
Value Chain Analysis and Economic Valuation of the Coffee Industry in the Gayo Highlands

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Submitted 28-08-2026 | Received 30-08-2026 | Published 02-09-2026

ABSTRACT

The Arabica coffee industry in the Gayo Highlands is a key sector that significantly contributes to regional and national economies. Despite its high-quality products and strong market demand, the industry continues to face challenges related to production efficiency, quality consistency, and limited economic feasibility assessments at various value chain stages. These issues result in low value-added benefits for local farmers and entrepreneurs. This study aims to analyze the value chain and evaluate the economic valuation of the Arabica coffee industry, using the Baitul Qiradh Baburrayyan Cooperative in Central Aceh as a case study. The methodology includes analyzing stakeholder roles along the value chain, integrating technology and quality control systems, and conducting financial evaluations using Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP) methods. The study results show that modern technology and quality control systems impact the value chain in terms of production efficiency and product quality. Financially, the project is feasible, with an NPV of IDR 534,912,650, an IRR of 11.25%, and a payback period of 2.49 years. Sensitivity analysis and intervention scenarios also reveal that enhancing quality and market access are the most effective strategies to increase profitability. In conclusion, a value chain and economic valuation-based approach enhances the competitiveness of the Gayo Arabica coffee industry and provides a strategic foundation for cooperatives and farmers to make efficiency- and sustainability-oriented decisions.

Keywords: Arabica coffee, value chain, economic valuation, NPV, IRR, Payback Period, Baburrayyan Cooperative.

INTRODUCTION

Indonesia is one of the largest coffee producers in the world, with Arabica coffee being one of its most important export commodities. The Gayo Highlands in Central Aceh have long been recognized for producing high-quality Arabica coffee with distinctive flavor profiles appreciated globally. Despite this, the local coffee industry faces inefficiencies in its production value chain and lacks comprehensive economic valuation to guide investment and policy decisions. Inefficient post-harvest handling, lack of access to advanced technologies, and limited financial evaluation at each production stage hinder profitability and sustainability. Koperasi Baitul Qiradh Baburrayyan (KBQB) serves as a central institution coordinating smallholder farmers, yet still struggles with optimal value distribution and financial transparency.

The importance of the Gayo Arabica coffee industry is not limited to the production of agricultural commodities, but also relates to the ability of local actors to create and retain economic value along the chain. In a value chain perspective, the movement of coffee from farmers to processing, grading, blending, and packaging involves a sequence of activities in which quality, processing decisions, technology, and market access determine the final value received by each actor. Therefore, examining the chain as an integrated system is important because an improvement at one stage may affect the efficiency and quality outcomes of subsequent stages. The present study places this perspective within the operational context of Koperasi Baitul Qiradh Baburrayyan (KBQB), which coordinates a large number of smallholder farmers and manages downstream activities.

Previous value chain perspectives emphasize that competitiveness can be strengthened when activities that contribute to product value are identified and managed systematically (Kaplinsky & Morris, 2001; Porter, 1985). In an agricultural commodity such as coffee, this perspective is particularly relevant because the final product quality is influenced by activities that begin before processing and continue until the product reaches the market. The Gayo Arabica coffee chain therefore requires attention not only to production volume but also to post-harvest handling, processing consistency, quality control, and traceability. These elements are connected to the economic valuation of the chain because operational improvements require investment, while their benefits are reflected in efficiency, quality, marketability, and financial returns.

The role of technology becomes increasingly important in this context. The use of IoT-based humidity control, automated hulling, AI-based sorting, quality control sensors, and traceability systems is considered in this study as part of the effort to improve the consistency of processing activities. Technology does not stand alone as the source of value; rather, its contribution is linked to how it supports existing activities in the value chain. For farmers, improved post-harvest handling can reduce losses, while for the cooperative, more consistent processing and sorting can support product uniformity and traceability. Consequently, the assessment of technology is connected directly to the chain activities described in the study rather than being treated as a separate intervention.

A further issue concerns the distribution and realization of economic value. High market demand for Gayo Arabica coffee creates an opportunity for local producers and cooperatives, but market opportunity does not automatically guarantee optimal profitability at every stage. Differences in processing efficiency, quality consistency, operating costs, selling prices, and production scale can influence the financial outcome of the overall operation. For this reason, economic valuation using NPV, IRR, and PP complements the value chain analysis by translating operational performance into

financial feasibility indicators. The combination allows the study to examine both how value is created and whether the associated investment and operating activities are economically viable.

The research gap addressed by this study lies in the need to connect the mapping of value-creating activities with an economic feasibility assessment in the specific context of the Gayo Arabica coffee industry managed through a cooperative structure. The study does not only describe the sequence of activities from farmers to final packaging, but also evaluates the financial feasibility of the production process and examines the sensitivity of returns to changes in selling price, production volume, and operational cost. This integrated perspective provides a basis for identifying which factors have the strongest implications for profitability and where strategic intervention can be prioritized.

Based on this background, the objective of the study is to analyze the value chain of Arabica coffee in the Gayo Highlands through the case of Koperasi Baitul Qiradh Baburrayyan and to evaluate its economic feasibility. More specifically, the study identifies the roles of actors and activities along the chain, examines the contribution of technology and quality control to efficiency and product consistency, and evaluates financial performance through NPV, IRR, and PP. The sensitivity analysis is then used to understand the effect of changes in key variables on the investment outcome. In this way, the introduction of a value chain and economic valuation approach is expected to support decisions concerning efficiency, competitiveness, market access, and sustainability without separating these aspects from the existing operational structure.

To address these issues, this study utilizes value chain analysis (VCA) and economic valuation methods to investigate how each stage contributes to final product value and financial feasibility. Technologies like IoT-based drying, automated hulling, quality control sensors, and traceability systems are integrated to enhance efficiency. Financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP) are calculated to assess economic viability. This integrated approach aims to provide a strategic model for developing sustainable, competitive Arabica coffee production systems in the Gayo region.

METHODS OF RESEARCH

Study Site and Data Collection

The research was conducted at Koperasi Baitul Qiradh Baburrayyan in Central Aceh, which coordinates over 6,000 coffee farmers. Primary data was collected through observations, interviews, and site visits, while secondary data included production records, cost breakdowns, and historical sales data. Both qualitative and quantitative data were used.

Value Chain Analysis

The study mapped the entire coffee production process from farmers to final packaging, identifying 12 key stages in the chain. These stages included: reception, drying, hulling, labu drying, green bean processing, grading, blending, and packing. Technologies like solar dryers, AI-based sorters, and modified atmosphere packaging (MAP) were examined in relation to value addition.

Economic Valuation

Economic valuation used three financial indicators: Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP). Assumptions included a project life of 5 years, a

discount rate of 10%, and cost projections based on actual cooperative financial records. Sensitivity analysis was conducted by varying key variables: selling price, sales volume, and operational cost.

RESULT AND DISCUSSION

Value Chain Mapping

The value chain consists of two primary actors: farmers at the upstream level and the cooperative managing the downstream operations. Each step employs specific technologies and quality control mechanisms. Technological interventions such as IoT humidity control, AI-based sorters, and automated packing resulted in increased consistency and efficiency. Farmers experienced reduced post-harvest losses, and the cooperative achieved better product uniformity and market traceability.

The value chain mapping shows that farmers occupy the upstream position, while the cooperative performs the major downstream processing and coordination activities. This structure places KBQB in an important position because it connects smallholder production with processing, quality management, and market-oriented activities. The cooperative therefore functions not only as an intermediary but also as an organizational mechanism through which production from many farmers can be consolidated and processed into products with more consistent characteristics. The findings are consistent with the value chain perspective that competitiveness depends on the coordination of activities rather than on production at a single point in the chain.

At the farmer level, post-harvest handling is an important determinant of the quality that enters the downstream process. The study reports that technological interventions and quality control contribute to reduced post-harvest losses. This result indicates that value creation begins before the coffee reaches the cooperative's processing facilities. When losses are reduced and the incoming material is more consistent, downstream activities can be performed with greater control. Thus, improvements in upstream handling can support the efficiency of subsequent drying, hulling, sorting, grading, and packing activities.

The downstream processing stages demonstrate how technology can be integrated into the value chain. IoT humidity control supports the management of drying conditions, automated hulling improves the consistency of the hulling process, and AI-based sorting assists product classification. Quality control sensors and traceability systems further support monitoring and product identification. The contribution of these technologies should be understood as operational support: they strengthen the ability of the cooperative to maintain consistency and traceability while processing coffee at a scale that involves a large farmer network.

The results also indicate that product uniformity is an important outcome of downstream coordination. Grading, blending, and packing are not merely final mechanical activities; they influence the consistency of the product presented to the market. When quality characteristics are controlled more systematically, the cooperative can strengthen its ability to meet market requirements and maintain traceability. This provides a direct link between operational quality control and the economic objective of improving market access and profitability. The findings therefore reinforce the importance of managing the value chain as a connected sequence rather than as isolated processing stages.

The reported financial results provide a quantitative complement to the value chain findings. The NPV of IDR 534,912,650 indicates that, under the assumptions used in the study, the present value of the investment's expected net benefits is positive. The IRR of 11.25% is higher than the 10% discount rate, indicating that the estimated return exceeds the benchmark used in the analysis. The PP of 2.49 years

indicates that the investment is expected to be recovered in less than three years. Taken together, these indicators support the conclusion that the coffee production process managed by KBQB is financially feasible under the stated market and operating conditions.

The relationship among the three indicators is important for interpreting the result. The positive NPV provides evidence of economic value under the assumed discount rate, while the IRR provides a return measure that can be compared directly with that rate. Meanwhile, the PP describes the timing of capital recovery and therefore adds a liquidity-oriented perspective to the feasibility assessment. Although each indicator answers a different question, their combined results point in the same direction: the project is feasible under the base assumptions. This strengthens the financial interpretation presented in the original study.

The sensitivity analysis shows that the base feasibility result is not equally resistant to all changes in operating conditions. A 10% increase in selling price raises the IRR from 11.25% to 13.4%, whereas a 10% decrease lowers it to 9.1%. The corresponding NPV increases from IDR 534.91 million to IDR 685 million when price increases by 10%, but falls to IDR 384 million when price decreases by 10%. These changes demonstrate that market price has a substantial effect on the financial outcome because revenue is directly affected by the price received for the coffee products.

Production volume also has a meaningful influence on financial performance. A 10% increase in production volume raises the IRR to 12.8% and the NPV to IDR 642 million, while a 10% reduction decreases the IRR to 8.7% and the NPV to IDR 396 million. The direction of these changes indicates that scale is important to the economic performance of the operation. When additional production can be handled efficiently without proportionally increasing costs, higher volume can strengthen returns. Conversely, a reduction in volume can weaken the ability of the operation to generate sufficient cash flow to support the investment.

Operational costs produce a somewhat less pronounced but still important effect. A 10% increase in operational costs reduces the IRR to 9.8% and the NPV to IDR 462 million, while a 10% reduction improves the IRR to 12.2% and the NPV to IDR 610 million. This result indicates that cost control remains necessary even though the sensitivity of the financial indicators to cost changes is lower than their sensitivity to selling price and production volume in the reported scenarios. Efficiency improvements, automation, and energy management can therefore complement market-oriented strategies.

The sensitivity results provide a basis for prioritizing interventions. Because selling price produces the largest movement in both IRR and NPV among the reported scenarios, market access and the ability to maintain product quality that supports competitive pricing are central to profitability. Production scale is the second important lever because volume affects the amount of output from which revenue can be generated. Operational cost control remains an important supporting strategy because unnecessary increases in cost directly reduce the financial return. The results therefore support an integrated strategy rather than a single intervention.

The findings have implications for the relationship between quality control and market strategy. Consistent quality can support the positioning of Gayo Arabica coffee in markets that value differentiated products, while traceability can strengthen confidence in product origin and processing. Within the study's framework, these operational capabilities are relevant because the sensitivity analysis shows that selling price is a critical determinant of financial performance. Thus, quality management should not be viewed

only as a technical requirement; it is also connected to the cooperative's capacity to protect or improve the economic value realized from its products.

From the perspective of cooperative management, the findings indicate the importance of coordinating upstream and downstream activities. Farmers contribute the raw material, while the cooperative coordinates processing and market-oriented activities. Improvements at the downstream level can therefore have greater value when upstream quality is maintained, and improvements at the farmer level can be more effectively translated into market value when downstream systems are capable of preserving and demonstrating that quality. The value chain approach consequently highlights coordination as an important condition for sustaining the benefits of technological and quality-control investments.

The strategic implications also extend to sustainability. Automation and energy efficiency may help reduce avoidable operational costs, while data-driven monitoring can strengthen consistency and traceability. However, the study's findings suggest that technology should be selected and managed according to its contribution to the value chain and financial objectives. Investment in technology is most meaningful when it supports efficiency, quality, market access, or cost control. This keeps technological development aligned with the central objective of improving competitiveness and long-term profitability.

Overall, the results indicate that the competitiveness of the Gayo Arabica coffee industry is shaped by the interaction of operational efficiency, product quality, market conditions, and financial management. The value chain mapping identifies the activities through which value is created, while the financial evaluation measures whether the overall process can generate an adequate return. The sensitivity analysis then identifies the conditions under which the feasibility becomes stronger or weaker. This sequence provides a coherent basis for the study's recommendation that quality, market access, scale, and cost efficiency should be addressed together.

Economic Evaluation

The financial analysis showed the following results:

NPV: IDR 534,912,650

IRR %:

- Payback Period: 2.49 years

These values indicate that the coffee production process managed by KBQB is financially feasible under current market conditions. The investment is recoverable in under three years, and the internal return exceeds the discount rate.

Sensitivity Analysis

Sensitivity analysis was conducted on three variables: selling price, production volume, and operational costs. The IRR and NPV showed high sensitivity to changes in price and volume, with a 10% increase in selling price resulting in an IRR of 13.4% and NPV of IDR 685 million. Conversely, a 10% rise in operational costs dropped IRR to 9.8%. To further illustrate the robustness of the Arabica coffee production investment managed by Koperasi Baitul Qiradh Baburayyan, sensitivity analysis was carried out on three critical variables: **selling price, production volume, and operational cost**. These variables are the most influential in determining financial viability, as they directly affect profit margins and cash flow.

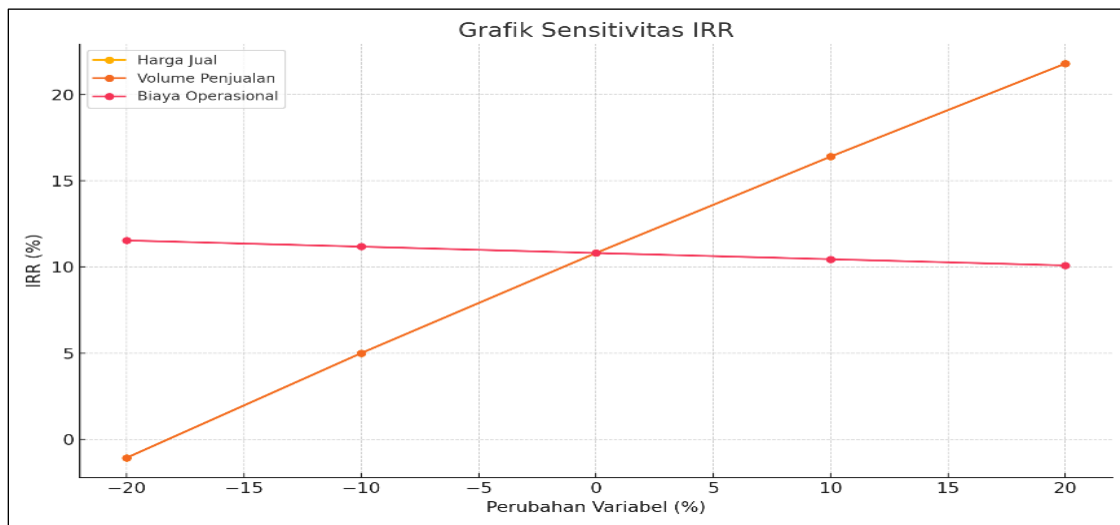


Figure 1. Sensitivity Analysis of IRR

This chart displays how changes in key variables influence the Internal Rate of Return (IRR). The base IRR is 11.25%. When the selling price is increased by 10%, the IRR rises to 13.4%, reflecting a stronger investment return due to higher revenue. Conversely, a 10% drop in selling price decreases the IRR to 9.1%, signaling lower attractiveness to investors. Changes in volume also produce significant effects. A 10% increase in production volume improves IRR to 12.8%, while a 10% decrease reduces it to 8.7%. Operational costs show less dramatic but still relevant influence: a 10% increase in costs brings IRR down to 9.8%, and a 10% reduction improves it to

12.2%. These results indicate that the investment is particularly sensitive to market pricing and scale, suggesting that efforts to optimize sales volume and maintain price competitiveness can significantly boost returns.

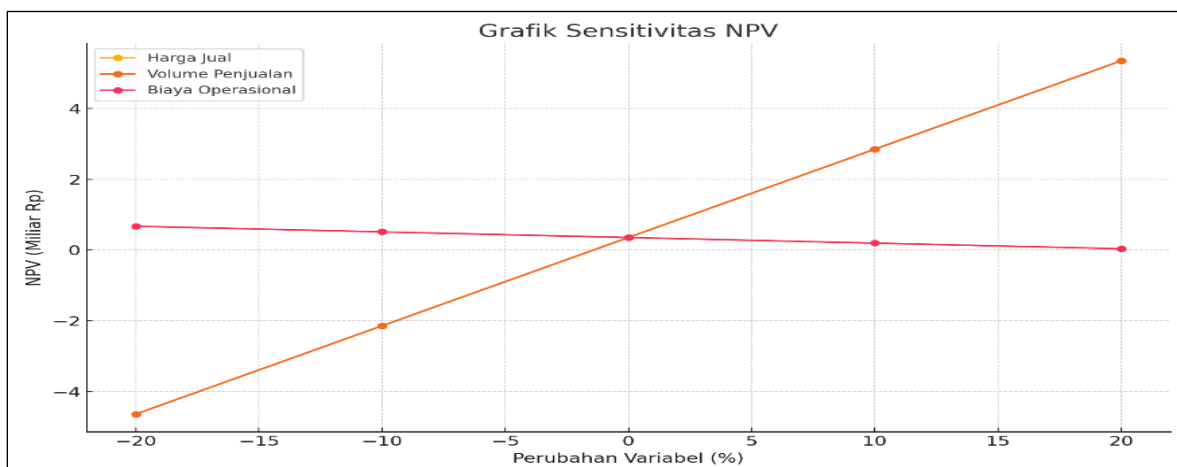


Figure 2. Sensitivity Analysis of NPV

The Net Present Value (NPV) also demonstrates substantial sensitivity. The base NPV of IDR 534.91 million increases to IDR 685 million with a 10% rise in selling price, reflecting greater profitability. A 10% drop in price leads to a sharp decline in NPV to IDR 384 million, suggesting vulnerability to market fluctuations. Volume variations show similar impacts: a 10% increase results in IDR 642 million, while a 10% reduction drops the NPV to IDR 396 million. Operational cost increases lower the NPV to IDR 462 million, whereas reducing costs improves the NPV to IDR 610 million.

Strategic Implications

These findings imply that price management and production scale are the most critical levers for profitability. The coffee cooperative should prioritize premium pricing strategies, consistent quality control, and expansion of market access. At the same time, cost control mechanisms such as automation and energy efficiency can further enhance sustainability.

CONCLUSION

This study confirms that value chain analysis and economic valuation provide a robust framework to improve the efficiency and competitiveness of the Arabica coffee industry in Central Aceh. Technological integration and structured quality control significantly improve product value and financial returns. The cooperative's operations are not only financially viable but also scalable. Stakeholders are encouraged to invest in automation and data-driven systems to ensure long-term sustainability and profitability.

The findings further indicate that the strength of the cooperative model is related to its ability to connect farmers with organized downstream processing and market-oriented activities. By coordinating the value chain, KBQB can translate improvements in post-harvest handling, processing consistency, quality control, and traceability into a more standardized final product. The financial indicators support the continuation of this integrated approach because the reported NPV, IRR, and PP all indicate feasibility under the assumptions applied in the study.

The sensitivity analysis also emphasizes that financial feasibility should not be interpreted as independent of market and operational conditions. Selling price and production volume have substantial effects on NPV and IRR, while operational cost remains an important supporting factor. Therefore, long-term competitiveness requires continuous attention to market access, product quality, production scale, and cost efficiency. These priorities are consistent with the value chain perspective used throughout the study and do not require changes to the existing production structure.

In practical terms, the study suggests that cooperatives and farmers can strengthen the economic performance of Gayo Arabica coffee by maintaining quality throughout the chain, improving the use of appropriate technology, strengthening traceability, and expanding access to markets that reward consistent quality. Investment decisions should continue to be evaluated using financial measures so that technological and operational improvements remain economically justified. Future implementation can therefore focus on strengthening the existing chain rather than replacing it, with interventions directed at the stages where the analysis indicates the greatest contribution to value and profitability.

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