

# Farm Size, Cost Structure, and Private Profitability in Smallholder Rice Farming: Evidence from Musi Rawas Regency

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## ABSTRACT

Smallholder rice farming in Indonesia faces persistent challenges in maintaining economic viability under limited operational scale and rising production costs. Understanding whether farm-size advantages arise primarily from lower production costs or from higher output prices is therefore important for assessing the economic performance of rice farming. This study aims to examine the association between farm size, cost competitiveness, and private profitability and to determine whether the observed farm-size–profitability relationship is more consistent with differences in unit production costs or realised farm-gate prices. Cross-sectional data were obtained from 228 rice farms in Musi Rawas Regency during the first planting season of 2024. Farms were classified by harvested area into  $\leq 0.50$  ha,  $>0.50$ – $1.00$  ha, and  $>1.00$  ha. The analysis employed descriptive statistics, the Kruskal–Wallis test, pairwise Mann–Whitney comparisons with Holm correction, and ordinary least squares regression with HC3 standard errors and sub-district fixed effects. The median total production cost per hectare declined from IDR6.41 million in the smallest farm-size group to IDR5.81 million and IDR3.14 million in the two larger groups, with statistically significant differences across farm-size classes. Unit production costs also differed across groups, although consistent pairwise differences were mainly observed between the smallest and medium-sized farms. In the multivariate models, larger farm size was significantly associated with lower production cost per hectare, whereas its associations with unit production cost, realised farm-gate price, and the R/C ratio were not statistically significant at conventional levels. The accounting decomposition indicates that the positive farm-size coefficient in private profitability is mechanically more consistent with the unit-cost component than with the price component, although this pattern is statistically inconclusive. These findings suggest the presence of a farm-size cost advantage but do not establish that expanding cultivated area directly improves profitability. Potential policy implications include facilitating operational consolidation, shared machinery services, collective input procurement, and more reliable irrigation management for smallholder rice farms.

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## 1. Introduction

Rice remains strategically important in Indonesia's food system as the principal staple crop and an important component of rural livelihoods and agricultural economic activity. In

2024, Indonesia harvested approximately 10.05 million hectares of paddy and produced 53.14 million tonnes of dry unhusked rice, equivalent to about 30.62 million tonnes of rice for domestic food consumption (BPS, 2025). However, the economic performance of rice farming cannot be assessed solely by production or land productivity. Farm competitiveness also depends on whether output is produced under a sustainable cost structure and generates adequate private returns. Recent Indonesian evidence shows that rice-farm competitiveness and profitability are jointly shaped by revenues, production costs, input use, and realised output prices rather than by physical production alone (Ningsih *et al.*, 2024; Widyastutik W *et al.*, 2026). This distinction is especially relevant in a smallholder-dominated production structure, where limited operational scale may constrain the organisation of production resources and cost efficiency.

Operational farm size can influence economic performance through the way production costs are organised and distributed. Larger cultivated areas may provide greater opportunities to spread relatively fixed costs, organise labour and machinery services, coordinate input use, and reduce production costs per unit of land or output. Conversely, small farms may benefit from intensive family-labour supervision but face constraints in mechanisation, input procurement, and the spreading of fixed costs. In this study, such relationships are interpreted as farm-size cost advantages or economies of size, rather than returns to scale, because the analysis does not estimate how output responds to proportional changes in all production inputs. Evidence from Indonesian rice farming indicates that cost efficiency is related to farm size, labour, fertiliser use, irrigation, and other operational characteristics (Siagian & Soetjipto, 2020; Ramadani *et al.*, 2024), while production-factor management is closely associated with rice-farm income and economic performance (Andajani *et al.*, 2022)

Farm-size advantages are nevertheless not automatic because the economic consequences of operational scale depend on how effectively labour, water, technology, and other inputs are converted into output. Indonesian studies show that varieties, nutrient management, irrigation, technological conditions, production environments, and farmer characteristics are associated with differences in rice productivity, technical efficiency, and economic performance (Erythrina *et al.*, 2021; Sumaryanto *et al.*, 2023; Rondhi *et al.*, 2024; Dewi *et al.*, 2026). Input availability and institutional arrangements can also affect farm profitability through their effects on production costs (Marendra *et al.*, 2026). These findings suggest that larger operational size should not be equated automatically with greater efficiency; instead, its economic relevance should be examined through the cost structure and profitability actually observed at the farm level.

Private profitability provides a useful framework for examining this relationship because farm returns depend jointly on realised output prices and production costs. The R/C ratio compares total farm revenue with recorded production costs (Andajani *et al.*, 2022). Because revenue can be expressed as realised price multiplied by output and total cost as unit production cost multiplied by the same output, the ratio can also be written as  $R/C = P/UC$ . This identity separates private profitability into a price component and a unit-cost component, allowing the observed farm-size–profitability relationship to be examined more directly. This distinction is consistent with recent evidence that input costs, output prices, and private profitability are jointly relevant to rice-farm competitiveness (Ningsih *et al.*, 2024)

Despite growing research on rice productivity, technical efficiency, cost efficiency, and profitability, these dimensions are commonly examined through separate analytical approaches. Cost-efficiency studies focus primarily on input use and production

characteristics, whereas profitability and competitiveness studies generally rely on aggregate farm-income or policy-based indicators (Ramadani *et al.*, 2024). Less attention has therefore been given to whether differences in private profitability associated with operational farm size are more consistent with lower unit production costs or with higher realised output prices. This study addresses that gap by jointly examining farm size, production cost per hectare, unit production cost, realised farm-gate price, and private profitability using the same farm-level observations. Specifically, it evaluates their conditional associations after accounting for farmer characteristics, irrigation access, and location heterogeneity and uses an accounting-based coefficient decomposition to assess whether the observed farm-size profitability association is mechanically more consistent with the unit-cost or price component. Because the data are cross-sectional, the decomposition is interpreted as an accounting relationship rather than evidence of causal mediation.

## 2. Methodology

### 2.1 Research Design, Location, and Data Sources

This study used a non-experimental cross-sectional design to examine conditional associations between operational farm size, production costs, realised farm-gate prices, and private profitability. Cross-sectional observational data are appropriate for assessing contemporaneous associations but do not, without stronger identification assumptions, establish causal effects (Sterrantino, 2024). Data were obtained from a rice-farming survey conducted in Musi Rawas Regency, South Sumatra, from May to August 2024, with the first rice-planting season of 2024 as the analytical reference period. The survey population comprised 18,216 rice farmers, and the original survey documentation reports that the sample size was determined using the Slovin method. The final analytical sample consisted of 228 farms. Verification of the respondent-level data identified ten observed location categories: Tugumulyo, Sumber Harta, Purwodadi, Megang Sakti, STL Ulu Terawas, Muara Beliti, Muara Kelingi, Muara Lakitan, Tuah Negeri, and Sukakarya. Because the source documentation does not provide sufficient detail to verify the within-location respondent-selection procedure, no stronger probability-sampling claim is made.

### 2.2 Variable Construction and Cost Competitiveness Indicators

Operational farm size was measured by harvested area in hectares and entered in logarithmic form in the regression models. For descriptive comparisons, farms were classified as  $\leq 0.50$  ha,  $>0.50$ – $1.00$  ha, and  $>1.00$  ha. Recorded total production cost included equipment depreciation and observed expenditures on seed, fertiliser, pesticides, labour, and other recorded production inputs. Because the survey does not comprehensively capture land rent, own-capital costs, family-labour opportunity costs, and other implicit costs, profitability is interpreted as private accounting profitability rather than full economic profit.

The principal economic indicators were constructed as follows:

$$UC_i = TC_i / Q_i \dots\dots\dots [1]$$

Where  $UC_i$  is the production cost per unit (Rp/kg),  $TC_i$  is the total recorded production cost per planting season (Rp/MT), and  $Q_i$  is the amount of output per planting season (kg/MT). The lower the  $UC_i$ , the stronger the cost competitiveness at the farming level, noting that the type of output and unit of product have been verified consistently.

$$CAPH_i = TC_i / A_i \dots\dots\dots[2]$$

CAPH<sub>i</sub> is the production cost per hectare (Rp/ha), and A<sub>i</sub> is the harvest area (ha). Cost per hectare is used as a supporting indicator to see if the scale of business is related to a decrease in cost per unit of land.

$$P_i = TR_i / Q_i \dots\dots\dots[3]$$

To maintain the consistency of the accounting identity in the analysis mechanism, the main output price is calculated from the receipts divided by the amount of output. The price recorded directly on the questionnaire is still stored as an audit variable and compared to the price of the calculation results. Thus, the price channel in the decomposition model uses calculated farm-gate prices to meet the revenue identity consistently.

$$RC_i = TR_i / TC_i \dots\dots\dots[4]$$

$$PM_i = (TR_i - TC_i) / TR_i \dots\dots\dots[5]$$

$$INC\_HA_i = (TR_i - TC_i) / A_i \dots\dots\dots[6]$$

$$UM_i = P_i - UC_i \dots\dots\dots[7]$$

Where UC is unit production cost, CAPH is production cost per hectare, P is realised farm-gate price, RC is the revenue–cost ratio, TC is recorded total cost, TR is total revenue, Q is output, and A is harvested area. Unit margin, revenue margin, and income per hectare were retained as supporting descriptive indicators rather than principal regression outcomes.

### 2.3 Descriptive and farm size group comparisons

The sample was summarised using the mean, median, standard deviation, interquartile range, minimum, and maximum. Because several economic variables were right-skewed and contained influential upper-tail observations, medians and interquartile ranges were emphasised in farm-size comparisons because they are less sensitive to extreme values (Sidebotham & Hewson, 2025). Differences across the three farm-size classes were tested using the Kruskal–Wallis rank test. Where the overall test was significant, pairwise Mann–Whitney comparisons were conducted with Holm adjustment to control the family-wise error rate. Effect sizes were reported alongside p-values so that interpretation did not rely on statistical significance alone.

### 2.4 Multivariate models and mechanical decomposition

Farm-size associations were estimated using ordinary least squares with the same sample, controls, and location fixed effects across four outcomes: production cost per hectare, unit production cost, realised farm-gate price, and the R/C ratio. The common specification was:

$$\ln(Y_{ij}) = \alpha + \beta \ln(A_{ij}) + \gamma_1 IRR_{ij} + \gamma_2 EXP_{ij} + \gamma_3 HH_{ij} + \delta_j + \varepsilon_{ij} \dots\dots\dots[8]$$

Where Y alternatively represents CAPH, UC, P, or RC; A is harvested area; IRR is irrigation access; EXP is farming experience; HH is household size; and  $\delta_j$  denotes location fixed effects. The ten observed locations imply one reference category and nine location indicators. The coefficient  $\beta$  is interpreted as a conditional association. For the cost-per-hectare equation, a negative coefficient is described as a farm-size cost advantage or

economies-of-size pattern, not as technical returns to scale, because no production function is estimated.

The profitability decomposition follows the accounting identity:

$$RC_i = P_i / UC_i \quad \text{and} \quad \ln(RC_i) = \ln(P_i) - \ln(UC_i) \dots \dots \dots [9]$$

$$\beta_{RC} = \beta_P - \beta_{UC} \dots \dots \dots [10]$$

When the same observations, controls, and fixed effects are used, this identity permits a mechanical decomposition of the farm-size–profitability coefficient into price and unit-cost components. The decomposition is interpreted as an accounting relationship among coefficients, not as causal mediation or as evidence that one component statistically causes profitability.

## 2.5 Statistical inference, robustness, and diagnostics

Baseline inference used HC3 heteroskedasticity-consistent standard errors, which provide improved finite-sample performance under heteroskedasticity and leverage. Because farms within the same location may share local production, infrastructure, market, and institutional conditions, sensitivity inference was also calculated using location-clustered standard errors. Given the limited number of location clusters, these results were supplemented with wild-cluster bootstrap inference, consistent with current guidance for cluster-robust inference when cluster counts are small or uneven

Robustness checks additionally replaced continuous farm size with the three farm-size classes. Multicollinearity, functional form, heteroskedasticity, leverage, Cook's distance, and studentised residuals were inspected as model diagnostics. Potentially influential observations were evaluated rather than automatically removed. Statistical conclusions were based on the stability of coefficient signs and magnitudes across alternative specifications and inference procedures, with particular attention to whether statistical significance remained robust.

## 3. Results and Discussion

The results are presented sequentially from the distributional characteristics of the sample to farm-size group comparisons and multivariate analysis. The empirical findings are interpreted within an economies-of-size and private-profitability framework, in which operational farm size may be associated with differences in cost structure, resource-use efficiency, and access to production technologies, while private profitability reflects the relationship among output, realised output prices, and production costs (Oelviani *et al.*, 2024; Ren *et al.*, 2024). Recent evidence confirms that farm size remains an important structural characteristic of agricultural production because farms of different sizes may differ in their capacity to use machinery, technology, labour, and other production resources efficiently (Ren *et al.*, 2024). In the Indonesian rice sector, competitiveness has likewise been evaluated through the relationship between revenues and production costs rather than physical production alone, while recent micro-level evidence shows that rice-farm profitability is associated with production quantity, realised rice prices, and total production costs (R A Chairunnisya *et al.*, 2025).

Because the data are cross-sectional, all regression coefficients are interpreted as conditional associations rather than causal effects. This distinction is important in observational research because estimated relationships may still reflect measured and

unmeasured heterogeneity, and causal claims require stronger identification assumptions than those provided by a conventional cross-sectional regression design (Sterrantino, 2024a). Recent research on Indonesian smallholder rice farming similarly highlights the importance of accounting for technological, managerial, and regional heterogeneity when interpreting differences in farm efficiency (Husna *et al.*, 2020; Rondhi *et al.*, 2024). Explanations involving fixed-cost spreading, labour organisation, machinery services, input procurement, and other production arrangements are therefore treated as possible economic mechanisms where these factors are not directly measured in the dataset. This cautious interpretation is consistent with recent evidence showing that agricultural mechanisation in Indonesia is shaped by heterogeneous farm, institutional, socioeconomic, and agroecological conditions and that access to mechanisation remains uneven among smallholders (Winarno *et al.*, 2025a)

### 3.1 Economic Characteristics and Private Profitability of Rice Farming

Descriptive statistics indicate that the sample is dominated by relatively small farms and that several economic variables exhibit substantial heterogeneity and right-skewed distributions. The mean harvested area is 0.77 ha, compared with a median of 0.57 ha. More pronounced differences between the mean and median are observed for production, recorded revenue per hectare, and the R/C ratio. Mean production is 2,334 kg compared with a median of 1,410 kg, mean recorded revenue per hectare is IDR28.34 million compared with a median of IDR16.96 million, and the mean R/C ratio is 6.22 compared with a median of 4.36. The relatively large standard deviations and upper ranges further indicate substantial variation among farms rather than a tightly concentrated distribution. For this reason, the median and interquartile range are emphasised in subsequent farm-size group comparisons because these measures provide a more informative representation of central tendency and dispersion when distributions are skewed and affected by extreme observations, whereas the mean and standard deviation are retained to describe the overall sample distribution (Das, 2024; Sidebotham & Hewson, 2025).

The median R/C ratio of 4.36 indicates that the typical farm generated recorded revenue greater than its recorded private production costs. However, the wide range of the R/C ratio, from 0.97 to 52.10, reinforces the considerable heterogeneity in farm-level economic performance. These values should not be interpreted as measures of full economic profitability because the recorded cost data do not comprehensively account for items such as the opportunity cost of family labour, land rent, own-capital costs, and potentially other non-recorded production expenses (Sari *et al.*, 2024). This distinction is important because farm profitability based only on explicit or recorded costs can differ substantially from profitability calculated using total costs that also include implicit costs such as family labour and land-use costs. Accordingly, the R/C ratio is interpreted throughout this study as an indicator of private accounting profitability rather than full economic profit. Recent evidence from Indonesian rice farming likewise shows that profitability measures are sensitive to how production costs are defined and to the extent to which both explicit and implicit farm costs are incorporated into the analysis (Prasania *et al.*, 2024; Ren *et al.*, 2024).

**Table 1.** Descriptive statistics of the rice farming economic variables (n = 228)

| Variabel                           | Average    | Median     | SD         | P25       | P75        | Min       | Max         |
|------------------------------------|------------|------------|------------|-----------|------------|-----------|-------------|
| Harvest area (ha)                  | 0,77       | 0,57       | 0,45       | 0,50      | 1,00       | 0,18      | 3,40        |
| Production (kg/MT)                 | 2.334      | 1.410      | 2.382      | 832       | 3.000      | 200       | 14.150      |
| Total cost recorded (Rp/MT)        | 4.295.948  | 3.832.250  | 2.142.027  | 2.463.958 | 5.506.938  | 1.203.833 | 12.333.750  |
| Cost recorded per ha (Rp/ha)       | 6.464.225  | 5.871.500  | 3.904.325  | 4.248.750 | 7.585.729  | 1.055.233 | 36.006.000  |
| Production cost per unit (Rp/kg)   | 3.355      | 2.443      | 2.581      | 1.518     | 4.537      | 192       | 10.851      |
| Farm-gate price calculated (Rp/kg) | 10.857     | 10.500     | 852        | 10.000    | 11.336     | 8.800     | 15.000      |
| Recorded revenue per ha (Rp/ha)    | 28.338.852 | 16.958.028 | 33.282.850 | 9.052.875 | 38.455.633 | -84.200   | 255.010.000 |
| R/C ratio                          | 6,22       | 4,36       | 6,57       | 2,31      | 7,36       | 0,97      | 52,10       |
| Revenue margin                     | 0,69       | 0,77       | 0,25       | 0,57      | 0,86       | -0,03     | 0,98        |
| Margin per unit (Rp/kg)            | 7.502      | 8.234      | 2.853      | 6.061     | 9.593      | -351      | 13.541      |

Source: Primary data processed, 2025

The distributional characteristics also support the use of medians for farm-size comparisons and a nonparametric Kruskal–Wallis procedure. The mean is retained as a useful description of the overall sample, but it is less representative of the typical farm when upper-tail observations are influential. For skewed distributions and data containing influential observations, medians and interquartile ranges provide more robust summaries of central tendency and dispersion, while rank-based nonparametric procedures such as the Kruskal–Wallis test are appropriate for comparisons across more than two independent groups when normality assumptions are not satisfied (Oelviani *et al.*, 2024). This distinction is important because competitiveness, efficiency, and profitability are related but conceptually different dimensions of farm performance, and their interpretation depends on both the indicator used and the scope of costs included (Ningsih *et al.*, 2024).

### 3.2 Farm Size Differences in Production Cost Structure

The clearest farm-size pattern is observed in production cost per hectare. As shown in Table 2, the median total cost per hectare decreases from IDR6.41 million among farms of  $\leq 0.50$  ha to IDR 5.81 million among farms of  $>0.50$ -1.00 ha and IDR3.14 million among farms larger than 1.00 ha. The overall difference is statistically significant, with a Kruskal-Wallis effect size of  $\epsilon^2 = 0.191$ . Among individual cost components, fixed cost per hectare exhibits the largest effect size ( $\epsilon^2 = 0.250$ ), followed by variable cost per hectare ( $\epsilon^2 = 0.169$ ).

This pattern is consistent with the theoretical concept of economies of size, under which relatively indivisible or quasi-fixed production costs can be distributed over a larger operational area. The pronounced decline in fixed cost per hectare is therefore consistent with a farm-size cost advantage. This interpretation is also consistent with recent evidence showing that farm size is associated with scale-related efficiency and economic performance in Indonesian rice farming (Prabowo, 2025), while broader evidence indicates that farm size is closely related to differences in resource-use efficiency, access to mechanisation, and production technology (Ren *et al.*, 2024). However, the present analysis does not estimate a

production function and therefore does not identify returns to scale in the technical sense. The observed relationship is more appropriately characterised as a farm-size cost advantage or an economies-of-size pattern.

**Table 2.** Cost structure per hectare by harvest area class

| Cost component    | ≤0,50 ha<br>(n=113) | >0,50–1,00 ha<br>(n=90) | >1,00 ha<br>(n=25) | p-value<br>KW | ε <sup>2</sup> |
|-------------------|---------------------|-------------------------|--------------------|---------------|----------------|
| Fixed cost/ha     | 442.000             | 242.180                 | 139.667            | <0,001        | 0,250          |
| Seed cost/ha      | 412.500             | 300.000                 | 240.000            | <0,001        | 0,143          |
| Urea Cost/ha      | 640.000             | 562.500                 | 321.429            | <0,001        | 0,105          |
| NPK fee/ha        | 700.000             | 587.500                 | 552.000            | <0,001        | 0,075          |
| Pesticide cost/ha | 560.000             | 505.000                 | 273.333            | <0,001        | 0,057          |
| Labor costs/ha    | 3.500.000           | 2.875.000               | 1.666.667          | <0,001        | 0,094          |
| Variable cost/ha  | 5.916.000           | 5.480.000               | 2.954.500          | <0,001        | 0,169          |
| Total cost/ha     | 6.408.462           | 5.809.875               | 3.139.611          | <0,001        | 0,191          |

Source: Primary data processed, 2025

Labour cost per hectare declines across farm-size groups, from a median of IDR3.50 million among the smallest farms to IDR1.67 million among farms larger than 1.00 ha. This pattern may reflect differences in labour organisation, machinery-service use, work scheduling, or the allocation of labour over larger cultivated areas. Recent Indonesian evidence links agricultural mechanisation and machinery use to labour productivity, technical efficiency, production costs, and farm economic performance (Mamilianti *et al.*, 2024; Winarno *et al.*, 2025b). However, because the dataset does not directly measure these factors in sufficient detail, they should be interpreted as plausible explanations rather than empirically established mechanisms.

### 3.3 Cost Competitiveness and Private Profitability by Broad Class

Table 3 extends the analysis from land-based production costs to output-based cost competitiveness and private profitability. To reduce repetition with Table 2, total cost per hectare is not repeated in Table 3. Median unit production cost decreases from IDR2,930/kg among farms of ≤0.50 ha to IDR2,120/kg among farms of >0.50-1.00 ha and IDR2,074/kg among farms larger than 1.00 ha. The overall difference is statistically significant, but its effect size is relatively small ( $\epsilon^2 = 0.025$ ). The R/C ratio and unit margin also differ across farm-size classes, whereas realised farm-gate price, recorded revenue per hectare, and productivity do not show statistically significant overall differences.

The distinction between cost per hectare and unit production cost is economically important. A lower expenditure per hectare does not necessarily imply a proportionately lower cost per kilogram because unit production cost depends jointly on total production cost and the quantity of output produced. Similarly, private profitability measured by the R/C ratio depends on both realised output prices and unit production costs. In accounting terms,  $R/C = P/UC$ , where P denotes the realised farm-gate price and UC denotes unit production cost. Consequently, a farm-size cost advantage per hectare may coexist with relatively modest differences in unit cost or profitability when output per unit of land is heterogeneous. This is

consistent with the empirical pattern in Table 3, where productivity does not differ significantly across farm-size groups.

**Table 3.** Cost competitiveness and private profitability by harvested-area class

| Indicator            | ≤0,50 ha<br>(n=113) | >0,50–1,00 ha<br>(n=90) | >1,00 ha<br>(n=25) | p-value<br>KW | ε <sup>2</sup> |
|----------------------|---------------------|-------------------------|--------------------|---------------|----------------|
| Total cost/ha        | 6.408.462           | 5.809.875               | 3.139.611          | <0,001        | 0,191          |
| Unit production cost | 2.930               | 2.120                   | 2.074              | 0,022         | 0,025          |
| Farm-gate price      | 10.500              | 11.000                  | 10.500             | 0,133         | 0,009          |
| Unit margin          | 7.637               | 8.701                   | 8.146              | 0,021         | 0,026          |
| R/C ratio            | 3,62                | 5,23                    | 5,78               | 0,026         | 0,023          |
| Profit margin        | 0,72                | 0,81                    | 0,83               | 0,026         | 0,023          |
| Income/ha            | 15.636.666          | 20.832.000              | 14.873.667         | 0,261         | 0,003          |
| Productivity         | 2.000               | 2.400                   | 1.800              | 0,173         | 0,007          |

Source: Primary data processed, 2025

The results therefore suggest that the most clearly observed farm-size advantage lies in the cost structure per unit of land rather than in systematically higher productivity or realised selling prices. This interpretation is broadly consistent with evidence that farm size, labour and input costs, irrigation conditions, and production arrangements are associated with the economic efficiency of rice farming (Darma *et al.*, 2025). Recent work on rice-farming competitiveness also emphasises the importance of production costs and private profitability in evaluating farm performance, while other studies highlight the role of production-factor management and managerial capacity in shaping smallholder outcomes (Prasania *et al.*, 2024). These comparisons provide economic context for the observed pattern but do not imply that the unmeasured organisational or managerial factors are the mechanisms operating in the present sample.

**Table 4.** Pairwise comparisons across harvested-area classes with Holm adjustment

| Indicator            | Group pairs               | Raw P  | p Holm | Conclusion      |
|----------------------|---------------------------|--------|--------|-----------------|
| Total cost/ha        | ≤0.50 ha vs >0.50–1.00 ha | <0,001 | <0,001 | Significant     |
| Total cost/ha        | ≤0.50 ha vs >1.00 ha      | <0,001 | <0,001 | Significant     |
| Total cost/ha        | >0.50–1.00 ha vs >1.00 ha | <0,001 | <0,001 | Significant     |
| Unit production cost | ≤0.50 ha vs >0.50–1.00 ha | 0,005  | 0,016  | Significant     |
| Unit production cost | ≤0.50 ha vs >1.00 ha      | 0,252  | 0,505  | Not significant |
| Unit production cost | >0.50–1.00 ha vs >1.00 ha | 0,997  | 0,997  | Not significant |
| Unit margin          | ≤0.50 ha vs >0.50–1.00 ha | 0,005  | 0,014  | Significant     |
| Unit margin          | ≤0.50 ha vs >1.00 ha      | 0,577  | 0,716  | Not significant |
| Unit margin          | >0.50–1.00 ha vs >1.00 ha | 0,358  | 0,716  | Not significant |
| R/C ratio            | ≤0.50 ha vs >0.50–1.00 ha | 0,006  | 0,017  | Significant     |
| R/C ratio            | ≤0.50 ha vs >1.00 ha      | 0,322  | 0,645  | Not significant |
| R/C ratio            | >0.50–1.00 ha vs >1.00 ha | 0,949  | 0,949  | Not significant |

Source: Primary Data Processed, 2025

The pairwise comparisons in Table 4 clarify where the overall farm-size differences identified by the Kruskal–Wallis tests occur. Total cost per hectare differs significantly across all three pairwise farm-size comparisons after the Holm adjustment, indicating that the decline in land-based production cost is the most consistent descriptive pattern across the farm-size distribution. The Holm procedure is appropriate in this context because it accounts for multiplicity across related pairwise tests while controlling the family-wise error rate (Neuhäuser & Ruxton, 2024). In contrast, statistically significant pairwise differences in unit production cost, unit margin, and the R/C ratio are concentrated between farms of  $\leq 0.50$  ha and those of  $>0.50$ – $1.00$  ha. Comparisons involving farms larger than  $1.00$  ha are not statistically significant for these indicators.

This pattern indicates that the clearest detectable contrast in output-based cost competitiveness and private profitability occurs between the smallest and medium farm-size categories. However, the results do not establish a threshold effect or demonstrate that efficiency stops increasing beyond one hectare. The  $>1.00$  ha group contains only 25 farms and displays considerable economic heterogeneity, which may reduce the precision of pairwise comparisons. A statistically non-significant result should not be interpreted as evidence that no difference exists, because such results may reflect limited sample size, substantial variability, a relatively small underlying association, or a combination of these factors. Accordingly, the evidence is better interpreted as showing no statistically distinguishable additional improvement in unit cost or R/C beyond the medium group in this sample, rather than as demonstrating a nonlinear causal relationship between farm size and efficiency (Healy, 2025).

### 3.4 Multivariate Relationship Between Farm Size, Cost, Price, and Profitability

The multivariate OLS-HC3 models assess whether the descriptive patterns persist after controlling for irrigation access, farming experience, household size, and sub-district heterogeneity. All models use the same 228 observations and the same set of controls and location fixed effects, allowing the farm-size coefficients across cost, price, and profitability outcomes to be compared on a common basis.

**Table 5.** Association between farm size, cost competitiveness, realised price, and private profitability

| Variabel                   | ln Cost/ha           | ln Unit Cost         | ln Price          | ln R/C              |
|----------------------------|----------------------|----------------------|-------------------|---------------------|
| ln Farm size               | -0,565***<br>(0,058) | -0,198<br>(0,123)    | -0,011<br>(0,011) | 0,188<br>(0,124)    |
| Irrigation                 | 0,085<br>(0,084)     | -0,503***<br>(0,154) | 0,017<br>(0,013)  | 0,519***<br>(0,153) |
| Farming experience         | -0,002<br>(0,003)    | -0,006<br>(0,005)    | -0,000<br>(0,001) | 0,006<br>(0,005)    |
| Number of family members   | 0,044<br>(0,029)     | 0,036<br>(0,050)     | -0,001<br>(0,005) | -0,037<br>(0,050)   |
| Fixed effects sub-district | Yes                  | Yes                  | Yes               | Yes                 |
| Observations               | 228                  | 228                  | 228               | 228                 |
| R <sup>2</sup>             | 0,466                | 0,227                | 0,176             | 0,237               |

Source: Primary data processed, 2025

Farm size is most strongly associated with production cost per hectare. The coefficient on  $\ln(\text{farm size})$  is  $-0.565$  and statistically significant at the 1% level, implying that a 10% increase in harvested area is associated with an approximately 5.6% lower cost per hectare, conditional on the included controls and location fixed effects. This result is consistent with a farm-size cost advantage and with recent evidence that farm size is associated with differences in resource-use efficiency, mechanisation constraints, and the economic organisation of agricultural production (Ren *et al.*, 2024; Rondhi *et al.*, 2024). The coefficient on unit production cost is negative but not statistically significant, indicating that lower land-based costs do not translate proportionately into lower costs per kilogram in the sample. The coefficients on realised farm-gate price and the R/C ratio are also statistically insignificant, so the multivariate evidence does not support the claim that larger farms systematically receive higher prices or achieve higher private profitability. This distinction is consistent with recent Indonesian evidence showing that rice-farm competitiveness and profitability depend on the interaction of production costs, output values, and input conditions rather than on farm size or physical production alone (Ningsih *et al.*, 2024).

These results strengthen the theoretical distinction between economies of size in land-based cost structure and profitability. A larger operational area may be associated with lower cost per hectare without necessarily increasing profitability when output per hectare and realised prices remain heterogeneous. Recent literature similarly emphasises that the economic implications of farm size are multidimensional, involving trade-offs among productivity, resource-use efficiency, technology access, and economic viability rather than a uniform advantage of larger farms (Ren *et al.*, 2024). The observed cost pattern is compatible with possible fixed-cost spreading and organisational advantages, but the present data do not directly measure machinery-service intensity, labour coordination, bulk-input discounts, or transaction costs. These should therefore be treated as plausible mechanisms suggested by economic theory and previous studies rather than as mechanisms demonstrated by the regression estimates. This cautious interpretation is supported by recent evidence that mechanisation outcomes in Indonesia depend on heterogeneous farm-level, institutional, socioeconomic, and agroecological conditions (Abuseeds & Campus, 2024; R A Chairunnisya *et al.*, 2025).

Among the controls, irrigation access is negatively associated with unit production cost and positively associated with the R/C ratio in the baseline specification. Because the dataset records irrigation access rather than reliability, water volume, timing, or governance, these coefficients should also be interpreted as conditional associations. Previous research shows that irrigation and water-management conditions can be related to rice-farm efficiency and profitability. (Rondhi *et al.*, 2024; Sumaryanto *et al.*, 2023), for example, document differences in technical-efficiency conditions between irrigated and non-irrigated rice farming in Indonesia, while (Erythrina *et al.*, 2021) show that appropriate crop and nutrient management combined with supplemental irrigation can improve rice productivity and net returns in Indonesian rainfed systems. However, the present study does not identify the specific pathway through which irrigation operates.

### 3.5 Mechanical Decomposition of The Farm Size Profitability Association

The empirical contribution of this study lies in separating the observed farm-size-profitability association into its price and unit-cost components. Because the  $\ln(\text{price})$ ,  $\ln(\text{unit cost})$ , and  $\ln(\text{R/C})$  models are estimated using the same sample and the same set of

explanatory variables, the coefficients satisfy the accounting identity  $\beta_{RC} = \beta_P - \beta_{UC}$ . Based on the unrounded estimates, the implied coefficient is approximately 0.188, which is identical to the direct farm-size coefficient obtained from the  $\ln(R/C)$  model.

**Table 6.** Mechanical decomposition of the farm size-profitability coefficient

| Components                                     | Coefficient | p-value | Interpretation                                                |
|------------------------------------------------|-------------|---------|---------------------------------------------------------------|
| Price channel ( $\beta_P$ )                    | -0,011      | 0,345   | Very small and statistically insignificant                    |
| Cost channel ( $-\beta_{UC}$ )                 | 0,198       | 0,106   | Mechanically larger, but statistically inconclusive           |
| Implied coefficient ( $\beta_P - \beta_{UC}$ ) | 0,188       | —       | Algebraically equivalent to the direct $\ln(R/C)$ coefficient |
| Direct $\ln(R/C)$ coefficient                  | 0,188       | 0,132   | Positive but statistically insignificant                      |

Source: Primary data processed, 2025

The mechanical decomposition shows that the unit-cost component (0.198) is substantially larger in magnitude than the price component (-0.011). The implied coefficient derived from the accounting identity is approximately 0.188 and is identical to the direct farm-size coefficient in the  $\ln(R/C)$  model when calculated from the unrounded estimates, confirming the internal consistency of the decomposition. However, neither the unit-cost coefficient ( $p = 0.106$ ) nor the direct  $R/C$  coefficient ( $p = 0.132$ ) is statistically significant at conventional levels, while the price component is also small and statistically insignificant ( $p = 0.345$ ). Therefore, the decomposition should not be interpreted as evidence that lower unit costs statistically explain higher profitability. Rather, it indicates that the observed positive farm-size coefficient for private profitability is mechanically more consistent with the unit-cost component than with the realised-price component. This pattern is suggestive of a cost-based association but remains statistically inconclusive and should therefore be interpreted as an accounting decomposition of the coefficient structure rather than as a causal mechanism (Sterrantino, 2024b).

**Table 7.** Robustness check using farm size class indicators (reference:  $\leq 0.50$  ha)

| Kategori farm size                   | Outcome         | Koefisien | p-value |
|--------------------------------------|-----------------|-----------|---------|
| Medium farm class ( $>0,50-1,00$ ha) | $\ln$ Unit Cost | -0,129    | 0,239   |
| Large farm class ( $>1,00$ ha)       | $\ln$ Unit Cost | -0,096    | 0,672   |
| Medium farm class ( $>0,50-1,00$ ha) | $\ln R/C$       | 0,132     | 0,230   |
| Large farm class ( $>1,00$ ha)       | $\ln R/C$       | 0,075     | 0,746   |

Source: Primary data processed, 2025

The farm size class specification produces coefficient directions consistent with the continuous farm-size models. Relative to farms of  $\leq 0.50$  ha, both the medium- and large-farm categories are associated with lower unit production costs and higher  $R/C$  ratios. However, none of these coefficients is statistically significant at conventional levels. The categorical specification therefore does not provide evidence of statistically distinct unit-cost or profitability effects across farm-size classes, but it confirms that the direction of the estimates is not sensitive to treating farm size as a continuous rather than categorical variable.

The robustness analysis indicates that the substantive pattern of the farm-size coefficients is stable across alternative inference procedures. The strongest result concerns production cost per hectare. The farm-size coefficient of  $-0.568$  remains statistically significant under HC3 inference ( $p < 0.001$ ), location-clustered standard errors ( $p < 0.001$ ), and the wild-cluster bootstrap ( $p = 0.002$ ). This provides robust evidence of a negative association between operational farm size and production cost per hectare, a pattern that is more appropriately interpreted as a farm-size cost advantage or an economies-of-size pattern rather than as returns to scale. In contrast, the coefficients for unit production cost ( $-0.196$ ), realised farm-gate price ( $-0.012$ ), and the R/C ratio ( $0.188$ ) are not consistently statistically significant across the alternative inference procedures. The negative unit-cost coefficient and positive R/C coefficient are directionally consistent with lower unit costs and higher private accounting profitability among larger farms, whereas the price coefficient is small, negative, and statistically inconclusive. Thus, the most statistically robust farm-size association is observed for production cost per hectare, while evidence of systematic associations with unit production cost, realised output price, and private profitability remains inconclusive. The stability of coefficient signs and magnitudes across inference procedures strengthens confidence in the overall empirical pattern, but the statistical uncertainty surrounding the unit-cost and R/C coefficients means that the price–cost decomposition should be interpreted only as a mechanical accounting decomposition of the coefficient structure rather than as evidence of a causal or statistically identified mediation mechanism.

**Table 8.** Robustness of farm-size coefficients under alternative inference procedures

| Outcome      | Farm size coefficient | HC3 SE | HC3 p  | Cluster SE | Cluster p | Wild-cluster p |
|--------------|-----------------------|--------|--------|------------|-----------|----------------|
| ln Cost/ha   | -0,568                | 0,058  | <0,001 | 0.098      | <0.001    | 0,002          |
| ln Unit Cost | -0,196                | 0,123  | 0,106  | 0.103      | 0.087     | 0,133          |
| ln Price     | -0,012                | 0,011  | 0,345  | 0.008      | 0.205     | 0,193          |
| ln R/C       | 0,188                 | 0,124  | 0,132  | 0.106      | 0.112     | 0,170          |

Source: Primary data processed, 2025

### 3.6 Access to Irrigation as A Condition to Support Cost Competitiveness

Although irrigation access is included primarily as a control variable rather than as the main variable of interest, it shows statistically significant associations with both unit production cost and the R/C ratio. The estimated coefficient of  $-0.503$  in the ln (unit cost) model corresponds to an approximately 39.5% lower unit cost for farms with irrigation access, while the coefficient of  $0.519$  in the ln(R/C) model corresponds to an approximately 68.0% higher R/C ratio, conditional on the other covariates and location fixed effects. These estimates indicate substantial conditional differences between farms with and without recorded irrigation access, but they should not be interpreted as causal effects of irrigation provision.

Several economic explanations may be consistent with these associations. More reliable water availability could potentially improve planting timing, support more effective input application, reduce exposure to yield losses, or allow production costs to be distributed over a larger quantity of output. Previous evidence also documents differences in rice-farming

performance between irrigated and non-irrigated production environments (Rondhi *et al.*, 2024; Sumaryanto *et al.*, 2023)

However, the present dataset records irrigation access rather than the reliability, timing, discharge, quality, or governance of water delivery. These potential pathways are therefore not directly identified by the analysis. Irrigation is consequently interpreted as an important conditioning factor associated with farm economic performance, while the principal focus of the study remains the relationship between farm size, production costs, realised prices, and private accounting profitability.

#### 4. Conclusion

This study shows that operational farm size is more consistently associated with the cost structure of smallholder rice farming than with realised output prices or private profitability. Larger farms exhibit a robust cost advantage in terms of lower production cost per hectare, whereas the associations of farm size with unit production cost, realised farm-gate price, and the R/C ratio remain statistically inconclusive. The mechanical decomposition further indicates that the observed positive farm-size–profitability coefficient is more consistent with the unit-cost component than with the price component; however, this accounting relationship should not be interpreted as evidence of a causal profitability mechanism. These findings suggest that improving the economic performance of smallholder rice farming need not depend solely on expanding cultivated area. Possible policy implications may include facilitating forms of operational coordination, access to shared agricultural machinery, collective input procurement, and more reliable irrigation management, particularly where such arrangements could help smaller farms achieve cost efficiencies; however, these interventions were not directly evaluated in this study and therefore require further empirical assessment. Because the analysis is based on cross-sectional data and recorded private production costs that do not comprehensively account for family labour, land rent, own-capital costs, and other opportunity costs, the profitability measures should be interpreted as private accounting profitability rather than full economic profitability. Future research using panel or multi-season data and more comprehensive measures of economic costs, land fragmentation, mechanisation, input arrangements, irrigation reliability, and marketing conditions would help determine more precisely when and how operational farm size is associated with sustainable cost advantages and improved farm income.

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