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Aggregation Strategies and Operational Performance of Dairy Cooperative Societies in Kiambu County, Kenya

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Abstract: Dairy cooperatives play a critical role in integrating smallholder farmers into milk markets by aggregating production, reducing transaction costs, strengthening collective bargaining power, and facilitating access to markets and services. However, their operational performance may be constrained by dispersed milk production, inefficient collection and transportation systems, inadequate infrastructure, and weak market coordination. This study examined the association between aggregation strategies and the operational performance of dairy cooperative societies in Kiambu County, Kenya. A descriptive cross-sectional research design was employed, covering 19 dairy cooperative societies. Managers, board members, and cooperative-member employees served as key informants. A stratified purposive sampling procedure targeted 78 respondents, of whom 69 completed the questionnaire, yielding an 88.46% response rate. Primary data were collected using structured questionnaires, while secondary data on 2024 milk production volumes and milk payment rates were obtained from the Kenya Dairy Board. Operational performance was measured using a composite Operational Performance Index (OPI), calculated as annual milk volume multiplied by the average annual milk payment per litre and subsequently natural-log transformed. Data were analysed using descriptive statistics, correlation analysis, diagnostic tests, and multiple linear regression. The findings revealed a strong positive correlation between aggregation strategies and operational performance ($r = 0.852$, $p < 0.01$). After controlling for technology adoption and governance practices, aggregation strategies remained a positive and statistically significant predictor of operational performance ($\beta = 0.988$, $SE = 0.346$, $t = 2.86$, $p = 0.012$). The overall regression model was statistically significant and explained 85.7% of the variation in log operational performance ($R^2 = 0.857$; $F(3,15) = 29.874$, $p < 0.001$). Qualitative findings identified decentralized milk collection, investment in collection and cooling infrastructure, collective marketing, coordinated transportation, and cost-efficient aggregation as key mechanisms through which cooperatives could improve operational efficiency and market coordination. The study concludes that well-organized aggregation strategies are an important organizational capability associated with stronger operational performance among dairy cooperatives. It recommends strategic investment in decentralized collection systems, cold-chain infrastructure, coordinated transportation, collective marketing, and cost-management practices, complemented by effective technology adoption and governance. Given the cross-sectional design and small number of cooperatives, the findings should be interpreted as evidence of association rather than definitive causality.

Keywords: *Dairy cooperatives; Aggregation strategies; Milk collection; Operational performance; Collective marketing; Smallholder farmers; Kenya.*

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Introduction

Dairy cooperatives play a critical role in integrating smallholder farmers into agricultural markets by facilitating milk collection, aggregation, marketing, payment, access to inputs and services, and coordination with processors. Through collective action, cooperatives can generate economies of scale, reduce transaction costs, strengthen farmers' bargaining power, and improve access to reliable markets. These functions are particularly important in smallholder dairy systems, where producers are often geographically dispersed and individually supply relatively small and variable volumes of milk. However, dairy cooperatives continue to face operational challenges associated with dispersed production, fluctuations in milk supply, high collection and transportation costs, inadequate infrastructure, and information asymmetries. Such challenges can undermine the efficiency and competitiveness of cooperative operations.

Aggregation strategies are therefore central to the effective management and performance of dairy cooperatives. These strategies encompass decentralized milk collection centres, collective marketing, investment in collection and storage infrastructure, collective procurement, milk collection route optimization, and cost-leadership approaches. When appropriately designed and implemented, aggregation can consolidate milk volumes, improve coordination among producers, reduce collection and transportation costs, enhance resource utilization, strengthen bargaining power, and facilitate access to processors and other markets. Evidence from agricultural value chains indicates that effective coordination and collective action can improve market participation and value-chain outcomes, including within the Kenyan dairy sector. Nevertheless, the effectiveness of specific aggregation strategies may vary according to the organizational,

infrastructural, and market conditions under which dairy cooperatives operate.

Despite the importance of aggregation in dairy value-chain coordination, empirical evidence directly examining the relationship between aggregation strategies and the operational performance of dairy cooperative societies in Kiambu County remains limited. This gap is important because Kiambu County has a substantial smallholder dairy sector in which cooperative societies provide critical aggregation and market-linkage functions. Understanding which aggregation strategies are adopted and the extent to which they contribute to operational performance can provide evidence for improving cooperative efficiency, reducing operational costs, and strengthening the competitiveness of smallholder dairy producers.

Against this background, the study examined the effect of aggregation strategies on the operational performance of dairy cooperative societies in Kiambu County, Kenya. Specifically, the study sought to: (i) identify the aggregation strategies adopted by dairy cooperative societies in the county; (ii) determine the effect of aggregation strategies on their operational performance; and (iii) establish which aggregation strategies have the greatest effect on operational performance. Accordingly, the study was guided by three research questions: (i) What aggregation strategies are adopted by dairy cooperative societies in Kiambu County, Kenya? (ii) How do aggregation strategies influence the operational performance of dairy cooperative societies in Kiambu County, Kenya? and (iii) Which aggregation strategies have the greatest effect on the operational performance of dairy cooperative societies in Kiambu County, Kenya?

To empirically assess the relationship between aggregation strategies and operational performance, the study tested the null hypothesis that aggregation strategies have no significant effect on the operational performance of dairy cooperative societies in Kiambu County, Kenya (H_0), against the alternative hypothesis that aggregation strategies have a significant effect on the operational performance of dairy cooperative societies in Kiambu County, Kenya (H_1).

Literature Review

Milk Aggregation Strategies and Economies of Scale

Milk aggregation strategies involve pooling resources, services, and efforts among dairy cooperative members and other stakeholders to achieve economies of scale, improve market access, and enhance operational efficiency (Wu & Leung, 2017). In dairy cooperatives, aggregation may include collective marketing, joint input procurement, pooled milk collection, shared processing, and access to financial services. Evidence from East Africa shows that dairy hubs, which combine milk bulking and chilling with access to processors and production services, can provide an institutional mechanism for linking smallholder farmers to larger markets (Omondi et al., 2017).

These strategies enable smallholder farmers to strengthen bargaining power, reduce transaction and operating costs, access larger and more reliable markets, and facilitate investments in infrastructure that may be unaffordable individually (Mwebia, 2024). In Kenya, cooperative participation has also been associated with improved farmer incomes, with recent evidence showing an approximately 10% income gain among farmers participating in cooperative milk marketing (Onyango et al., 2023). However, the benefits of aggregation depend on the cooperative's ability to effectively coordinate members, manage resources, and maintain efficient operational systems.

Collective Marketing and Procurement

Collective marketing is one of the most widely applied aggregation strategies in dairy cooperatives because it can strengthen farmers' bargaining power, reduce transaction costs, and improve market access. Githinji et al. (2023) reported that cooperatives using collective marketing achieved higher milk-sale revenues, while Singh et al. (2020) found that Indian dairy cooperatives secured higher prices per litre than farmers marketing milk individually. Similarly, Okello et al. (2020) found that group marketing and other agribusiness support services significantly increased the likelihood that Kenyan smallholder dairy farmers would select cooperative marketing channels. This approach also benefits farmers engaged in other market-driven value chains, including live animals, beef, hides and skins, and livestock by-products (Anno, Khavetsa, & Etabo, 2023).

Mwebia (2023) established that digital platforms supporting collective marketing could expand market outreach and improve milk prices. However, collective marketing does not automatically translate into improved operational performance, as excessive dependence on cooperative marketing may weaken individual farmers' market connections, while weak management and corruption in price negotiations can undermine the benefits of collective action (Kariuki et al., 2023). Recent evidence from Kenya further shows that side-selling can weaken cooperative milk volumes when farmers face cash constraints or unexpected financial shocks, particularly where cooperatives make delayed payments (Geng et al., 2023).

Collective procurement is another important aggregation strategy, with Ongwech et al. (2022) finding that East African dairy cooperatives reduced production costs through bulk input purchasing, consistent with findings from Ethiopian dairy cooperatives (Githinji et al., 2023). In Kenya, technology-supported procurement systems have also been shown to reduce fraud-related losses and improve supply-chain efficiency (KDB, 2024), although bulk purchasing may fail to generate cost savings where governance, distribution, and resource-management systems are weak (Kilelu, et al 2017). This reinforces the importance of institutional trust and effective coordination in determining whether collective arrangements generate sustained benefits.

Shared Processing, Value Addition and Infrastructure

Shared processing facilities and related milk infrastructure are important dimensions of milk aggregation because they enable dairy cooperatives to undertake value addition, reduce milk losses, improve resource utilization, and strengthen supply-chain coordination. Gitau (2021) reported higher profitability among South African dairy cooperatives with processing facilities than those selling raw milk, while Ngeno et al. (2017) found that shared cooling and pasteurization facilities in Uganda reduced milk spoilage and improved operational performance. Similarly, Githinji et al. (2023) reported lower operational costs among cooperatives using renewable-energy-based processing facilities in Rwanda. Omondi et al. (2017) demonstrate that dairy hubs in Kenya and Uganda function as farmer-owned milk bulking and chilling facilities that connect smallholders with processors and provide access to inputs and other dairy services.

Infrastructure such as milk collection centres, cooling and storage facilities, transportation networks, and processing plants can expand market coverage, reduce transportation inefficiencies, lower operating costs, and improve resource utilization (Okello, et al., 2020). Van der Lee et al. (2018) further show that dairy-sector upgrading in East African dairy clusters depends on interactions among technical, value-chain, and institutional factors, including milk collection, input supply, financing, and service provision. However, the development and maintenance of shared processing infrastructure require substantial capital investment, and financing constraints, high maintenance costs, and weak facility management may limit the expected operational benefits, particularly among Kenyan dairy cooperatives (Ongwech et al., 2022).

Operational Performance of Dairy Cooperative Societies

Operational performance refers to the extent to which a dairy cooperative efficiently transforms its available resources and activities into desirable outputs, as reflected in indicators such as milk production volume, milk yield per cow, operating costs, milk payment rates, revenue generation, and market performance. Increased milk production can enhance cooperative revenues and overall performance, although these benefits depend on effective control of production and operating costs, including feed, labour, transportation, and maintenance (Mwebia, 2024). Similarly, milk yield per cow is an important productivity indicator because it reflects the effectiveness of feeding, breeding, veterinary services, and general dairy management practices (KDB, 2024).

Empirical evidence suggests, however, that aggregation does not necessarily improve farm-level productivity automatically. Omondi et al. (2017) found no strong farm-level productivity effect attributable solely to different processor-linkage arrangements through dairy hubs, indicating that the maturity and efficiency of aggregation institutions must be accompanied by appropriate extension and support services. At the cooperative level, Gitau (2021) also found that credit management significantly influenced the financial performance of Kenyan dairy marketing cooperatives. Aggregation strategies can therefore improve performance by generating economies of scale, reducing transaction and procurement costs, strengthening bargaining power, improving market access and milk quality, facilitating value addition, and promoting better utilization of infrastructure, but these effects depend on complementary organizational capabilities.

Governance, Institutional Factors and Theoretical Perspectives

The effectiveness of milk aggregation strategies is strongly influenced by governance, institutional arrangements, financing, technology, infrastructure, and managerial capacity. Githinji et al. (2023) observed that poorly managed cooperatives may experience inefficiencies that undermine operational performance, while Muriuki et al. (2019) identified regulatory limitations and inadequate government support as barriers to effective aggregation. Njoroge et al. (2024) further highlighted digital literacy gaps as a constraint to technology-supported aggregation. Evidence from Kenyan dairy value chains also demonstrates that power relationships, trust, and social networks influence actors' behaviour and decisions concerning milk quality, highlighting the institutional dimension of dairy-chain performance (Bett et al., 2023).

Similarly, research on emerging dairy clusters in Kenya and Ethiopia indicates that governance, service provision, value-chain coordination, and farmer organization characteristics shape the upgrading and competitiveness of dairy systems (Van der Lee et al., 2018; Anno & Pjero, 2021). These challenges suggest that the benefits of collective marketing, joint procurement, milk collection, shared processing, and infrastructure development cannot be realized through aggregation alone but require effective governance, institutional support, adequate financial resources, and managerial competence. The Kenyan evidence on cooperative participation, side-selling, financial management, and market-channel choice collectively suggests that operational performance depends not simply on whether farmers aggregate milk, but on how effectively the cooperative manages incentives, payment systems, services, infrastructure, and member relationships (Geng et al., 2023; Gitau, 2021; Okello et al., 2020; Onyango et al., 2023).

Theoretical Perspective

The study was primarily informed by Transaction Cost Economics (TCE) and the Resource-Based View (RBV). Transaction Cost Economics, advanced by Williamson (1979), posits that organizations adopt structures and strategies that minimize the costs associated with market transactions; in dairy cooperatives, aggregation can reduce transaction costs by consolidating milk from dispersed producers, coordinating transportation, improving information flow, and strengthening collective bargaining.

The Resource-Based View complements this perspective by suggesting that organizations can achieve superior performance through valuable resources and organizational capabilities, such as aggregation infrastructure, coordinated distribution networks, collective marketing arrangements, and operational knowledge. Together, these theoretical perspectives provide a useful explanation of how well-organized milk aggregation mechanisms can reduce transaction costs, strengthen organizational capabilities, and ultimately enhance the operational performance of dairy cooperative societies.

Methodology

Research Design and Population

A descriptive research design was adopted for the study. The study focused on 19 dairy cooperative societies in Kiambu County, Kenya. The target population comprised individuals involved in the operations and activities of the dairy cooperatives. The units of study and analysis were the 19 dairy cooperative societies, while managers, board members, and employees who were also cooperative members served as key informants. These respondents were considered knowledgeable about the cooperatives' aggregation strategies and operational practices and were therefore well positioned to provide relevant information for the study.

Sampling

A stratified purposive sampling procedure was used. Each cooperative was treated as a stratum, and respondents were selected from three functional categories: board members, managers, and stakeholders/member-employees. A total sample of 78 respondents was targeted where 69 completed the questionnaire, giving an 88.46% response rate.

Data Collection

Primary data were collected using structured self-administered questionnaires distributed physically and through Google Forms. The questionnaire employed five-point Likert-scale

items ranging from 1 = strongly disagree to 5 = strongly agree. A pilot study involving 15 respondents was conducted to assess clarity, reliability, and validity of the instrument. Secondary operational data for 2024 were obtained from the Kenya Dairy Board. These included monthly milk production volumes and milk payment rates. Annual milk volume was calculated as the sum of monthly production, while the annual average payment rate was calculated from monthly payment rates.

Measurement of Variables

Aggregation strategies were measured using several Likert-scale items covering aspects such as decentralized distribution, infrastructure development, collective marketing, and cost-efficiency strategies. Operational performance was measured using an Operational Performance Index: OPI = Total annual milk volume × Average annual milk payment per litre Because the resulting performance measure was highly skewed, its natural logarithm was used in the regression analysis. The regression model was specified as: $\log OPI = \beta_0 + \beta_1 AS + \beta_2 TA + \beta_3 GP + \varepsilon$

where:

- logOPI = logarithm of operational performance index;
- AS = aggregation strategies;
- TA = technology adoption;
- GP = governance practices;
- β_0 = constant;
- β_1, β_2, β_3 = regression coefficients; and
- ε = error term.

Reliability and Diagnostic Tests

The aggregation strategies scale demonstrated acceptable internal consistency with a Cronbach's alpha of 0.738. Diagnostic tests included the Shapiro-Wilk test for residual normality, Breusch-Pagan/Cook-Weisberg test for heteroscedasticity, variance inflation factor (VIF) analysis for multicollinearity, and visual assessment of residual plots for linearity.

Results

Quantitative Results

Descriptive Results

The descriptive analysis provides an overview of respondents' perceptions of aggregation strategies and the operational performance of the 19 cooperatives included in the study. The results indicate that aggregation strategies recorded a mean score of 3.398, with a standard deviation of 0.592. The mean score suggests that, overall, the cooperatives demonstrated a moderately strong orientation towards aggregation strategies. These strategies may include activities such as collective collection of produce, bulking, coordination of supply, consolidation of products for larger buyers, and the use of cooperative structures to improve members' access to markets. The relatively moderate mean score suggests that, although aggregation was practiced across the cooperatives, the intensity and effectiveness of these strategies varied to some extent.

The standard deviation of **0.592** is comparatively small relative to the mean, indicating that respondents' perceptions of aggregation strategies were relatively consistent across the cooperatives. In other words, there was limited dispersion in the reported application or perceived strength of aggregation strategies. Most cooperatives therefore appear to have operated within a relatively similar range in terms of their aggregation practices. This consistency is important because it suggests that aggregation was not concentrated in only a small number of highly developed cooperatives but represented a relatively common organizational practice across the study population.

However, the consistency in aggregation scores contrasts with the greater variation observed in operational performance. The operational performance measure, expressed as logOPI**,** had a mean of 4.616 and a standard deviation of 1.298. The substantially larger standard deviation indicates considerable differences in operational performance among the 19 cooperatives. While cooperatives reported relatively similar levels of aggregation strategies, their actual operational outcomes differed more substantially. This finding suggests that aggregation strategies alone may not fully account for differences in cooperative performance. Other organizational and institutional capabilities, including technology adoption, governance practices, financial management, market access, managerial capacity, and the ability to convert aggregated products into commercially viable transactions, may contribute to these differences.

The descriptive results therefore provide an initial indication that aggregation is an important but potentially incomplete component of cooperative performance. The relatively consistent aggregation scores provide a useful basis for examining whether differences in the strength of aggregation strategies are systematically associated with operational performance. At the same time, the greater variation in logOPI reinforces the importance of considering other explanatory variables. The subsequent correlation and regression analyses were therefore undertaken to establish the strength of the relationships between aggregation strategies, technology adoption, governance practices, and operational performance.

Correlation Analysis

The correlation analysis indicates a strong and positive relationship between aggregation strategies and operational performance ($r = 0.852$, $p < 0.01$), suggesting that cooperatives with stronger aggregation mechanisms tended to report higher operational performance. Effective aggregation may improve performance by consolidating volumes, reducing transaction costs, strengthening bargaining power, meeting buyer requirements, and improving coordination between producers and markets. However, the correlation does not establish causality, as better-performing cooperatives may also have greater resources and managerial capacity to implement aggregation strategies.

Aggregation strategies were also strongly and positively associated with technology adoption ($r = 0.761$, $p < 0.01$), indicating that cooperatives with stronger aggregation mechanisms tended to have higher levels of technology adoption. This relationship may reflect the complementary role of technology in supporting milk collection, record keeping, communication, logistics, quality control, and market coordination. A positive and significant relationship was also observed between aggregation strategies and governance practices ($r = 0.461$, $p < 0.05$). Although weaker than the other relationships, this finding suggests that effective governance, accountability, transparency, and collective

decision-making may support aggregation activities. Overall, the results indicate that aggregation strategies are embedded within a broader system of organizational capabilities, particularly technology adoption and governance, providing justification for examining these factors together in the regression analysis.

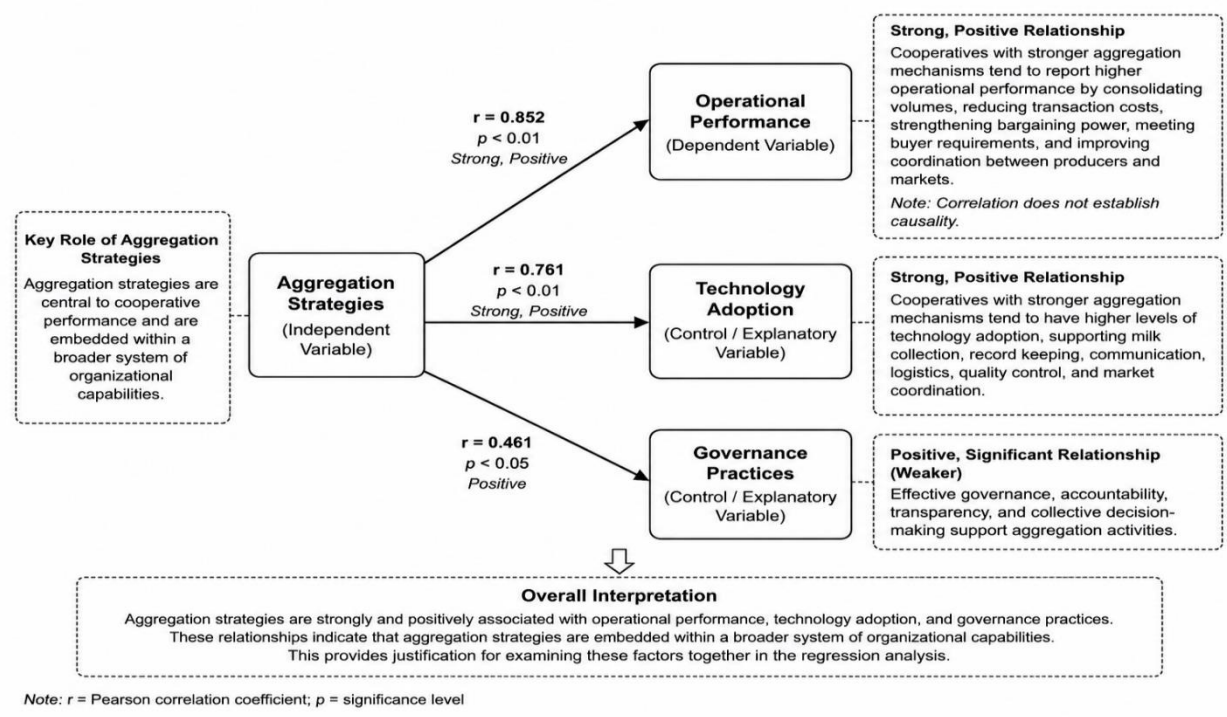

Figure 1: Correlation analysis results. Source: Researcher made.

Regression Results

A multiple regression analysis was conducted to assess the association between aggregation strategies and operational performance while controlling for technology adoption and governance practices. The overall model was statistically significant ($R^2 = 0.857$, $F(3,15) = 29.874$, $p < 0.001$), indicating that the three variables jointly explained 85.7% of the variation in log operational performance among the 19 cooperatives. The remaining 14.3% may reflect other factors not included in the model, such as finance, market conditions, infrastructure, management capacity, cooperative size, and external support.

Aggregation strategies had a positive and statistically significant coefficient ($\beta = 0.988$, $SE = 0.346$, $t = 2.86$, $p = 0.012$). Holding technology adoption and governance practices constant, a one-unit increase in the aggregation strategy score was associated with a 0.988-unit increase in log operational performance. In multiplicative terms, this corresponds to an estimated 168.5% increase in expected OPI ($e^{0.988} - 1$), although this should be interpreted as a model-based association rather than a causal effect. Overall, the findings indicate that stronger aggregation strategies are independently associated with higher operational performance, consistent with the correlation results. However, given the small sample of 19 cooperatives and the cross-sectional design, the results demonstrate statistical association rather than definitive causality.

Table 1: Multiple regression results for operational performance.

Variable	B (β)	Std. Error	t	p-value	95% CI	Interpretation
Aggregation strategies	0.988	0.346	2.86	0.012	[0.310, 1.666]	Positive and statistically significant
Model R^2	0.857					85.7% of variation explained
F-statistic	29.874			$p < 0.001$		Overall model statistically significant
Degrees of freedom	F(3,15)					Three explanatory variables; 15 residual df
Sample size	19					19 dairy cooperatives

Note. Dependent variable: log operational performance. The 95% confidence interval is approximated as $\beta \pm 1.96(SE)$. The model includes aggregation strategies, technology adoption and governance practices.

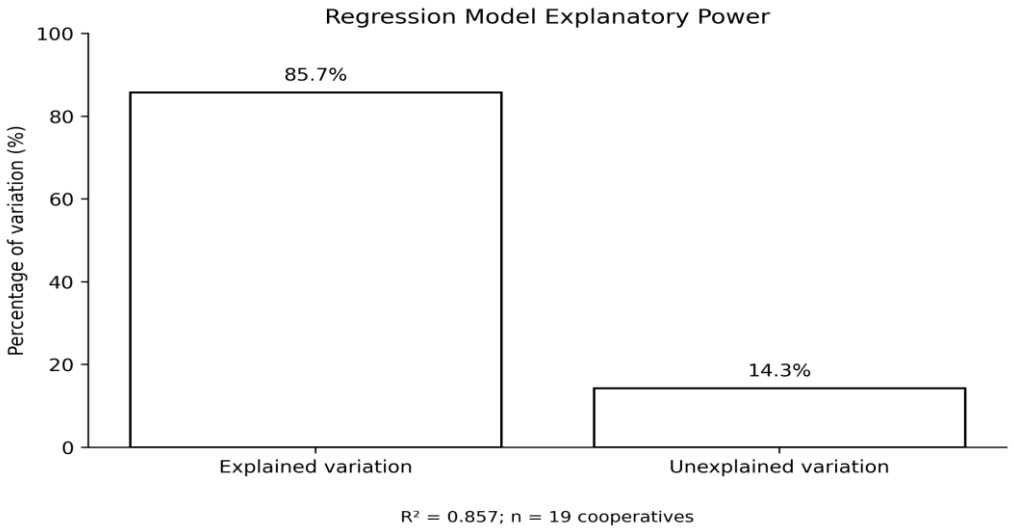

Figure 2: Regression model explanatory power. Source: Researcher made.

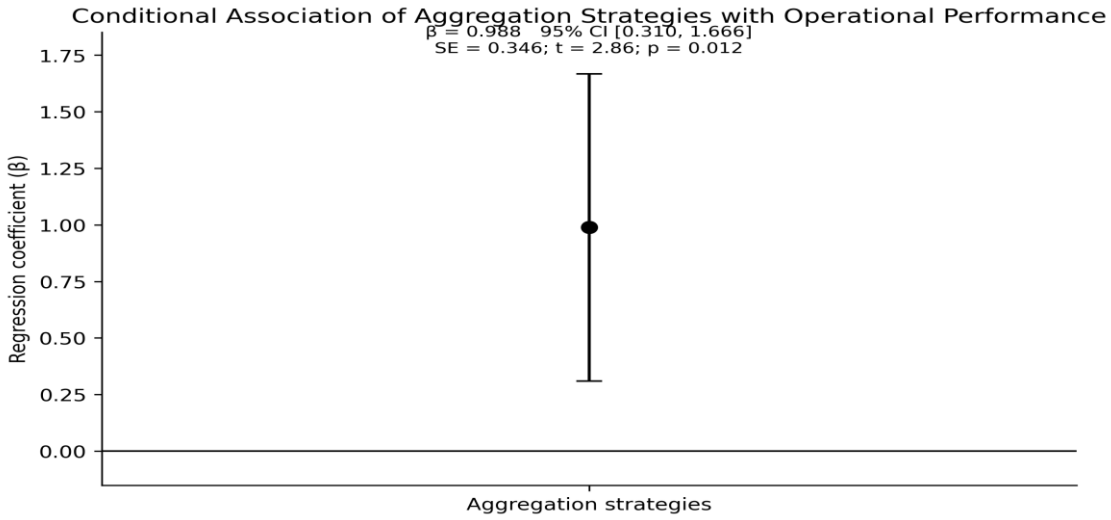

Figure 3: Conditional regression coefficient for aggregation strategies. Source: Researcher made.

The multiple regression model was statistically significant, $F(3,15) = 29.874$, $p < 0.001$, and explained 85.7% of the variation in log operational performance ($R^2 = 0.857$). Aggregation strategies had a positive and statistically significant conditional association with operational performance ($\beta = 0.988$, SE = 0.346, $t = 2.86$, $p = 0.012$), after controlling for technology adoption and governance practices. The approximate 95% confidence interval for the coefficient was 0.310 to 1.666, indicating that the estimated association was positive within the fitted model. Because the dependent variable was logarithmic, $\exp(0.988) - 1$ corresponds to an estimated 168.5% multiplicative increase in expected operational performance for a one-unit increase in the aggregation strategy score, holding the control variables constant. This multiplicative interpretation should be treated cautiously and should not be interpreted as a causal effect, given the cross-sectional design and the small sample of 19 cooperatives.

Diagnostic Results

Diagnostic tests were conducted to assess whether the assumptions underlying the multiple regression model were adequately satisfied. The results indicate that the model did not exhibit serious violations of the principal regression assumptions. This provides greater confidence that the estimated coefficients and statistical significance tests are reasonably reliable for the data analysed.

The assessment of multicollinearity produced a mean Variance Inflation Factor (VIF) of 2.084, with individual VIF values below 5. These results indicate that there was no serious multicollinearity among aggregation strategies, technology adoption, and governance practices. Although the variables were positively correlated with one another, as indicated by the correlation analysis, the degree of overlap was not sufficiently high to create a major statistical problem. This is important because excessive multicollinearity can inflate standard errors and make it difficult to determine the individual contribution of explanatory variables. The VIF results therefore suggest that the estimated coefficient for aggregation strategies can be interpreted without substantial concern that it is being distorted by excessive linear dependence among the predictors.

The Breusch-Pagan test produced a p-value of 0.1766. Since this value is greater than the conventional 0.05 significance level, the null hypothesis of constant error variance is not rejected. There is therefore no statistically significant evidence of heteroscedasticity in the regression residuals. This finding indicates

that the variability of the residuals did not systematically increase or decrease across the predicted values in a manner that would undermine the conventional regression inference.

The normality of residuals was assessed using the Shapiro-Wilk test**,** which produced a p-value of 0.383. Since the p-value is greater than 0.05, there is no statistically significant evidence of departure from the assumption of normally distributed residuals. Visual inspection of the residuals also provided support for the normality and linearity assumptions. The residual patterns did not indicate an obvious systematic departure from linearity.

Overall, the diagnostic results provide support for the adequacy of the fitted regression model. There was no evidence of serious multicollinearity, heteroscedasticity, non-normality of residuals, or major violation of linearity. The model can therefore be considered statistically appropriate for examining the association between aggregation strategies and operational performance within the available data.

Qualitative Results

Perceptions of Aggregation Strategies among Dairy Cooperatives

The qualitative findings indicate that aggregation was perceived as a critical organizational and operational strategy for improving the performance of dairy cooperative societies in Kiambu County. Respondents generally associated effective aggregation with the ability of cooperatives to consolidate milk from geographically dispersed smallholder farmers and channel it efficiently to markets. The main aggregation practices identified included decentralized milk collection, investment in collection and storage infrastructure, collective marketing, coordinated transportation, and cost-efficient aggregation mechanisms. These practices were viewed as interconnected rather than isolated activities, with improvements in one area supporting efficiency in others. The relatively consistent perceptions of aggregation strategies across respondents, reflected in the mean score of 3.398 and standard deviation of 0.592, suggest that respondents broadly recognized the importance of aggregation in cooperative operations.

Decentralized Milk Collection and Accessibility

A prominent theme emerging from the findings was the importance of decentralized milk collection systems in improving accessibility and collection efficiency. Respondents perceived strategically located collection centres as mechanisms for reducing the distance that farmers travel to deliver milk and for facilitating the consolidation of milk from dispersed producers. This was particularly relevant given the geographically dispersed nature of smallholder dairy production. Decentralized collection was therefore viewed not merely as a logistical arrangement but as a means of strengthening farmers' participation in cooperative marketing systems. By bringing collection services closer to producers, cooperatives could potentially increase the volumes of milk aggregated while reducing inefficiencies associated with transporting small quantities from individual farms.

Milk Collection, Cooling and Storage Infrastructure

Another major qualitative theme concerned the role of physical infrastructure in supporting effective aggregation. Respondents linked milk collection centres, cooling facilities, storage capacity, and transportation infrastructure with the ability of cooperatives to handle larger milk volumes while maintaining quality and reducing losses. Infrastructure was perceived as an important organizational capability because it enabled cooperatives to coordinate milk flows from producers to buyers more efficiently. The findings suggest that infrastructure investment can strengthen the operational foundations of aggregation by improving collection efficiency, reducing milk spoilage, and supporting reliable supply to processors and other buyers. However, the broader study also indicates that such investments require adequate financial resources and effective facility management if the expected operational benefits are to be realized.

Collective Marketing and Bargaining Power

Collective marketing emerged as another important dimension of aggregation. Respondents perceived collective marketing as a mechanism through which cooperatives could consolidate farmers' relatively small and irregular milk volumes into larger and more predictable supplies. Such consolidation was considered important for strengthening the bargaining position of cooperatives when negotiating with processors and other buyers. The qualitative evidence therefore suggests that aggregation extends beyond the physical collection of milk to include the strategic coordination of market relationships. Through collective marketing, cooperatives can potentially reduce individual farmers' exposure to market uncertainty, improve market access, and strengthen their position within the dairy value chain.

Cost Efficiency and Coordination of Transportation

Cost efficiency was identified as an important pathway through which aggregation can contribute to operational performance. The findings suggest that cooperatives benefit when milk collection routes, transportation arrangements, and aggregation points are effectively coordinated. By consolidating milk from multiple farmers and organizing transportation collectively, cooperatives can reduce duplication and potentially lower transaction and operating costs. This finding is consistent with the transaction-cost perspective underpinning the study, which proposes that coordinated organizational arrangements can reduce the costs associated with market exchange. The qualitative results consequently indicate that effective aggregation requires not only higher milk volumes but also deliberate management of collection routes, transportation costs, milk losses, and the utilization of collection facilities.

Interaction between Aggregation, Technology and Governance

The findings further indicate that aggregation strategies do not operate independently of other organizational capabilities. The positive correlation between aggregation strategies and technology adoption, as well as the positive relationship with governance practices, suggests that effective aggregation is supported by appropriate technological and institutional capacities. Respondents' perceptions therefore point to the importance of managerial coordination, accountability, information flow, and technology-supported operational systems. The regression results reinforce this interpretation, showing that aggregation strategies, technology adoption, and governance practices jointly explained 85.7% of the observed variation in log operational performance. This suggests that the benefits of aggregation are likely to be greater where cooperatives possess the organizational capacity required to coordinate resources and implement aggregation systems effectively.

Aggregation as a Strategic Capability for Operational Performance

The qualitative findings suggest that aggregation should be understood as a strategic capability rather than simply a milk collection function. Respondents' views, together with the statistical findings, indicate that effective aggregation can influence operational performance through several interconnected mechanisms, including economies of scale, reduced transaction costs, improved market access, stronger bargaining power, better infrastructure utilization, and improved coordination of milk flows. This interpretation is consistent with the Resource-Based View, under which coordinated distribution networks, aggregation infrastructure, collective marketing arrangements, and operational knowledge can become organizational capabilities that contribute to competitive advantage. The strong positive correlation between aggregation strategies and operational performance ($r = 0.852$, $p < 0.01$) provides further evidence of this relationship.

Overall Implication for Cooperative Operational Performance

Overall, the qualitative results indicate that dairy cooperatives can strengthen operational performance by developing integrated and commercially oriented aggregation systems. The evidence points particularly to the importance of decentralized collection systems, strategic investment in milk collection and cooling infrastructure, collective marketing, coordinated transportation, and cost-efficient aggregation arrangements. However, the findings also suggest that aggregation alone is insufficient; its effectiveness depends on technology adoption, governance, managerial competence, financial capacity, and the ability of cooperatives to maintain and effectively utilize their infrastructure. The statistically significant positive association between aggregation strategies and operational performance ($\beta = 0.988$, $p = 0.012$) supports the qualitative interpretation that stronger aggregation is associated with better cooperative performance. Nevertheless, because the study employed a cross-sectional design, the findings should be interpreted as an association rather than definitive evidence of causality.

Summary of Key Results

Overall, the results demonstrate a consistent positive relationship between aggregation strategies and cooperative operational performance. Descriptively, aggregation strategies recorded a mean score of 3.398 (SD = 0.592), while operational performance had a mean logOPI of 4.616 (SD = 1.298)**,** indicating substantially greater variation in performance across cooperatives. The correlation analysis showed a strong positive association between aggregation strategies and operational performance **(**$r = 0.852$, $p < 0.01$), as well as significant positive relationships between aggregation and technology adoption ($r = 0.761$, $p < 0.01$**)** and governance practices ($r = 0.461$, $p < 0.05$**).**

The regression analysis further demonstrated that aggregation strategies, technology adoption, and governance practices jointly explained 85.7% of the variation in log operational performance **(**$R^2 = 0.857$, $F(3,15) = 29.874$, $p < 0.001$**).** Importantly, aggregation strategies remained a statistically significant positive predictor of operational performance after controlling for the other variables ($\beta = 0.988$, $p = 0.012$**).** The diagnostic tests indicated that the model satisfied the principal regression assumptions. Collectively, these findings suggest that aggregation strategies represent an important organizational capability associated with stronger cooperative operational performance, while also highlighting the complementary role of technology adoption and governance practices.

The qualitative findings indicate that aggregation was perceived as a critical strategic capability for improving the operational performance of dairy cooperatives in Kiambu County. Respondents emphasized decentralized milk collection, investment in collection, cooling and storage infrastructure, collective marketing, coordinated transportation, and cost-efficient aggregation as key practices that improve accessibility, milk handling, economies of scale, market access, bargaining power, and operational efficiency. The findings further showed that aggregation is closely supported by technology adoption, effective governance, managerial coordination, and adequate financial capacity, suggesting that its benefits depend on complementary organizational capabilities.

These qualitative perceptions are consistent with the statistical results, which showed a strong positive relationship between aggregation strategies and operational performance ($r = 0.852$, $p < 0.01$; $\beta = 0.988$, $p = 0.012$), while aggregation, technology adoption, and governance jointly explained 85.7% of the variation in operational performance. Overall, the findings suggest that integrated and commercially oriented aggregation systems can strengthen cooperative performance, although the cross-sectional design means the results demonstrate association rather than definitive causality.

Discussion

The findings demonstrate a strong positive association between aggregation strategies and the operational performance of dairy cooperative societies in Kiambu County ($r = 0.852$, $p < 0.01$; $\beta = 0.988$, $p = 0.012$). Cooperatives with stronger aggregation mechanisms tended to achieve better operational outcomes, with qualitative evidence identifying decentralized milk collection, infrastructure investment, collective marketing, coordinated transportation, and cost-efficient aggregation as key mechanisms. Consistent with Transaction Cost Economics, aggregation reduces transaction and transportation costs by consolidating milk from dispersed smallholders, improving coordination, supply reliability, market access, and bargaining power.

Decentralized collection centres bring services closer to farmers while enabling cooperatives to consolidate variable milk supplies into commercially viable volumes. Physical infrastructure, including collection centres, cooling, storage, and transport systems, further supports quality maintenance, loss reduction, and volume handling, although its benefits depend on financing, maintenance, managerial capacity, and effective utilization. Collective marketing similarly strengthens bargaining power and market access but requires sound governance, price negotiation, cost management, and market coordination. Thus, aggregation extends beyond milk collection to serve as an organizational mechanism linking farmers to markets and improving operational efficiency.

Aggregation also operates alongside technology adoption and governance. It was strongly correlated with technology adoption ($r = 0.761$, $p < 0.01$) and moderately correlated with governance practices ($r = 0.461$, $p < 0.05$), while the three factors jointly explained 85.7% of the variation in log operational performance ($R^2 = 0.857$, $p < 0.001$). This supports the Resource-Based View, which suggests that infrastructure, technology, coordinated marketing and distribution, managerial knowledge,

and governance can function as organizational capabilities that enhance performance. The low mean VIF (2.084) indicates that the predictors were related but sufficiently distinct. Overall, the findings suggest that cooperatives derive greater benefits from aggregation when they possess the managerial and institutional capacity to organize and utilize these resources effectively.

Aggregation should therefore be treated as a strategic organizational capability rather than merely a logistical function. Strengthening decentralized collection, strategically investing in cooling and storage, improving collective marketing, coordinating transportation, and controlling aggregation costs can enhance cooperative efficiency and competitiveness. However, aggregation is not a stand-alone solution, as finance, leadership, cooperative size, member commitment, managerial capacity, market conditions, and market structure may also influence performance. Given the cross-sectional design and small sample of 19 cooperatives, the findings indicate strong associations rather than definitive causal effects. Nevertheless, they provide a strong basis for promoting well-designed aggregation systems to improve the efficiency, market position, and sustainability of dairy cooperatives in Kiambu County.

Conclusion

The study concludes that aggregation strategies have a significant and positive association with the operational performance of dairy cooperative societies in Kiambu County, Kenya. Aggregation strategies recorded a mean score of 3.398 and showed a strong positive correlation with operational performance ($r = 0.852$, $p < 0.01$). The regression model was statistically significant, explaining 85.7% of the variation in operational performance ($R^2 = 0.857$, $F(3,15) = 29.874$, $p < 0.001$), while aggregation remained a significant positive predictor after controlling for technology adoption and governance ($\beta = 0.988$, $p = 0.012$). The findings indicate that effective milk consolidation, collection, transportation, cooling, storage, and collective marketing enhance economies of scale, reduce transaction costs and milk losses, improve market coordination and bargaining power, and ultimately strengthen cooperative performance.

However, aggregation is most effective when complemented by technology adoption and sound governance, as shown by its significant relationships with both technology adoption ($r = 0.761$, $p < 0.01$) and governance practices ($r = 0.461$, $p < 0.05$). Since 14.3% of performance variation remained unexplained, other factors such as financial capacity, market conditions, leadership, infrastructure, member commitment, and institutional conditions may also influence outcomes. The study therefore recommends prioritizing strategic investments in collection centres, cold-chain infrastructure, transportation, collective marketing, technology, and governance, while recognizing that the findings are based on only 19 cooperatives and a cross-sectional design. Future longitudinal and comparative studies should examine the causal and contextual dimensions of the aggregation–performance relationship.

Policy and Managerial Implications

The findings have important policy and managerial implications for dairy cooperative development in Kenya**.** County and national governments should promote aggregation as an integrated component of dairy-sector policy by supporting strategically located collection centres, cooling and storage infrastructure, rural transport, digital traceability and payment systems, collective marketing, and stronger cooperative–processor linkages. Such support should enable commercially viable aggregation systems while avoiding long-term dependence on subsidies.

At the cooperative level, boards and managers should treat aggregation as a strategic capability by optimizing collection routes and centre locations, improving facility utilization and maintenance, strengthening collective marketing and processor relationships, and monitoring milk volumes, quality, costs, payment rates, capacity utilization, and profitability. Capacity building should also strengthen governance, financial management, digital literacy, and managerial skills. Although the high explanatory power of the model ($R^2 = 0.857$) demonstrates the importance of aggregation, technology, and governance, cooperatives should also address finance, leadership, member commitment, market conditions, and organizational size when pursuing improved operational performance.

Study Limitations and Future Research

Limitations

1. Geographical scope: Limited to 19 dairy cooperatives in Kiambu County, reducing generalizability.
2. Small sample: The 19 cooperatives limit statistical power.
3. Cross-sectional design: Establishes association, not causality, and may involve reverse causality.
4. Performance measure: The Operational Performance Index did not capture profitability, costs, milk losses, quality, asset utilization, or member satisfaction.
5. Self-reported data: Likert-scale responses may be affected by respondent bias.
6. Unexplained variation: The 14.3% unexplained variation indicates that finance, management, infrastructure, market structure, milk quality, transport, and institutional support may also influence performance.

Future Research

1. Use longitudinal studies to establish causality and long-term effects.
2. Conduct comparative studies across counties and agro-ecological zones.
3. Examine specific aggregation components, including collection, collective marketing, transport, cooling, digital systems, procurement, and value addition.
4. Include broader performance indicators, such as costs, profitability, milk losses, quality, efficiency, market share, and member satisfaction.
5. Conduct cost-benefit analyses of aggregation infrastructure and services.
6. Assess inclusiveness, particularly for smallholders, women, youth, and remote farmers.
7. Examine digital technologies such as electronic milk recording, mobile payments, route optimization, traceability, and real-time market information.

Disclaimer

- The views stated in this article are those of the author and do not necessarily represent those of any of the entities mentioned.

Interest Conflicts

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