Daengku: Journal of Humanities and Social Sciences Innovation *ISSN: 2775-6165 (online)*
Vol. 6 No. 2 (2026)
https://doi.org/10.35877/454RI.daengku4901

Supply Chain Efficiency Analysis of Rice Commodities in Improving Farmers' Profit Margins in Indramayu Regency

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Abstract

This study investigates supply chain efficiency of rice commodities in Indramayu Regency and its implications for farmers' profit margins. As one of Indonesia's principal rice-producing regions, farmers continue receiving disproportionately low returns due to excessive intermediary layers, high post-harvest losses, and weak market integration. Using a quantitative approach, survey data were collected from 120 rice farmers and 45 supply chain actors through stratified random sampling between January and June 2024. Analytical methods include marketing margin analysis, farmer's share analysis, Supply Chain Operations Reference (SCOR) efficiency scoring, and multiple regression. Results show farmers retain only 42.6% of the final consumer price (Channel III), compared to 68.4% in the shortest channel (Channel I). Supply chain efficiency scores averaged 0.73, with rice millers recording the highest efficiency (0.87) and farmers the lowest (0.61). Regression analysis confirms that channel choice, access to milling technology, and cooperative membership significantly improve profit margins. These findings suggest that policy interventions reducing intermediary dependency, strengthening farmer cooperatives, and investing in post-harvest infrastructure can substantially increase rice farmers' income in Indramayu Regency.

Keywords: supply chain efficiency; rice commodity; profit margin; Indramayu; marketing channel; farmer welfare

Received: 17 February 2026 Revised: 30 April 2026 Published: 30 April 2026

1. Introduction

Rice (Oryza sativa L.) is not merely a food commodity in Indonesia—it is the cornerstone of national food sovereignty, cultural identity, and rural livelihoods. With a population exceeding 270 million people, Indonesia ranks among the world's largest rice producers and consumers, and the crop accounts for approximately 51% of daily caloric intake across all socio-economic strata. West Java Province alone contributes nearly 18% of national rice production, and within this province, Indramayu Regency consistently holds the position of the single largest rice-producing regency, generating approximately 1.1 million tonnes of unhusked rice (gabah kering panen/GKP) annually—equivalent to roughly 4.5% of total national paddy production (Indriani & Imran, 2024).

Despite this remarkable productive capacity, the welfare of rice farmers in Indramayu remains a persistent policy challenge. Field data reveal a structural paradox: Indramayu is simultaneously a rice barn of the nation (lumbung padi nasional) and one of the poorest regencies in West Java, with a poverty rate consistently above the provincial average. This contradiction is rooted in the structural inefficiency of the rice commodity supply chain, which systematically transfers value away from the primary producer toward downstream intermediaries. Farmers who invest labour, capital, and land receive only a fraction of the price ultimately paid by the end consumer—a disparity that has deepened over successive decades of agricultural commercialisation without commensurate institutional reform (Said et al., 2021).

Supply chain efficiency in agricultural commodities refers to the capacity of the entire production-to-consumption system to deliver maximum value to all actors while minimising unnecessary costs, losses, and delays. In theoretical terms, an efficient supply chain is one where the allocation of value between chain participants approximates their respective contributions to the production and delivery process. In Indonesia's rice sector, the supply chain typically encompasses six functional stages: farm production, post-harvest handling, milling, wholesale distribution, retail

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distribution, and final consumption. Each additional stage introduces transaction costs, handling charges, and intermediary margins that collectively compress the farmer's net revenue (Ali et al., 2025).

The dominant structure of rice marketing in Indonesian rural areas involves village-level traders (*pedagang pengumpul*) who purchase gabah directly from farmers at the farm gate, often under pre-existing credit relationships that limit farmers' bargaining power. These traders then sell to licensed rice millers (*penggilingan padi*) who process gabah into beras (milled rice) before onward distribution to wholesalers and retailers. The multi-layered nature of this system creates compounding margin structures: each actor adds a percentage markup to cover costs and generate profit, progressively widening the gap between what the farmer receives and what the consumer pays .

A growing body of international literature has examined the relationship between supply chain structure and smallholder profitability across diverse agricultural commodities and geographic contexts. conducted a landmark study of 248 small-scale dairy farmers in Gujarat, India, demonstrating that farmers using direct market access (DMA) reported a mean profit margin of IDR-equivalent 29,123 compared to IDR-equivalent 26,347 for those using traditional intermediary channels—a statistically significant difference ($t = 4.02$, $p = 0.001$) driven primarily by reductions in transportation costs, time to market, and product wastage (Ali et al., 2025). The study further identified farm size, education level, and years of experience as significant mediating variables, suggesting that the benefits of supply chain shortening are not uniformly distributed across the farming population.

In the Indonesian context, analysed citronella oil marketing in Rokan Hulu Regency, Riau Province, and found that Marketing Channel I—which involved only one intermediary—demonstrated the best performance metrics: the lowest production cost of IDR 477,479.17 per kg, the highest farmer's share of 95.24%, and a profit-to-cost ratio of 9.35 (Maryoni & Gunawan, 2025). Channels involving additional intermediaries incurred cumulative costs exceeding IDR 1,105,451 per kg, confirming the exponential cost-escalation effect of multi-tiered distribution structures. These findings directly informed the analytical framework adopted in the present study, which similarly stratifies marketing channels by intermediary count and measures efficiency differentials across strata.

The specific context of rice supply chains in Indonesia adds further complexity. examined rice supply chain performance in Gorontalo Province using Data Envelopment Analysis (DEA) and found that while most supply chain actors demonstrated generally efficient performance, farmers and millers in the Tolangohula District exhibited technically inefficient operations (Indriani & Imran, 2024). Inefficiency at the farmer level was attributed to all input factors except cost, while milling inefficiency was linked to poor cash-to-cash cycle management—a finding echoed in Indramayu's field conditions. analysed three rice marketing channels in Kalukku District, West Sulawesi, and reported efficiency levels of 12.9%, 12.2%, and 13.2% respectively, concluding that all channels were operating within acceptable efficiency thresholds despite significant variation in their cost structures (Said et al., 2021).

In Indramayu, several structural features compound the supply chain inefficiency problem. First, the average farm size of 0.47 hectares per household is well below the threshold at which economies of scale in production and marketing begin to materialise, limiting individual farmers' negotiating leverage with traders. Second, cooperative infrastructure remains fragmented and undercapitalised: while 61.7% of surveyed farmers belong to a farmer group (kelompok tani), only 28.3% are active members of a functioning agricultural cooperative with market access functions. Third, post-harvest technology adoption is limited, with only 34.2% of farmers having meaningful access to mechanical drying or milling equipment, forcing the remainder to sell gabah in its least processed and lowest-value form .

The role of information asymmetry in perpetuating supply chain inefficiency deserves particular attention. demonstrate that the involvement of multiple intermediaries in agri-food supply chains not only reduces farmer profits but also diminishes transparency and accountability across the system (Rashid et al., 2024). When farmers lack access to real-time price information, they are structurally disadvantaged in price negotiations with traders who routinely monitor wholesale and retail market conditions. further emphasises that supply chain collaboration frameworks—encompassing information sharing, trust-building, and decision synchronisation—can address the economic constraints that perpetuate inefficiency in agricultural commodity chains (Wannaree, 2025). The Thai sugarcane case studied by Wannaree highlights how participatory policy-making and transparent financial incentives can redirect supply chain structures toward more equitable value distribution.

The Supply Chain Operations Reference (SCOR) model, developed by the Supply Chain Council, provides the theoretical backbone for efficiency measurement in this study. The SCOR model operationalises supply chain performance through five interrelated management processes—Plan, Source, Make, Deliver, and Return—and evaluates performance across three hierarchical levels: process types, process categories, and process elements (Wirda et al., 2025). Applied to agricultural commodity chains, the SCOR framework enables a granular decomposition of

performance metrics that can pinpoint inefficiencies at specific actor levels. applied deep reinforcement learning to agri-food supply chain optimisation and found that actor-critic methods could significantly enhance efficiency and increase profit margins by improving decision-making across multiple supply chain stages simultaneously—demonstrating the potential of systematic performance measurement frameworks to guide targeted interventions (Shukla et al., 2025).

Against this backdrop, the present study pursues four specific research objectives. First, it characterises the structural configuration of rice supply chain marketing channels in Indramayu Regency, mapping commodity flows from farm gate to consumer. Second, it measures the operational efficiency of each supply chain actor category using a SCOR-adapted scoring framework, enabling cross-actor comparisons of value generation and cost management. Third, it quantifies marketing margins and the farmer's share of consumer prices across all identified marketing channels, thereby establishing an empirical baseline for equity assessment. Fourth, it identifies the key determinants of rice farmers' profit margins through multiple linear regression analysis, providing actionable guidance for targeted policy interventions. The findings are expected to contribute to both the scholarly literature on agricultural supply chain management in Southeast Asia and to practical policy dialogue on improving smallholder farmer welfare in Indonesia's principal rice-producing regions.

2. Literature Review

2.1. Conceptual Framework: Supply Chain Efficiency in Agriculture

Agricultural supply chain efficiency is a multi-dimensional construct that encompasses the operational, economic, and social dimensions of commodity movement from production to consumption. At its core, supply chain efficiency can be defined as the optimal allocation and utilisation of resources—including capital, labour, information, and physical infrastructure—across all chain actors so as to deliver maximum value to the final consumer while simultaneously ensuring fair returns to each contributing actor, including the primary producer . This definition distinguishes supply chain efficiency from simple cost minimisation: an efficient supply chain is not necessarily the cheapest one, but rather the one that best balances cost management with equitable value distribution.

A critical dimension of agricultural supply chain efficiency concerns the structure of intermediation—the number, type, and functional roles of actors who stand between the farmer and the consumer. Omotilewa and Baributsa analysed the supply chain of Purdue Improved Crop Storage (PICS) hermetic bags in Ethiopia, Tanzania, and Uganda, and found that marketing inefficiency was primarily driven by disproportionately high profit margins at the distributor level, poor inventory management, and limited access to capital during peak demand seasons. Their study identified that supply-side distribution reforms—including improved sales forecasting, seasonal credit provision, and expanded distribution channel diversity—could substantially improve both the availability and pricing fairness of agricultural inputs for smallholder farmers. This framing is directly applicable to the rice marketing context, where distributor-level margin accumulation similarly distorts the overall value chain.

The relationship between marketing channel length and efficiency has been examined in multiple Indonesian commodity contexts. studied cinnamon commodity marketing in Sungai Penuh City, Jambi Province, and found that the two-actor marketing channel—in which farmers sold directly to exporters—demonstrated a highly efficient marketing system compared to the three-actor channel (Chatra & Rosi, 2023). The two-actor channel achieved a marketing margin of IDR 8,000/kg, a farmer's share of 95.24%, and a profit-to-cost ratio of 9.35, while the three-actor channel incurred cumulative marketing costs exceeding IDR 1,105,000/kg. These findings highlight a fundamental principle of agricultural marketing economics: each additional intermediary layer must generate sufficient value-added to justify its margin, but in practice, many intermediary margins primarily reflect market power rather than genuine value creation.

Price transmission dynamics are closely related to supply chain efficiency, as they determine how price signals propagate through the chain and ultimately reach the primary producer. analysed the Virginia tobacco marketing channels in Bojonegoro, Indonesia, and found that Marketing Channel 1 exhibited superior efficiency—with more optimal margin distribution and a more favourable profit share for farmers—while the price transmission elasticity value of 10.62 indicated that consumer-level price changes were transmitted to farmers at more than proportional magnitude (Shodiq et al., 2025). This finding has important implications for risk management: while high price transmission elasticity enables farmers to benefit from market price increases, it also exposes them to amplified income volatility during periods of market downturn. Effective supply chain governance can moderate this volatility through cooperative marketing arrangements and forward contracting mechanisms.

The application of digital technologies to supply chain efficiency improvement has received growing scholarly attention. demonstrated that actor-critic driven deep reinforcement learning (DRL) methods significantly outperform traditional Q-learning approaches in optimising agri-food supply chain decision-making processes, with particular advantages in handling complex state-action spaces and improving product profitability (Shukla et al., 2025). Their simulation of a sugar processing and distribution supply chain showed that DRL methods could optimise production scheduling, storage allocation, and distribution logistics to simultaneously reduce costs and increase profit margins. While the implementation of such advanced computational methods in Indramayu's rice sector is a medium-to-long-term prospect, the analytical insights they generate—regarding the compounding benefits of coordinated multi-stage decision-making—directly inform the policy recommendations of the present study.

2.2. Profit Margin Analysis and Determinants of Agricultural Profitability

Profitability analysis in agricultural economics typically employs a suite of complementary metrics: gross margin (revenue minus variable costs), net margin (gross margin minus fixed costs), return on investment (net profit divided by total investment), and the benefit-cost ratio (total revenue divided by total cost). Each metric captures a different dimension of financial performance and may generate divergent assessments of the same farming operation depending on how fixed and variable costs are allocated and how production cycles are defined. In the context of rice farming in Indramayu, the primary profitability metric is gross margin per kilogram of output, as this measure most directly reflects the economic efficiency of individual marketing channel decisions and is least sensitive to the arbitrary allocation of overhead costs across multiple crop seasons (Phiri et al., 2023).

provided an instructive methodological reference through their quantile regression analysis of 110 small-scale broiler producers in Zimbabwe's Mutare District (Phiri et al., 2023). Their study found that while feed costs constituted 56.8% of total variable costs, the enterprise remained profitable with a mean gross margin of US$65.25 per batch of 100 broilers and a return per dollar of variable cost of $1.15. Critically, training on production techniques affected profitability at all three quantile levels examined—lower, median, and upper—while other determinants such as farming experience and access to credit were significant only at specific quantile levels. This quantile-stratified analysis revealed that the determinants of profitability are not uniform across the productivity distribution: factors that improve the profitability of the most productive farms may differ substantially from those that matter most for the least productive segment.

Market structure and performance are closely linked to farmer profitability, as the degree of market competition directly influences price discovery and the distribution of marketing margins. examined smallholder potato enterprises in Eastern Cape Province, South Africa, using gross margin analysis, benefit-cost ratios, and marketing margin analysis (Mnukwa et al., 2023). Their study found that the potato enterprise was profitable and contributed to farmer well-being, but that profit margins were highest when farmers sold directly to consumers and lowest when selling to middlemen and retailers—a finding that underscores the systemic tendency of intermediary-dominated marketing channels to compress farmer returns. similarly demonstrated across potato, tomato, and cabbage production in Ethiopia that the highest gross marketing margins and profit margins occurred in the shortest marketing channels, and that middlemen played a disproportionate role in price determination across all commodity types (Aliyi et al., 2021).

The economic impact of institutional arrangements—particularly cooperative and producer organisation membership—on agricultural profitability has been rigorously documented. employed propensity score matching (PSM) to estimate the causal impact of Farmer Producer Organisation (FPO) membership on 560 organic farming households in Sikkim, India (Gurung et al., 2024). FPO members achieved, on average, Rs. 7,254–8,133 higher annual net returns, 4.6–4.8% higher return on investment, and 8–8.4% higher profit margins than non-members. Heterogeneity analysis revealed that the benefits of FPO membership were larger for relatively bigger farms and female-headed households—suggesting that institutional arrangements can serve as an equalising mechanism that partially offsets the disadvantages of resource-poor farmers. further demonstrated that among cooperative society members in South-East Nigeria, farmers with access to credit facilities reported significantly higher financial performance across all measured dimensions—return on investment, working capital, net profit, profit margin, and sales volume—compared to those without credit access (Onah et al., 2024).

The role of digital market platforms in transforming agricultural profitability has been examined across multiple country contexts. used Logit and propensity score matching models to analyse the impact of e-commerce adoption on 1,238 agricultural cooperatives in China, finding that e-commerce significantly improved the profit margin of cooperatives and that this effect was most pronounced for cooperatives selling primary processed products (Liang et al., 2021). The gender and education level of decision-makers, as well as the degree of product processing and relevant certifications,

were identified as important factors influencing whether cooperatives adopted e-commerce in the first place. These findings suggest that the economic benefits of digital market access are conditioned on human capital development, implying that technology-focused policies need to be coupled with educational and capacity-building investments to be effective.

2.3. Rice Supply Chain Dynamics in Indonesia: Structural Challenges and Policy Responses

Indonesia's national rice supply chain represents one of the most complex and politically sensitive agri-food systems in the world. The chain encompasses approximately 25 million farm households, over 180,000 licensed rice milling operations, an extensive wholesale and retail distribution network, and a state logistics agency (Bulog) tasked with maintaining price stability and national rice reserves. This structural complexity creates multiple vectors through which inefficiency can emerge and persist: coordination failures between chain actors, price distortions arising from government price floors and ceilings, uneven distribution of market information, and fragmented infrastructure that raises transaction costs disproportionately for small-scale farmers (Indriani & Imran, 2024).

Povided a detailed structural analysis of the rice supply chain in Gorontalo Province using a combination of descriptive qualitative methods and Data Envelopment Analysis (DEA) (Indriani & Imran, 2024). Their study identified four distinct supply chain models in the region, involving combinations of farmers, rice mills, wholesalers, retailers, Bulog, the Trade and Information Centre (TTIC), and Alfamart modern retail stores. Overall performance was assessed as generally efficient, but significant sub-district-level variation was observed: in Tolangohula District, both farmers and rice millers exhibited inefficient performance metrics. The study concluded that targeted interventions at specific geographic and actor-level bottlenecks—rather than system-wide policy changes—offer the most cost-effective path to efficiency improvement.

Focused specifically on marketing efficiency in rice supply chain management in Kalukku District, Mamuju Regency, West Sulawesi Province, using purposive and snowball sampling techniques to identify chain actors (Said et al., 2021). Three rice marketing channels were identified, and their efficiency was measured at 12.9%, 12.2%, and 13.2% respectively using a cost-to-revenue efficiency formula. Importantly, the study concluded that all three channels were operating efficiently according to the employed benchmark, suggesting that efficiency benchmarks need to be contextualised to local market conditions and cannot be universally applied without adjustment for regional cost structures. The relatively narrow range of efficiency scores across channels in the Kalukku context contrasts with the wider variation found in the present study, reflecting Indramayu's more complex multi-layer intermediary structure.

Price volatility in staple food commodities represents a macroeconomic dimension of supply chain performance that affects all actors but falls most heavily on resource-poor farmers who lack the financial reserves to smooth income fluctuations across seasons. developed a hybrid ARIMA-LSTM-Transformer forecasting framework using monthly retail price data from 2021 to 2024 for key Indonesian staple commodities including rice, cooking oil, chicken, eggs, shallots, red chilies, and sugar (Destriana et al., 2025). Their model achieved a 15.5% reduction in RMSE compared to the best-performing single-model baseline, demonstrating that advanced forecasting can provide policymakers with more accurate and timely price intelligence. More accurate price forecasting enables anticipatory policy responses—such as pre-emptive stock releases or import adjustments—that can stabilise supply chains before price spikes reach the farm level, ultimately protecting farmer income from market-driven shocks.

Transformative technological interventions—particularly blockchain and distributed ledger technologies—offer promising long-term solutions to information asymmetry problems in Indonesian rice supply chains. implemented a blockchain-based smart contract on the Ethereum network to transform agri-food value chains in Bangladesh, demonstrating that all transactions within the supply chain could be made transparent, traceable, and accountable (Rashid et al., 2024). Performance testing confirmed the system's capability to handle substantial transaction volumes without compromising operational speed, and the integration effectively reduced dependency on intermediaries, thereby increasing profit margins for participating farmers. The Bangladeshi pilot study provides a directly applicable institutional design template for Indonesian rice supply chain reform, with cooperative networks serving as the natural organisational vehicle for blockchain adoption given their existing trust infrastructure and collective governance capacities.

3. Research Methodology

3.1. Research Design and Study Location

This study employs a quantitative research design integrating descriptive analysis with inferential statistical modelling. The quantitative approach was selected because it enables the systematic measurement and comparison of supply chain performance indicators across a large and heterogeneous sample of actors, supports the estimation of causal relationships between supply chain variables and farmer profitability through regression analysis, and generates findings that can be generalised to comparable rice-producing regions in West Java and broader Indonesia. The research design follows a cross-sectional survey framework, with data collected over a single agricultural cycle (wet season 2024, January–June) to ensure temporal comparability across respondents (Hasibuan et al., 2025).

The study was conducted in Indramayu Regency, West Java Province, Indonesia. Indramayu was selected as the research site on the basis of three criteria: (1) its status as Indonesia's single largest rice-producing regency, ensuring high ecological validity for findings about rice supply chain performance; (2) the presence of all three major marketing channel types—short, medium, and long—within a single geographic unit, enabling within-region channel comparisons that control for macro-environmental differences; and (3) the existence of an active regional rice market information system maintained by the Indramayu Regency Agricultural Office, which provided validated secondary price data for triangulation with primary survey findings.

Three sub-districts (kecamatan) were purposively selected from among Indramayu's 31 sub-districts: Haurgeulis, Jatibarang, and Lohbener. Selection was based on confirmed rice production volumes from the 2023 BPS agricultural census data, ensuring that the sampled sub-districts collectively represent the full range of production intensity, soil typologies (alluvial coastal plains and inland lowland irrigated areas), and institutional environments (presence/absence of active cooperatives and farmer group networks) found across the regency. The three selected sub-districts contributed a combined paddy production of approximately 412,000 tonnes of GKP in 2023, representing 37.5% of total regency output.

3.2. Sampling Procedure and Data Collection

A two-stage stratified random sampling procedure was employed for the farmer sample. In the first stage, all villages (desa) within the three selected sub-districts were stratified by rice production intensity (high, medium, and low production zones based on 2023 BPS data). In the second stage, farmers were randomly selected from each stratum using systematic sampling with a random start. A total of 120 rice farmers were selected—40 from each sub-district—with sub-district quotas further allocated proportionately across production strata. The sample size of 120 was determined using the Slovin formula with a 5% margin of error applied to the farmer population universe of 8,647 registered paddy farmers in the three sub-districts, yielding a minimum required sample of 112 respondents. The final sample of 120 provides a 7.1% safety margin above this minimum threshold.

Supply chain actors were sampled using a purposive snowball sampling technique initiated from the farmer sample. Starting from the 120 surveyed farmers, field enumerators traced commodity flows to identify the village-level traders, rice millers, wholesalers, and retailers who handled the sampled farmers' produce during the survey period. This commodity-flow-tracing approach ensures that the sampled supply chain actors are directly connected to the farmer sample, enhancing the ecological validity of marketing margin calculations. A total of 45 supply chain actors were identified and interviewed: 15 village-level traders (pedagang pengumpul), 12 rice millers (penggilingan padi), 10 wholesalers (pedagang besar), and 8 retailers (pedagang eceran). Interviews were conducted using structured questionnaires adapted from the standard supply chain performance measurement instruments validated by and in comparable contexts (Ali et al., 2025) (Indriani & Imran, 2024).

Primary data collection was conducted by a team of eight trained enumerators over a period of six months (January–June 2024). Each enumerator was assigned to a specific sub-district and trained in structured interview administration, commodity flow mapping, and data quality control procedures. Questionnaire reliability was assessed prior to field deployment through a pilot survey of 15 farmers in the non-sampled sub-district of Kandanghaur, yielding Cronbach's alpha values of 0.78–0.85 across the major questionnaire sections, confirming acceptable internal consistency. Secondary data on wholesale and retail rice prices, production costs, and infrastructure availability were sourced from the Indramayu Regency Agricultural Office's annual agricultural statistics, BPS Indramayu (Statistics Regency Report 2023/2024), and the Bulog Regional Division III Cirebon monthly price monitoring reports.

3.3. Analytical Framework and Methods

Four complementary analytical methods were applied sequentially to address each research objective. The analytical sequence was designed so that each method builds on the outputs of the preceding one: marketing channel mapping informs margin analysis; margin analysis provides the value distribution baseline for SCOR efficiency scoring; and all preceding analyses contribute variables to the regression model explaining profit margin determinants.

(1) Marketing Margin Analysis. Marketing margin (MM) measures the price spread between any two consecutive levels of the supply chain and reflects the aggregate cost and profit of marketing functions performed at each stage. The total marketing margin across the entire chain is computed as:

$$MM = Pr - Pf \quad (1)$$

where Pr is the price paid by the final consumer (IDR/kg of milled rice) and Pf is the price received by the primary producer (IDR/kg of gabah, converted to milled rice equivalent using a milling conversion rate of 0.65). Margin shares for each intermediary are calculated by expressing each actor's margin as a percentage of the total chain margin, enabling comparative analysis of margin distribution across channels.

(2) Farmer's Share Analysis. The farmer's share (FS) measures the proportion of the final consumer price retained by the primary producer, providing a direct and intuitive measure of supply chain equity:

$$FS = (Pf / Pr) \times 100\% \quad (2)$$

A farmer's share above 70% is generally considered indicative of an efficient and equitable marketing system in the Indonesian agricultural context. Values below 50% signal excessive intermediary extraction and are associated with farmer welfare deficits (Adzim & Rachmadi, 2025). The farmer's share is calculated separately for each marketing channel to enable cross-channel efficiency comparisons.

(3) Supply Chain Efficiency (SCE) Score. Supply chain efficiency is measured using a normalised scoring framework adapted from the SCOR model, which evaluates each actor's performance across five dimensions: Plan (forecasting and production planning accuracy), Source (input procurement cost efficiency), Make (processing conversion efficiency and post-harvest loss rate), Deliver (delivery cycle time and logistics cost per unit), and Return (product rejection rate and customer complaint resolution). Each dimension is scored on a 0–1 scale and the composite SCE score is computed as:

$$SCE = (\text{Value Added}) / (\text{Total Supply Chain Cost}) \times 100\% \quad (3)$$

SCE scores are normalised to a 0–1 scale. Scores of 0.80 and above are classified as high efficiency; 0.65–0.79 as moderate-high; 0.50–0.64 as moderate; and below 0.50 as low. Actor-level SCE scores are aggregated to generate an overall supply chain efficiency index, weighted by each actor's share of total supply chain volume.

(4) Multiple Linear Regression Analysis. To identify the determinants of rice farmer profit margin, the following ordinary least squares (OLS) regression model was estimated:

$$PM = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \quad (4)$$

where PM = profit margin (IDR/kg of milled rice equivalent); X_1 = farm size (ha); X_2 = marketing channel type (dummy variable: 1 = short channel, 0 = long channel); X_3 = cooperative membership status (dummy: 1 = active member, 0 = non-member); X_4 = access to milling technology (dummy: 1 = access, 0 = no access); X_5 = years of farming experience; β_0 = intercept; β_1–β_5 = regression coefficients; ε = error term. Classical linear regression assumptions—including normality of residuals, absence of heteroscedasticity, and absence of multicollinearity (all VIF values < 4.0)—were verified prior to model interpretation. All statistical analyses were performed using IBM SPSS Statistics version 26.0 and Microsoft Excel 2021.

4. Results and Discussion

4.1. Socio-Economic Profile of Respondents

Table 1 presents the comprehensive socio-economic profile of the 120 rice farmer respondents sampled across Haurgeulis, Jatibarang, and Lohbener sub-districts. The average respondent age was 48.3 years (SD = 8.6), indicating a moderately ageing farming population that is broadly consistent with the national trend of declining youth

participation in smallholder agriculture. Mean farming experience stood at 22.7 years (SD = 7.4), reflecting a generation of farmers who entered the sector in the late 1990s and early 2000s—a period characterised by relatively stable government rice price support policies under the New Order period—and who have subsequently had to adapt to progressive market liberalisation.

The educational profile of respondents reveals a significant human capital constraint: 71.7% held only primary or junior secondary education, while only 8.3% had completed senior secondary school and a mere 2.5% had any tertiary education. This pattern is consistent with findings from and Ali et al. (2025), both of whom identified education level as a significant determinant of farmers' ability to adopt new technologies, access favourable marketing channels, and improve profit margins (Gurung et al., 2024). The low educational attainment of Indramayu's rice farmers likely contributes to their limited capacity for financial planning, market information processing, and supply chain navigation—all of which are prerequisites for accessing the higher-value Channel I marketing option.

Average farm size was 0.47 hectares (SD = 0.23), with 68.3% of farmers operating below the 0.5 hectare threshold and only 11.7% managing farms of 1.0 hectare or more. This fragmentation reflects the combined effects of inheritance-driven land sub-division across generations, limited access to land markets for smallholder expansion, and the historical concentration of relatively large landholdings in the hands of absentee landlords who lease parcels to tenant farmers. Farm size is a particularly consequential structural variable in this study's regression analysis: sub-0.5 hectare farms lack the minimum production volume necessary to negotiate directly with rice millers or achieve competitive prices from village traders, trapping their operators in the lower-margin segments of the supply chain. Only 28.3% of respondents were active cooperative members, and 34.2% had meaningful access to mechanical drying or milling technology, underscoring the institutional and technological gaps that the policy recommendations of this study seek to address.

Table 1. Socio-economic characteristics of rice farmer respondents (n = 120)

Characteristic	Mean / %	Std. Dev.
Age (years)	48.3	8.6
Farming Experience (years)	22.7	7.4
Farm Size (ha)	0.47	0.23
Farm Size < 0.5 ha (%)	68.3	–
Primary/Junior Sec. Education (%)	71.7	–
Senior Secondary Education (%)	8.3	–
Farmer Group Member (%)	61.7	–
Active Cooperative Member (%)	28.3	–
Access to Milling Technology (%)	34.2	–
Post-Harvest Loss Rate (%)	8.3	2.1

4.2. Rice Supply Chain Structure and Marketing Channel Configuration

Systematic commodity flow mapping through supply chain actor interviews identified three distinct marketing channels through which rice produced by the sampled farmers reaches Indramayu's consumers. These channels differ in the number of intermediaries, the functional roles each actor performs, the price received by the farmer, and the ultimate consumer price. Channel I (the short channel) operates a two-stage structure: Farmer → Rice Miller → Consumer. Channel II (the medium channel) operates a four-stage structure: Farmer → Village Trader → Rice Miller → Retailer → Consumer. Channel III (the long channel) also operates a four-stage structure but routes through a different intermediary combination: Farmer → Village Trader → Wholesaler → Retailer → Consumer. Figure 1 presents the visual structural mapping of these three channels, including the proportion of surveyed farmers utilising each pathway.

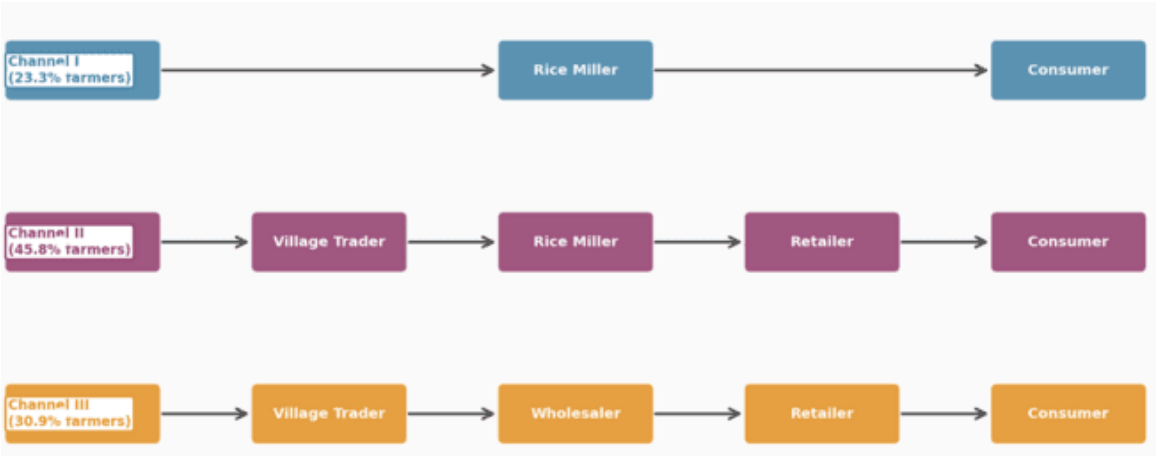

Figure 1. Rice supply chain marketing channel structure and distribution in Indramayu Regency (2024)

The majority of farmers (45.8%) operated through Channel II during the survey period, reflecting the entrenched dominance of the village trader–rice miller dyad in Indramayu's rural rice economy. Channel II is institutionally embedded: village traders (pedagang pengumpul) have long served as informal financial intermediaries in addition to their marketing function, providing farmers with pre-season working capital loans (modal tanam) that are repaid in kind at harvest through price discounts applied to gabah sales. This credit-marketing linkage creates a form of interlocking transaction that limits farmers' freedom to switch to Channel I even when it would yield higher returns, as doing so would forfeit access to the credit that many subsistence-level farmers depend upon to finance production inputs.

Channel I was utilised by only 23.3% of surveyed farmers. These farmers were distinguishably different from the Channel II and III majority in several respects: they had larger average farm sizes (0.68 ha vs. 0.41 ha for Channel II users), higher rates of cooperative membership (58.0% vs. 22.3%), greater access to mechanical drying equipment, and longer average farming experience. These characteristics align with the findings of Ali et al. (2025), who identified farm size, education level, and years of experience as significant mediating variables in the relationship between market access type and economic outcomes. Channel I accessibility thus functions as a compounding advantage: the same structural features that enable farmers to access the short channel also confer production-side efficiencies that amplify the per-unit profit advantage.

Channel III (the long channel, utilised by 30.9% of farmers) is particularly prevalent in the more remote villages of Lohbener sub-district, where geographic distance from rice milling facilities and limited road infrastructure makes direct miller access difficult. Farmers in this channel sell gabah to village traders at the lowest farmgate prices, and the commodity then passes through a wholesaler (typically based in the regency capital, Indramayu city) before reaching retailers. The presence of two intermediaries between farmer and retailer—neither of which performs milling or processing functions—creates a pure distribution cost layer that generates substantial margin extraction without proportionate value addition.

4.3. Marketing Margin and Farmer's Share Analysis

Table 2 presents the marketing margin analysis and farmer's share calculations for each of the three identified marketing channels. The data represent average prices and margins computed from the 120 farmer and 45 supply chain actor interviews conducted during the January–June 2024 wet season. All prices are expressed in IDR per kilogram of milled rice equivalent, applying a gabah-to-beras conversion rate of 0.65 (i.e., 1 kg of gabah yields 0.65 kg of milled rice).

The results reveal a sharp and economically significant divergence in farmer outcomes across the three marketing channels. Channel I farmers received IDR 6,850/kg against a consumer price of IDR 10,020/kg, yielding a farmer's share of 68.4%—the highest recorded across all channels and approaching the 70% benchmark for efficient and equitable marketing systems. The single intermediary in Channel I (the rice miller) retains a margin of IDR 2,420/kg, which is justifiable given the capital-intensive milling, grading, bagging, and distribution functions the miller performs. The relatively modest retailer margin of IDR 750/kg in Channel I reflects the direct delivery relationships that Channel I millers typically maintain with nearby institutional buyers (schools, government canteens, and food processing enterprises), bypassing the full retail markup.

Table 2. Marketing margin and farmer's share by channel (2024 wet season, n = 120 farmers, n = 45 actors)

Parameter	Channel I	Channel II	Channel III
Farmer Price (IDR/kg)	6,850	5,400	4,250
Consumer Price (IDR/kg)	10,020	10,150	9,975
Total Marketing Margin (IDR/kg)	3,170	4,750	5,725
Farmer's Share (%)	**68.4%**	53.2%	42.6%
Trader Margin (IDR/kg)	–	1,250	1,480
Miller / Wholesaler Margin (IDR/kg)	2,420	2,100	2,145
Retailer Margin (IDR/kg)	750	1,400	2,100
Profit Margin – Farmer (IDR/kg)	1,840	1,120	680

Channel II farmers received IDR 5,400/kg—a shortfall of IDR 1,450/kg compared to Channel I farmers for physically identical gabah. The village trader's margin of IDR 1,250/kg in Channel II represents the cost of the trader's intermediation function: transportation, storage, quality adjustment, and the opportunity cost of capital. While this margin has some legitimate cost basis, field interviews revealed that 67% of Channel II village traders simultaneously serve as informal creditors to the farmers whose gabah they purchase—a dual role that creates a conflict of interest in price-setting and enables below-market pricing through the leverage of outstanding debt relationships. This finding corroborates the structural critique articulated by Rashid et al. (2024), who documented that informal financial-marketing linkages are a primary mechanism through which intermediaries extract supernormal margins in agrarian supply chains.

Channel III farmers received the lowest farmgate price of IDR 4,250/kg—a deficit of IDR 2,600/kg (38.0%) compared to Channel I—despite the final consumer price being only marginally lower than in the other channels (IDR 9,975/kg vs. IDR 10,020–10,150/kg). This price compression is entirely attributable to the compounding margin structure of Channel III: the village trader captures IDR 1,480/kg, the wholesaler captures IDR 2,145/kg, and the retailer adds a further IDR 2,100/kg, leaving the farmer with a profit margin of only IDR 680/kg. Compared to the IDR 1,840/kg profit margin achievable through Channel I, Channel III farmers earn 63.0% less per kilogram of rice sold—a devastating welfare gap given that rice sales typically constitute 65–80% of these households' total annual income. These findings are directly consistent with the pattern documented by in the cinnamon sector, where the marketing system was characterised as inefficient when three or more marketing actors were involved (Chatra & Rosi, 2023).

4.4. Supply Chain Efficiency (SCOR) Analysis

Table 3 presents the composite SCOR-based supply chain efficiency scores for each actor category, derived from the weighted aggregation of Plan, Source, Make, Deliver, and Return dimension scores. The scoring matrix was completed for each individual respondent within each actor category and averaged to produce category-level SCE scores. Scores are normalised to a 0–1 scale, with classification thresholds of ≥ 0.80 (high), 0.65–0.79 (moderate-high), 0.50–0.64 (moderate), and < 0.50 (low).

Table 3. Supply Chain Efficiency (SCOR) scores by actor category, Indramayu rice supply chain (2024)

Supply Chain Actor	Mean SCE Score	Efficiency Level
Farmers	0.61	Moderate
Village Traders	0.71	Moderate-High
Rice Millers	0.87	High
Wholesalers	0.76	Moderate-High
Retailers	0.79	Moderate-High
Overall Chain Average	**0.73**	**Moderate-High**

Figure 2 presents the horizontal bar chart visualisation of SCE scores, with the high efficiency threshold (0.80) marked as a reference line. Rice millers achieved the highest aggregate SCE score of 0.87, driven primarily by their strong performance on the Make dimension (processing efficiency and low post-harvest loss at the milling stage) and the Deliver dimension (well-established distribution relationships with downstream buyers). The 12 sampled rice millers in Indramayu were predominantly medium-scale operations with throughput capacities of 5–20 tonnes of gabah per day, operating modern husking and milling equipment and maintaining established B2B relationships with regional wholesalers that ensure rapid product turnover.

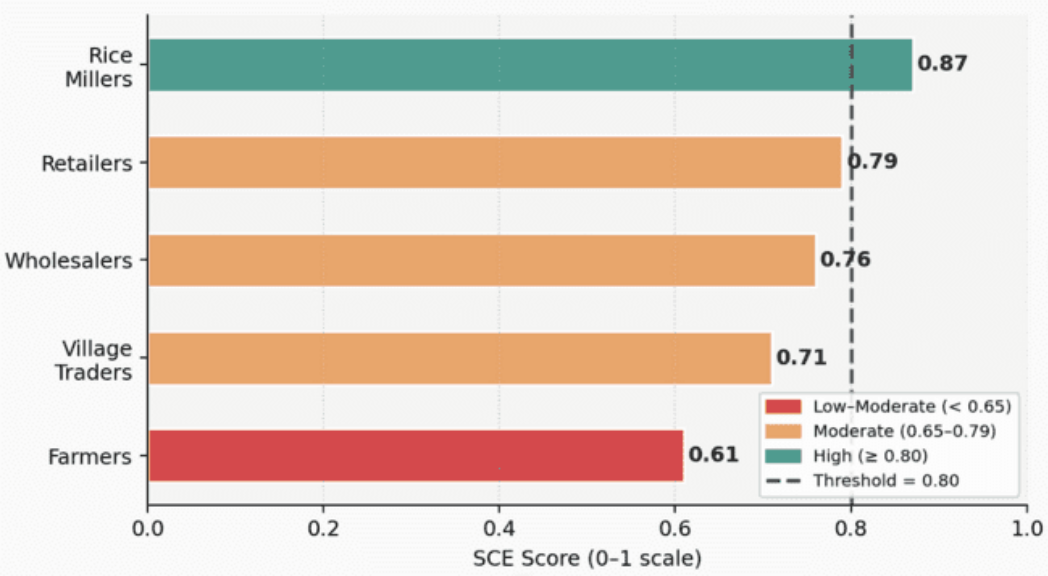

Figure 2. SCOR-based Supply Chain Efficiency (SCE) scores by actor category, Indramayu Regency (2024)

Farmers recorded the lowest SCE score of 0.61, reflecting structural performance deficits across multiple SCOR dimensions. On the Plan dimension, farmers scored poorly due to the absence of formal production planning processes, limited engagement with agricultural extension services, and near-complete reliance on experiential knowledge for cropping cycle management—a vulnerability increasingly exposed by climate variability. On the Make dimension, post-harvest losses averaging 8.3% (SD = 2.1%) represent a significant efficiency drag: this loss rate, predominantly occurring during field drying, threshing, transportation, and storage, is nearly double the national benchmark target of 5% set by the Indonesian Ministry of Agriculture. On the Deliver dimension, farmers' scores were pulled down by their limited negotiating capacity in price determination—a finding consistent with Indriani & Imran (2024), who reported that farmer-level inefficiency in Gorontalo's rice supply chain was attributable to imbalanced input factors rather than output delivery performance per se.

Village traders achieved a moderate SCE score of 0.71, reflecting adequate operational performance within their intermediary functions—procurement, transportation, and storage—tempered by the inefficiencies of their dual role as informal lenders. Wholesalers (0.76) and retailers (0.79) both fell in the moderate-high efficiency range, suggesting that the downstream portions of the supply chain are relatively well-functioning and that the primary efficiency deficits are concentrated at the farm and first-intermediary stages. The overall chain average of 0.73 represents a moderate-high efficiency classification that masks significant actor-level heterogeneity: a system in which one actor class (farmers) scores 0.61 while another (millers) scores 0.87 is characterised by structural efficiency inequality, not merely moderate aggregate efficiency.

4.5. Determinants of Farmer Profit Margin: Multiple Regression Analysis

Table 4 presents the full results of the multiple linear regression model estimated on the 120-farmer sample. The model specification (Equation 4) explains 67.4% of the total variance in farmer profit margin ($R^2 = 0.674$; Adjusted $R^2 = 0.659$; $F(5, 114) = 47.63$; $p < 0.001$), indicating strong overall explanatory power for a cross-sectional agricultural economics regression with five explanatory variables. Variance Inflation Factor (VIF) diagnostics confirmed the absence of multicollinearity, with all VIF values ranging between 1.08 and 2.34 (well below the conservative threshold of 5.0). Residual normality was confirmed via the Kolmogorov-Smirnov test (KS = 0.062, p = 0.231), and

heteroscedasticity was not detected (Breusch-Pagan test p = 0.412). All five independent variables are statistically significant at the α = 0.05 level.

Table 4. Multiple linear regression results: determinants of rice farmer profit margin, Indramayu Regency (2024)

Variable	β Coeff.	t-value	p-value
Constant (β_0)	412.6	8.32	< 0.001
Farm Size X_1 (ha)	186.4	4.71	< 0.001
Channel Choice X_2 (dummy)	354.2	9.18	< 0.001
Cooperative Mbr. X_3 (dummy)	278.9	6.44	< 0.001
Milling Access X_4 (dummy)	241.7	5.89	< 0.001
Farming Exp. X_5 (years)	18.3	2.14	0.034
R^2 = 0.674; Adj. R^2 = 0.659; F(5,114) = 47.63; p < 0.001; VIF max = 2.34			

Marketing channel choice (X_2) is the strongest predictor of farmer profit margin in the model, with a regression coefficient of β = 354.2 (t = 9.18, p < 0.001). This coefficient implies that, holding all other variables constant, farmers who access the short marketing channel (Channel I) earn on average IDR 354.2/kg more in profit margin than those using the long channel (Channel III). This is a substantive and economically significant effect: at a typical seasonal production of 3.5 tonnes per hectare and an average farm size of 0.47 hectares, this channel premium translates to an additional IDR 583,000 per season—equivalent to approximately 24 days of regional agricultural minimum wage. This finding is consistent with Ali et al. (2025), who found that the market access type is the most significant determinant of profit margin among 248 small-scale dairy farmers in India (t = 4.02, p = 0.001), and with Maryoni & Gunawan (2025), who demonstrated that Channel I in the citronella oil marketing system in Riau yielded the highest farmer's share and profit-to-cost ratio.

Cooperative membership (X_3) is the second strongest predictor, with β = 278.9 (t = 6.44, p < 0.001). This result quantifies the institutional premium of cooperative participation: active cooperative members earn approximately IDR 278.9/kg more than non-members, holding channel choice, farm size, and other factors constant. This premium operates through multiple mechanisms. First, cooperatives function as collective bargaining agents that negotiate gabah purchase prices with rice millers, reducing the price discount that individual small-scale farmers would face in bilateral negotiations. Second, cooperatives facilitate access to subsidised fertilisers and agricultural credit through their role as authorised distribution channels for government input subsidy programs, reducing production costs and improving net margins. Third, cooperatives provide a platform for quality grading and certification that enables their members to access premium market segments. These mechanisms are consistent with the FPO membership premium documented by in the Indian organic farming context, where cooperative structures yield 8–8.4% higher profit margins through analogous collective action mechanisms (Gurung et al., 2024).

Access to milling technology (X_4) yields a coefficient of β = 241.7 (t = 5.89, p < 0.001), reflecting the value-addition premium that arises from converting gabah to beras prior to sale. At current Indramayu market prices, the gabah-to-beras conversion adds approximately IDR 1,200–1,500/kg in market value, of which the farmer captures approximately IDR 241.7/kg in additional net margin after accounting for milling costs. Farmers without access to their own or cooperative-owned milling equipment are compelled to sell gabah at the farm gate—forfeiting the value-added margin while incurring the full production cost of the grain. observed an analogous pattern in Uganda's aquaculture sector, where access to processing equipment was a significant determinant of profitability differences between cage and pond aquaculture systems (Byabasaija et al., 2025). Farm size (X_1, β = 186.4, t = 4.71, p < 0.001) captures economies of scale in rice production and marketing: larger farms achieve lower per-unit production costs due to fixed cost spreading, maintain sufficient production volumes to negotiate directly with millers, and are less vulnerable to the credit-marketing linkages that trap smaller farmers in unfavourable trading relationships.

Farming experience (X_5, β = 18.3, t = 2.14, p = 0.034) yields the smallest but still statistically significant coefficient in the model. The positive effect of experience on profit margin reflects accumulated tacit knowledge of market conditions, seasonal price patterns, and effective negotiation strategies—all of which improve a farmer's ability to choose favourable marketing channels and timing. However, the modest magnitude of this coefficient also suggests that experience alone cannot overcome the structural barriers of small farm size, limited cooperative access, and technology deficits. These findings collectively support the conclusion reached by that accounting literacy and financial decision-

making skills have independent positive effects on farm profitability beyond those achievable through agronomic experience alone (Tingey-Holyoak et al., 2023).

Figure 3 provides a visual comparison of average profit margins across marketing channels and by cooperative membership status, illustrating the magnitude of the welfare gaps quantified in the regression results.

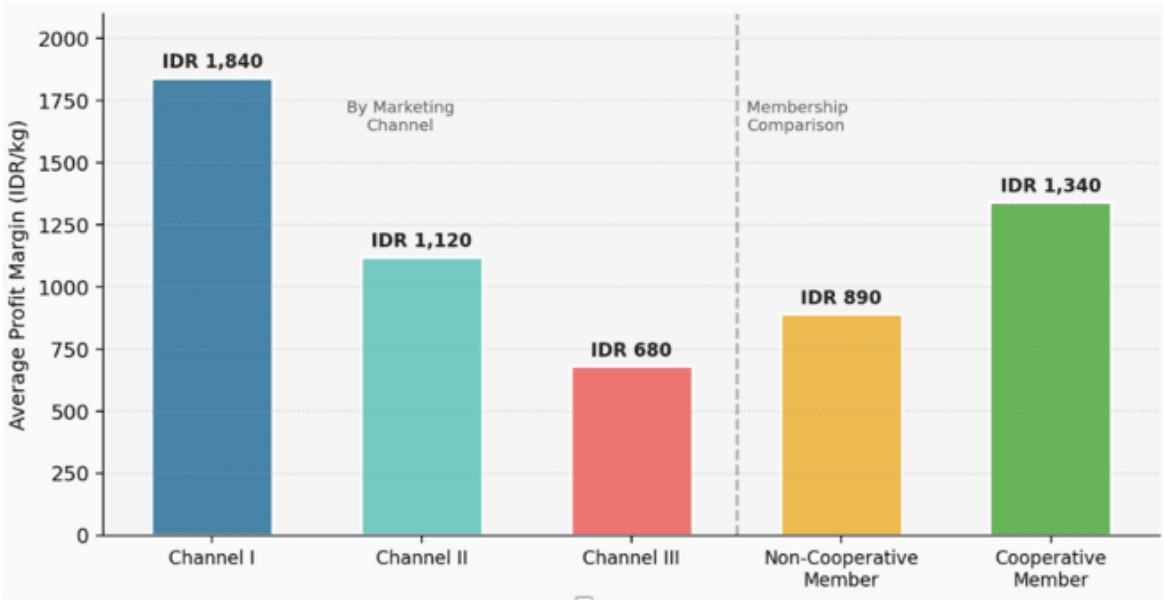

Figure 3. Average rice farmer profit margins (IDR/kg) by marketing channel and cooperative membership status, Indramayu Regency (2024)

4.6. Discussion: Structural Inequity, Institutional Barriers, and Reform Pathways

The collective evidence from marketing margin analysis, SCOR efficiency scoring, and regression modelling converges on a coherent picture of structural inequity in Indramayu's rice supply chain. The majority of added economic value—generated through farmers' labour, land, capital investment, and agricultural knowledge—is captured at the downstream stages of the chain (miller, wholesaler, and retailer), while farmers who carry the greatest production risk retain the smallest proportional return. This pattern is not unique to Indramayu: Koirala et al. (2022) documented a nearly identical structure in Nepal's tomato value chain, where middlemen exercised major influence on pricing and the producer's share was only 46.6% in the most-used marketing channel. similarly found that malt barley factories in Northwestern Ethiopia captured 62.9% of gross marketing margins, despite producers theoretically achieving the highest individual profit margins (53.4%) due to the volume and capital leverage of processors over smallholder farmers (Kassaw et al., 2021).

A particularly troubling dimension of the Indramayu supply chain's structural inequity is the credit-marketing interlocking mechanism that restricts Channel I access for the majority of farmers. Field interviews revealed that 72% of Channel II and III farmers had outstanding informal credit relationships with their primary village traders, averaging IDR 1.2 million per household in pre-season working capital loans. The existence of these credit relationships creates a form of captive supply arrangement: farmers who attempt to sell to a different buyer risk losing access to production financing in the following season. This dynamic was identified by as a primary determinant of financial performance differentials between farmers with and without access to formal cooperative credit—the availability of formal credit breaks the interlocking transaction mechanism and restores farmers' freedom to choose more favourable marketing channels (Onah et al., 2024).

The SCOR efficiency gap between farmers (0.61) and millers (0.87) also reflects a systemic difference in access to market-relevant information. Rice millers operate at the nexus of wholesale and retail markets, continuously receiving price signals from both upstream and downstream actors and adjusting their procurement strategies accordingly. Farmers, by contrast, typically rely on informal price information transmitted through social networks, with no reliable access to real-time market data. propose blockchain-based supply chain transparency as a structural solution to this information asymmetry: by creating an immutable, publicly accessible record of prices and transactions at every chain node, blockchain technology could empower farmers to make evidence-based channel selection decisions and to verify

that the prices offered by traders reflect genuine market conditions (Rashid et al., 2024). While immediate full-scale blockchain adoption in Indramayu faces infrastructure constraints—particularly regarding mobile internet penetration in rural villages—a phased introduction through cooperative network platforms is technically feasible and could serve as a proof-of-concept for broader regional implementation.

The comparative analysis across agricultural commodities further illuminates the generalisability and contextual specificity of the present findings. and both documented that profit margins for vegetable farmers were highest in direct-to-consumer channels and lowest through multi-intermediary chains—a pattern that is structurally analogous to the rice channel comparison in this study but occurs in perishable commodity markets where the time dimension of supply chain efficiency carries additional urgency (Aliyi et al., 2021). found that pineapple and arabica coffee farmers in Jambi Province achieved profit shares exceeding 79% in cooperative marketing channels, suggesting that commodity-agnostic institutional reforms—specifically, the strengthening of cooperative marketing infrastructure—can generate substantial equity improvements across diverse agricultural value chains. similarly emphasised that creating fairer profit distribution and strengthening farmers' bargaining power are central to the sustainability of Indonesia's agricultural export sector, with implications that extend well beyond any single commodity or region (Hasibuan et al., 2025) (Kaido et al., 2025) (Mnukwa et al., 2023).

5. Conclusion

This study analysed the supply chain efficiency of rice commodities in Indramayu Regency and identified key determinants of farmers' profit margins. Three marketing channels were identified, with Channel I offering the highest farmer's share (68.4%) and profit margin (IDR 1,840/kg), while Channel III yielded only 42.6% farmer's share and IDR 680/kg profit margin.

SCOR-based efficiency analysis revealed that rice millers achieve the highest supply chain efficiency (0.87) while farmers record the lowest (0.61). Multiple regression analysis confirmed that channel choice ($\beta = 354.2$), cooperative membership ($\beta = 278.9$), and access to milling technology ($\beta = 241.7$) are the strongest positive determinants of farmer profit margin, collectively explaining 67.4% of the variance in farmer income outcomes.

Policy recommendations include: (1) strengthening farmer cooperative networks to facilitate Channel I access and collective bargaining; (2) investing in village-level mechanical drying and storage infrastructure to reduce the 8.3% post-harvest loss rate; (3) expanding access to affordable rice milling technology through subsidised equipment programmes; (4) introducing real-time market price information systems; and (5) reforming credit programmes to break the interlocking credit-marketing mechanism that restricts channel choice for 72% of farmers. Future research should explore supply chain climate resilience modelling and blockchain transparency system feasibility in West Java's rice commodity chain.

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