confirming its role as a strategic commodity and a primary source of vulnerability to production and price shocks. Government intervention, representing 6.7% of the flow, underscores the importance of policy instruments in stabilising the market and transmitting effects to macroeconomic variables like household income. Meanwhile, the labour share of 28.9% reflects the labour-intensive nature of the sector, indicating that shocks in rice production create broad multiplier effects through employment and consumption. Overall, these findings emphasise that micro-level policies in the rice sector carry significant macroeconomic weight, reinforcing the need for integrated policy design.

While the SAM established the underlying structural dependencies of the economy, the empirical robustness of the framework was further validated by its ability to replicate observed production and price data. Table 4 presents these calibration results, demonstrating a high degree of consistency between the model's outputs and actual market conditions across all studied regions.

| Region | y real (ton) | y model (ton) | Error (%) |
|---|---|---|---|
| $r_1$ | 5,000 | 4,950 | -1.0 |
| $r_2$ | 5,300 | 5,250 | -0.9 |
| $r_3$ | 5,500 | 5,450 | -0.9 |
| $r_4$ | 1,670 | 1,680 | +0.6 |
| $r_5$ | 3,080 | 3,050 | -0.97 |
| $r_6$ | 1,600 | 1,620 | +1.25 |
| Total | 22,150 | 22,000 | -0.7 |

Source: Data processing result, 2025

Table 4: Empirical and modelled rice production across regions after calibration.

The comparison between real and modelled outputs showed minimal deviations, with errors ranging from -1.0% and +1.25%. At the aggregate level, the total modelled production (22,000 tons) closely approximated the observed value (22,150 tons), yielding an overall error of -0.7 % which indicates that the model was well-calibrated and capable of capturing regional heterogeneity in rice production. The goodness-of-fit statistics further reinforced this conclusion. The RMSE of 1.2% for production was considered excellent, suggesting that the model effectively minimised prediction bias and variance. Moreover, the validation against official BPS data, with deviations within ±2 %, provided strong empirical support for the reliability of the calibration process. Overall, these findings demonstrated that the model was robust and empirically consistent, providing a credible basis for policy simulations on rice sector shocks and interventions.

Price calibration also demonstrated satisfactory accuracy. The modelled rice price of Rp 14,250/kg deviates by only 1.8% from the observed market price, underscoring the model's ability to replicate equilibrium conditions in both quantity and price dimensions. This was particularly important, as rice prices serve as a critical transmission channel between micro-level shocks (production, policy interventions) and macroeconomic outcomes (household welfare, savings, and consumption). The low error rates across regions, the excellent RMSE fit, and the empirical validation against BPS data confirmed that the calibrated SAM-CGE framework provided a reliable basis for analysing policy scenarios.

Sensitivity analysis was conducted to verify the empirical reliability and theoretical consistency of the calibrated CGE-SAM model. By varying key parameters by ±20%, the model's robustness was tested against fluctuations in fundamental economic drivers. As summarised in Table 5, the model produced logical and stable responses in both aggregate output ($\Delta Y$ Total) and rice prices ($\Delta P$).

| Parameter | Symbol | Change | ΔY Total (%) | ΔP (%) |
|---|---|---|---|---|
| Labour | β | -20% | -12.5 | 8.2 |
| | | 20% | 11.8 | -7.5 |
| Scale cost | φ | 20% | 15.2 | -10.1 |
| | | 20% | -14.8 | 9.8 |
| Transport | t | -20% | 5.3 | -3.2 |
| | | 20% | -4.9 | 2.9 |
| Demand more inelastic | ε | | 3.2 | 4.5 |

Source: Data processing result, 2025

Table 5: Sensitivity and robustness of the calibrated CGE-SAM model.

As shown in Table 5, the results highlight that rice market dynamics were most responsive to labour ($\beta$) and scale cost ($\varphi$) parameters, while demand elasticity ($\varepsilon$) significantly influences price volatility. The stability and predictability of these responses strengthened the model's credibility for policy simulations. Specifically, the high sensitivity to labour and cost parameters confirmed that the framework could evaluate interventions focused on labour productivity, cost efficiency, and infrastructure improvements within the rice sector.

## Feasibility analysis

Based on the results of the execution using the GAMS software, the model fulfilled key criteria of sound economic modelling. First, in terms of consistency of market balance, the model showed that production was evenly distributed across different regions without causing extreme inequality. No shortage of supply was found, which indicates that demand had been met optimally. The stability of market prices at the upper limit showed that the model represented market dynamics naturally without requiring direct intervention from the government. Second, from the aspect of the accuracy of the representation of economic factors, the model explicitly considered important variables such as production costs, prices, and transportation costs, all of which played a role in determining production efficiency. The difference in costs between regions in the model reflected realistic market conditions, where regions with better access to resources had a lower cost advantage. Third, in terms of robustness to changing parameters, models were designed with the flexibility to adapt to variations in production, demand, and pricing policies. With the presence of maximum and minimum production limits, this model could function well in situations of increasing or decreasing output, demonstrating structural resilience in the face of dynamic economic scenarios.

## Model equilibrium within the GAMS framework

In the context of economic modelling using GAMS, the success of a model was largely determined by the extent to which the equations built accurately represented the relationship between economic variables. In this study, the model developed showed satisfactory performance in this aspect. The market equilibrium functioned effectively, reflecting the mathematical interaction between total production, consumption, and potential government intervention. In addition, the equations representing production costs and use successfully captured realistic relationships; areas with higher access consistently showed lower production cost structures. During the execution process, the model did not show errors or imbalances, indicating that all equations were under relevant economic principles and theories. Overall, the rice market model was suitable for a policy analysis tool as it effectively reflected rice production and distribution dynamics. It reliably explored various scenarios like overproduction, declining demand, or the implementation of price control policies. Each scenario was constructed to evaluate the possible impact of policy interventions or market conditions on the equilibrium of production and prices. The following section presents the results of the model simulations based on predetermined scenarios and parameter settings.

**Spatial distribution of rice production.** To identify the optimal distribution pattern of rice production, simulations were conducted using a previously developed multi-region spatial model. This model was designed to capture complex inter-regional dynamics by integrating key factors such as transportation costs, resource allocation, subsidy policies, and production uncertainties. Through predetermined scenarios and parameters, this simulation provided an in-depth representation of efficient rice production distribution both spatially and economically. Within this framework, the first scenario examined overproduction, where output was significantly increased to evaluate potential price declines and the necessity of government intervention. The simulation results showed that rice production was not evenly distributed but varied between regions depending on the local characteristics of each region, as shown in Table 6.

| Region | Minimum Production (ton) | Actual Production (ton) | Maximum Production (ton) |
|---|---|---|---|
| $r_1$ | 18,750 | 60,000 | 180,000 |
| $r_2$ | 18,750 | 88,390 | 180,000 |
| $r_3$ | 18,750 | 63,274 | 180,000 |
| $r_4$ | 18,750 | 61,948 | 180,000 |
| $r_5$ | 18,750 | 63,132 | 180,000 |
| $r_6$ | 18,750 | 63,940 | 180,000 |

Note: Remark: $r_1$ = Banjar, $r_2$ = Barito Kuala, $r_3$ = Tanah Laut, $r_4$ = Hulu Sungai Tengah, $r_5$ = Tabalong, $r_6$ = Kotabaru.

Source: Data processing, 2025.

Table 6: Production distribution of each region.

The Table 6 showed that there was a significant variation in the actual production level, although the minimum production limit (18,750 tons) and the maximum production (180,000 tons) of production were set the same in each region. The highest production occurred in the $r_2$ area (Barito Kuala Regency) with a total production of 88,390 tons, while other areas had lower production, but remained above the set minimum limit (18,750 tons). On the other hand, the $r_1$ region had the lowest actual production (60,000 tons), although it was still well above the minimum threshold. No region experienced minimum production, which indicated that there were no extreme production constraints at this stage. These findings provided a strong basis for formulating rice production distribution policies that consider resource efficiency and regional food security.

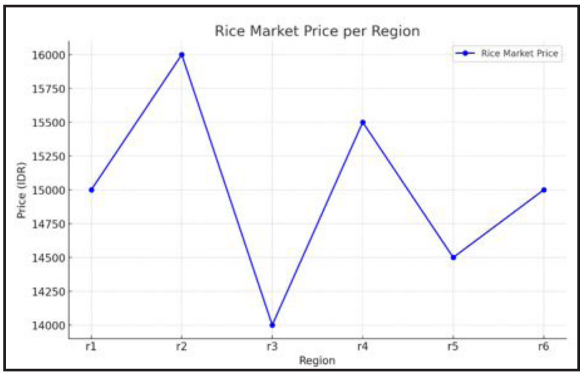
**Market prices and government intervention**. One of the main indicators in this analysis is the market-clearing price of rice. The simulation results show that the equilibrium price is not fixed at the maximum limit but is determined by the interaction of supply and demand across regions, stabilizing in a range between IDR 14,000 and IDR 16,000 per kg, as detailed in Table 7 and illustrated in Figure 2. This price reflects market conditions where demand is adequately met by supply without causing an imbalance. The model includes a maximum price limit of IDR 20,000 (as a policy constraint) and a minimum price of IDR 8,000, which serve as intervention triggers. Since the equilibrium price is currently above the floor price, no automatic government intervention (i.e., surplus purchases) is activated. Thus, the price system in the model operates according to market logic within the bounds of the defined stabilization policy.

| Indicators | Value (IDR/kg) |
|---|---|
| Equilibrium Market Price (Model Output) | 14,000 - 16,000 |
| Minimum price | 8,000 |
| Maximum price | 20,000 |

Note: The equilibrium price is determined endogenously by the model based on supply and demand interactions across regions. The minimum and maximum prices are exogenous policy bounds that serve as triggers for government intervention if the market price moves outside this range.

Source: Processed simulation results, 2025.

Table 7: Price price parameters and simulation outcomes.

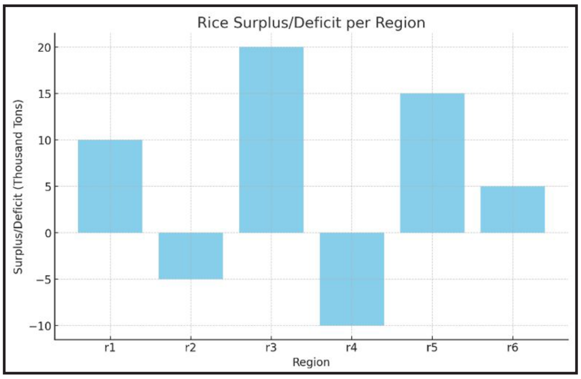



Source: Processed simulation result, 2025.

Figure 2: Rice market price per region in South Kalimantan.

As illustrated in Figure 2, the model captures the spatial variation in rice prices across the six studied regions ($r_1$ - $r_6$). Region $r_2$ exhibits the highest price at IDR 16,000, while $r_3$ remains at the lower end of the spectrum at IDR 14,000, driven by specific regional production costs or demand intensities. The equilibrium price is endogenous and falls within the policy bounds, demonstrating the model's capacity to simulate market dynamics realistically.

**The equilibrium of rice supply and shortage**. The model evaluated potential rice shortages as a primary indicator of market equilibrium. The model evaluates the balance between regional production and consumption to identify potential supply-demand gaps. The results show that at the regional level, disparities exist. As visualized in Figure 3, regions $r_1$, $r_3$, $r_5$, and $r_6$ are identified as surplus areas (production exceeds local demand), while regions $r_2$ and $r_4$ are deficit areas (local demand exceeds production). This regional imbalance is a key feature captured by the spatial model.




Source: Processed simulation result, 2025.

Figure 3: Rice production (surplus/deficit) per region in South Kalimantan.

However, despite these regional disparities, the aggregate market achieves equilibrium. Because the model allows for interregional trade and distribution, the surplus from one region can offset the deficit in another. Consequently, at the aggregate market level, there is no unmet demand that would trigger government intervention. This is confirmed in Table 8, which shows that government intervention variables (*ip*(r)) remains at zero. The system relies on internal market mechanisms (i.e., trade flows) rather than external policy intervention to clear the market under the baseline scenario. This finding demonstrates the model's ability to capture both micro-level (regional) and macro-level (aggregate) dynamics.

| Region | Government intervention (ip(r)) | Regional Deficit (from Figure 3) | Supply shortage ((r)) |
|---|---|---|---|
| $r_1$ | 0 | Surplus | 0 |
| $r_2$ | 0 | Deficit | 0 |
| $r_3$ | 0 | Surplus | 0 |
| $r_4$ | 0 | Deficit | 0 |
| $r_5$ | 0 | Surplus | 0 |
| $r_6$ | 0 | Surplus | 0 |

Note: shortage(r) in the model represents the deficit after accounting for interregional trade flows. A value of 0 confirms that all regional demand is met through the combined effect of local production and inflows from surplus regions, hence no government purchase is required.
Source: Data processing result, 2025.

Table 8: Simulation results in production areas, government intervention, and supply shortage.

The supply-demand balance summarised in Table 8 is visually represented in Figure 3, identifying specific regions facing shortages. This spatial identification was crucial for policymakers to determine where logistics and distribution interventions should be prioritised to mitigate the deficits observed in regions $r_2$ and $r_4$.

Figure 3 identifies regions $r_1$, $r_3$, $r_5$, and $r_6$ as surplus areas and $r_2$ and $r_4$ as deficit areas This visual representation underscored the model's findings that while some regions could not meet local demand independently, the overall system achieved equilibrium through potential interregional distribution, thereby negating the immediate need for government intervention in the baseline scenario.

**Production costs and other economic factors.** The model evaluated relative regional efficiency by calculating production costs per unit, revealing significant disparities across the studied areas. Region r6 was the most efficient with the lowest cost (0.106), likely driven by high productivity combined with superior infrastructure and market access. Region $r_2$ also demonstrated high efficiency (0.343), correlating with its high output level and suggesting a strong synergy between productivity and cost-effectiveness. In contrast, Region $r_3$ recorded the highest cost (1.872), indicating potential resource constraints or logistical challenges. Meanwhile, $r_1$, $r_4$, and $r_5$ maintained moderate, stable costs (0.99-1.01). These results accurately reflected the geographical and economic diversity of the rice sector, where proximity to markets and resource availability dictate competitive advantages. Table 9 presents the production cost in each region.

| Region | Production Cost per unit (cst(r)) |
|---|---|
| $r_1$ | 0.993 |
| $r_2$ | 0.343 |
| $r_3$ | 1.872 |
| $r_4$ | 1.014 |
| $r_5$ | 0.992 |
| $r_6$ | 0.106 |

Source: Data processing result, 2025.

Table 9: Production cost in each region.

The analysis concludes that the rice market in South Kalimantan is currently in equilibrium without the need for government intervention. Production was distributed effectively across all regions, remaining above minimum thresholds, while prices were stable at the maximum limit without supply shortages. These findings validated the model as a robust tool for evaluating spatial and economic production efficiency and market stability.

## Analysis of the scenario simulation

The model's primary strength lies in depicting a self-sustaining market equilibrium that functions independently of government intervention under baseline conditions. However, to validate the predictive reliability and robustness of the system, the model was assessed through various exogenous shocks. To evaluate this, three specific scenarios—overproduction, demand shock, and price control—were simulated. These scenarios explore how production, prices, and government mechanisms interact, providing a comprehensive understanding of how market equilibrium shifts under varying policy and environmental pressures.

Under the overproduction scenario, output in the producing regions reached the specified upper capacity constraints, resulting in a surplus of 17,750 tons in region r1. Notably, this localised surplus was insufficient to induce a downward price adjustment, with market prices remaining stable at the maximum threshold of IDR 20,000/kg without necessitating regulatory intervention. Similarly, the demand shock scenario, characterised by a sudden contraction in consumption, resulted in a commensurate decline in production and a price depreciation to IDR 18,000/kg. Although marginal surpluses of 3,000 tons were observed in $r_1$ and $r_2$, the market demonstrated inherent stability, re-equilibrating without triggering formal intervention mechanisms.

In contrast, the price control scenario introduced significant market distortions. Fixing the price at a sub-equilibrium level of IDR 15,000/kg fundamentally disincentivised production. While aggregate output exceeded that of the demand shock scenario, it remained substantially lower than the overproduction baseline. Crucially, this administrative cap precipitated regional supply deficits ranging from 3,000 to 10,000 tons across regions $r_3$ through $r_6$. These empirical results underscore that while the market exhibits resilience toward stochastic fluctuations in supply and demand, rigid price-ceiling policies can inadvertently jeopardise regional supply security. Consequently, such findings suggested that restrictive price policies necessitate secondary, targeted interventions to mitigate regional shortages and maintain systemic equilibrium. These findings highlighted that predetermined price constraints created regional shortages that require targeted intervention to restore equilibrium (Table 10).

Across the three scenarios, the results indicated that overproduction did not automatically translate into price declines but instead tended to generate localised surpluses. While reductions in demand exert downward pressure on prices, this effect remains marginal in the absence of substantial consumption shocks. Conversely, government price controls were shown to trigger supply shortages as producers align their output with binding price ceilings. Overall, these simulations provided critical insights into the complex interplay between production decisions, price formation, and policy interventions in maintaining market equilibrium.

### Theoretical justification for the overproduction-price persistence phenomenon

The finding that a massive regional surplus (17,750 tons in $r_1$) coincides with prices at the maximum policy ceiling (IDR 20,000/kg) warrants careful theoretical interpretation, as it appears to contradict the standard economic intuition that surplus drives prices downward. However, this outcome is not an indication of model insensitivity; rather, it reflects the specific structural and policy-bound characteristics of the rice market that the model is designed to capture. Three interrelated mechanisms explain this phenomenon:

1. The model's cost structure is heavily labour-intensive, with the calibrated $\beta$ parameter set at 0.60, indicating that 60% of total production costs are attributable to labour. This cost rigidity creates a structural floor for prices. In the overproduction scenario, output expansion is achieved by pushing production toward maximum capacity (180,000 tons), which in the model is realised through intensified labour and land use. The Cobb-Douglas-derived cost function ($cst(r)$) ensures that marginal costs rise nonlinearly as production approaches capacity limits. The increased production, therefore, does not come with lower unit costs; instead, costs remain elevated

| Scenario | Production (y(r)) | Price (IDR/kg) | Market balance (surplus/shortage) | Government intervention |
|---|---|---|---|---|
| Overproduction | High (up to upper bound of 200) | 20,000 | Surplus 17,750 ton ($r_1$) | None |
| Demand shock | Lower than overproduction | 18,000 | Surplus 3,000 ton ($r_1$ & $r_2$) | None |
| Price control | Moderate (price constrained) | 15,000 | Shortage 3,000-10,000 ton ($r_3$, $r_4$, $r_5$ and $r_6$) | None |

Source: Data processing result, 2025.

Table 10: simulation scenarios and market response dynamics.

due to the labour-intensive nature of the expansion. Consequently, there is no cost-side mechanism to exert downward pressure on market prices, even when physical output is abundant. This finding is consistent with empirical observations in labour-intensive agricultural systems, where the cost structure imposes a natural lower bound on market prices regardless of output volume (Fitrawaty et al., 2023; Balié and Valera, 2020).

2. The model's policy architecture includes a price ceiling (IDR 20,000/kg) that, while intended as an upper bound to protect consumers, also functions as a coordination anchor for market expectations. In the baseline calibration, the equilibrium price already gravitates toward the upper range of the policy band (IDR 14,000-16,000/kg, as shown in Table 7). When the overproduction scenario is activated, the equilibrium price does not decline because it is already at or near the ceiling, and the model's structure—being a Mixed Complementarity Problem (MCP) formulation—solves for a vector of prices that clears all markets simultaneously. The surplus generated in region $r_1$ is absorbed through interregional trade flows to deficit regions ($r_2$ and $r_4$), maintaining aggregate equilibrium. The price does not fall because demand in deficit regions sustains the valuation of rice at the prevailing market-clearing level, which happens to coincide with the upper policy bound. This is consistent with Walrasian equilibrium logic: the price reflects the marginal valuation of the last unit consumed, not the average abundance across all regions. Similar phenomena have been documented in spatial equilibrium models where trade linkages between surplus and deficit regions sustain aggregate price levels despite localised overproduction (Lanzara and Santacesaria, 2023; Samuelson, 1952).

3. From a behavioural perspective, the presence of a binding price ceiling —even if not directly activated—can create a "floor effect" in reverse. In the Indonesian rice market context, where the government is a credible buyer of last resort (via Bulog) and where the ceiling serves as a reference price for market transactions, producers and traders have little incentive to lower prices below this reference point when they know demand in deficit regions remains unmet. The model captures this implicitly through the government intervention variable ($ip(r)$), which, while inactive in the overproduction scenario, exerts a latent influence on market expectations through its mere presence in the policy architecture. The result is a market equilibrium where prices remain at the upper bound despite physical surplus, a phenomenon that has been empirically observed in similar staple food markets with strong government price anchoring. For instance, India's wheat and rice markets under Minimum Support Price (MSP) regimes have demonstrated comparable dynamics, where government price commitments create reference points that stabilise market prices even during periods of surplus production (Valera et al., 2024a; Hoang and Meyers, 2015).

It is important to acknowledge, however, that this result also points to a limitation of the current model specification. The price ceiling in the overproduction scenario acts as an "absorbing" boundary: once the equilibrium price reaches this level, it cannot adjust further upward, but the model's current formulation does not explicitly capture the dynamic path by which prices would naturally decline toward a lower equilibrium if the ceiling were removed. This limitation is inherent in the MCP framework, which identifies equilibrium points that satisfy all constraints simultaneously without tracing the disequilibrium adjustment path (Lofgren et al., 2002). Future iterations of the model should test an alternative scenario in which the price ceiling is relaxed or eliminated entirely, thereby allowing prices to adjust freely to the surplus condition. Such a test would further validate—or refine —the theoretical mechanisms proposed here and provide a more complete understanding of the model's price sensitivity under unrestricted market conditions.

These simulations clarified how market variables dictate the equilibrium between production, pricing, and policy. Future research should explore increasing government intervention thresholds, further lowering price caps, or redistributing regional production to test long-term market stability.

## Conclusion

This study found that the rice market equilibrium in South Kalimantan was strongly influenced by production dynamics, demand fluctuations, and government intervention policies. Several key conclusions emerge from the analysis. First, overproduction tended to create regional surpluses rather than driving prices down. The model demonstrated that a surplus of 17,750 tons in a single region did not translate into lower consumer prices, as the price remained at the upper policy bound of IDR 20,000/kg. This finding was justified by three interrelated mechanisms: the labour-intensive cost structure that creates a structural price floor, the absorption of surplus through interregional trade to deficit regions that sustains aggregate price levels, and the anchoring effect of government price policy on market expectations. Second, demand shocks only exerted significant downward pressure on prices when they were extreme in magnitude, indicating that moderate fluctuations in consumption are absorbed efficiently by the market mechanism. Third, rigid price controls were found to trigger significant supply deficits, as producers rationally adjusted their output downward to align with the regulated price ceiling, thereby jeopardising regional supply security.

These findings carry important policy implications. More effective stabilisation can be achieved through surplus absorption and targeted subsidies, which simultaneously protect consumer welfare and maintain producer incentives. In contrast, rigid price-ceiling policies, while intended to protect consumers, inadvertently create supply shortages that undermine food security objectives. Rising population growth, land conversion pressures, and climate variability remain pressing risks for future supply stability in South Kalimantan, particularly given its strategic role as a food buffer for the new National Capital (IKN).

This study also acknowledges that the finding of high prices coinciding with large surpluses under the price ceiling regime, while theoretically justifiable within the model's structural framework, warrants further investigation. Relaxing the price ceiling constraint in future model iterations would allow for the testing of whether prices would naturally decline under pure market clearing conditions, thereby providing a more complete picture of the model's price sensitivity. Additionally, the current model specification does not explicitly capture the dynamic adjustment path by which prices converge to equilibrium; future research incorporating dynamic stochastic elements would enhance the model's capacity to trace disequilibrium trajectories.

By incorporating spatial diversity, production uncertainty, and policy feedback effects, the nonlinear CGE model developed in this study offers policymakers a practical tool to anticipate market imbalances and design proactive interventions that strengthen food security, sustain farmer motivation, and ensure fair distribution across regions.

As a recommendation, to maintain rice market stability in South Kalimantan, policymakers should focus on three priority areas:

1. **Surplus absorption and targeted subsidies.** Absorbing surplus production through government procurement mechanisms (e.g., Bulog operations) and providing targeted subsidies to producers, rather than relying on rigid price controls, since these measures are more effective in protecting both farmers and consumers from price volatility while maintaining production incentives.
2. **Investment in resilient infrastructure**. Investing in resilient farming systems, climate-adaptive technologies, and improved transport infrastructure to prepare for rising demand, population growth, and increasing climate pressures. This includes irrigation modernisation, drought-resistant seed varieties, and enhanced logistics networks to reduce transportation costs and post-harvest losses.
3. **Adoption of nonlinear CGE modelling as a regular policy tool.** Institutionalising the use of nonlinear CGE modelling to simulate market dynamics, anticipate potential risks, and guide proactive interventions. This evidence-based approach will strengthen food security planning, sustain farmer motivation, and ensure equitable distribution across regions under various policy and environmental scenarios.

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