

Digital Service Ecosystem for Rural SME Competitiveness Through Smart Agribusiness Transformation

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ABSTRACT

Rural Small and Medium-sized Enterprises (SMEs) increasingly face a structural gap between established production capabilities and limited digital capacity to capture market value directly. In rural agribusiness settings, this challenge is compounded by intermediary dependence, uneven digital literacy, and fragmented institutional support. **This study examines** how a rural entrepreneurial ecosystem can strengthen SME competitiveness through the integration of smart farming, village institutions, market connectivity, and digital transformation in Desa Cibodas, West Java, Indonesia. A sequential explanatory **mixed-methods** design was employed, combining a survey of 95 agricultural SME actors with qualitative case study analysis based on interviews with 14 key informants and documentary evidence. The findings show that digital adoption readiness, institutional support, and smart farming capability jointly contribute to SME competitiveness, with digital capability emerging as the strongest predictor. Qualitative findings further identify five interconnected themes and show how BUMDes, smart farming, packaging infrastructure, and emerging digital marketplace initiatives interact within a four-layer rural entrepreneurial ecosystem. The study **contributes** by conceptualizing digital transformation as a connecting ecosystem-level capability that links production and institutional strengths with market-oriented competitiveness. The **findings** highlight the need for integrated digital marketplace development, stronger BUMDes coordination, and targeted digital capacity building to improve rural SMEs' market autonomy and competitiveness.

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1. INTRODUCTION

Small and medium-sized enterprises (SMEs) are widely recognized as the backbone of economic development in emerging economies, contributing to employment, income distribution, and local economic resilience [1]. In rural Indonesia, where the majority of the population remains tied to agriculture, the capacity of village-based SMEs to compete in modern markets is increasingly linked not only to production capability but to the broader entrepreneurial ecosystem in which this study operate [2]. Yet rural SMEs frequently confront structural disadvantages, limited access to capital, dependence on intermediary distributors, inadequate digital infrastructure, and fragmented institutional support [3].

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The entrepreneurial ecosystem framework offers a productive lens for analysing these dynamics. Rather than attributing competitiveness to individual entrepreneurial traits, the ecosystem perspective situates firm performance within a broader socio-institutional context of networks, institutions, knowledge flows, and market access [4]. However, most entrepreneurial ecosystem scholarship has focused on urban innovation hubs and technology startups, leaving rural and agricultural contexts undertheorized. This gap is consequential for developing economies like Indonesia, where rural digital transformation is simultaneously a national development priority and an empirical puzzle.

Desa Cibodas, West Bandung Regency, West Java, presents a compelling empirical site, it operates greenhouse-based smart farming, eight packaging facilities, a nationally recognised agricultural BUMDes (Village Owned Enterprise), and market channels extending to national modern retail and international export markets (Taiwan, Singapore) [5]. Simultaneously, it confronts shrinking agricultural land, persistent intermediary dependence, uneven digital literacy, and insufficient capital for technology scaling. It is, in short, a village navigating the complex transition from a traditional agrarian system to an integrated digital agribusiness ecosystem.

Although existing entrepreneurial ecosystem research emphasizes systemic conditions such as institutions, networks, resources, and market access, less attention has been given to how these elements are integrated through digital transformation in rural agribusiness settings. This study extends the entrepreneurial ecosystem perspective by proposing a four-layer rural entrepreneurial ecosystem comprising production, institutional, market, and digital layers. The distinctive theoretical contribution lies in conceptualizing digital transformation as a connecting layer that links production capacity and institutional support with market connectivity and SME competitiveness [6]. Within this framework, smart farming represents the production foundation, while BUMDes and related village institutions provide institutional coordination and facilitate market linkages. The digital layer then represents the ecosystem capability through which these production and institutional resources can be translated into greater market autonomy and value-capture potential. Thus, rather than treating entrepreneurial ecosystem conditions and digital technology adoption as relatively separate dimensions, the proposed framework explains how digital capability connects production and institutional strengths with market-oriented competitive outcomes [7]. The study consequently extends entrepreneurial ecosystem theory by conceptualizing rural SME competitiveness as an ecosystem-level outcome shaped by the interaction of complementary production, institutional, market, and digital capabilities. This study addresses four research questions:

- How does the structure of the Desa Cibodas entrepreneurial ecosystem shape local SME competitiveness?
- How do smart farming, village institutions, and packaging infrastructure interact to create value addition?
- How can digital marketing adoption strengthen farmer and SME market autonomy?
- What generalizable lessons does Desa Cibodas offer as a rural digital entrepreneurial ecosystem model?

Through a sequential explanatory mixed-methods design, the study contributes empirically and theoretically to the literature on rural digital entrepreneurship [8].

2. LITERATURE REVIEW

2.1. Entrepreneurial Ecosystem Theory

The entrepreneurial ecosystem framework, developed by [9–11], conceptualises entrepreneurship as a systemic phenomenon shaped by the interplay of culture, networks, market access, human capital, finance, and institutional support. Unlike earlier linear models, ecosystem theory emphasises emergence, co-evolution, and place specificity. A foundational contribution is the shift from individual-level to system-level analysis, [9] argue that systemic conditions such as institutional quality and density, network density, and resource availability explain regional entrepreneurial performance beyond what can be explained by individual-level variables.

2.2. Rural Entrepreneurial Ecosystems

Rural ecosystems are characterised by place-based resources, community embeddedness, and relational capital [12]. Formal institution density is typically lower, and informal networks, such as farmer associations and cooperatives, traditional village governance play a disproportionate coordinating role. In Indonesia,

BUMDes function as institutional anchors for village economic activity [13]. Research confirms that BUMDes with strong management capacity and diversified business units contribute significantly to household income and local SME development, with effectiveness contingent on governance quality and embeddedness in productive networks.

2.3. Digital Transformation in Rural SMEs

Digital transformation in SMEs encompasses a fundamental reconfiguration of value creation, delivery, and capture not merely technology tool adoption. For rural agricultural SMEs, this transformation can restructure market access, reducing intermediary dependence and enabling direct-to-consumer relationships [14]. [15] identifies digital marketing adoption as a critical determinant of MSME performance, finding that SMEs integrating digital marketing strategies demonstrate significantly better market reach and revenue growth. Demonstrate that digital technologies enable SMEs to develop second-order dynamic capabilities resilience and adaptability particularly valuable in transition contexts [16].

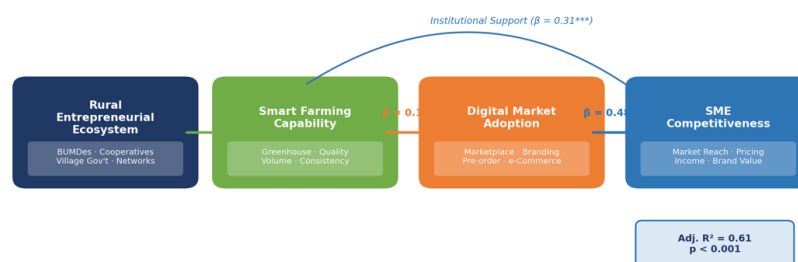
Nevertheless, structural barriers persist, including uneven digital literacy, limited broadband infrastructure, insufficient capital for platform adoption, and cultural preferences for face-to-face trade [17]. Overcoming these requires targeted policy interventions and ecosystem-level support.

2.4. SME Competitiveness in Agribusiness

SME competitiveness in agribusiness encompasses product quality consistency, supply chain reliability, brand recognition, pricing power, and market reach [18]. SMEs that participate more fully in value chains including post-harvest processing, packaging, and branding tend to capture higher margins and demonstrate greater stability. Collective action and institutional support are documented drivers, farmer cooperatives and village enterprises that aggregate production, standardise quality, and negotiate collectively with buyers demonstrate superior performance compared to individually operating smallholders [19].

2.5. Conceptual Framework

Building on this literature, the study proposes the following four-layer rural entrepreneurial ecosystem model as its conceptual framework. The framework is conceptualized as four interconnected layers production, institutional, market, and digital rather than as sequential stages, because these dimensions operate simultaneously and interactively within the rural entrepreneurial ecosystem. The four-layer framework was specified a priori from the reviewed literature and served as the conceptual model guiding the empirical analysis. The production, institutional, market, and digital layers were therefore defined before the quantitative analysis, while the regression coefficients reported in Figure 1 were subsequently estimated from the survey data and overlaid on the conceptual framework to show the observed empirical relationships [20]. The institutional support arc represents its theoretically proposed cross-layer facilitating role in the ecosystem rather than a post hoc modification introduced after examining the regression results.



Note: β coefficients from multiple regression analysis. *** $p < 0.001$; * $p < 0.01$. The institutional support arc reflects its cross-layer moderating function in the ecosystem.

Figure 1. Four-Layer Rural Entrepreneurial Ecosystem Model Proposed Pathway to SME Competitiveness

The β coefficients shown in the Figure 1 are empirical estimates obtained from the subsequent multiple regression analysis and are overlaid on the conceptual framework for comparison. $p < 0.001$, $p < 0.01$. The institutional support arc represents its theoretically proposed cross-layer facilitating role and was not introduced as a post hoc modification of the conceptual framework.

Within the conceptual framework, the rural entrepreneurial ecosystem comprises institutional (BUMDes, cooperatives, village government), infrastructural (packaging houses, greenhouse, logistics), and social (community networks, cultural capital) components. Smart farming capability provides the production foundation, while digital market adoption represents the digital layer that connects production and institutional capabilities with market-oriented outcomes. The empirical regression results reported later in the manuscript are used to evaluate the predictive relationships among the focal constructs and should therefore be interpreted as empirical evidence of the proposed framework rather than as a redefinition of the conceptual model.

3. RESEARCH METHODS

3.1. Research Design

This study employs a sequential explanatory mixed-methods design. Quantitative survey data are collected and analysed first, followed by qualitative case study data to deepen and contextualise quantitative findings. This design provides triangulation and is appropriate because the research questions require both breadth (patterns across SME actors) and depth (mechanisms of ecosystem interaction) [21]. The quantitative phase establishes statistical patterns. The qualitative phase explains them through participant experience and documentary evidence.

3.2. Research Site

Desa Cibodas, West Bandung Regency (Kabupaten Bandung Barat), West Java Province, was selected through purposive sampling based on three criteria:

- An active, formally recognised agricultural BUMDes.
- Documented smart farming implementation.
- Demonstrated market reach beyond the local area, including exports.

All three criteria are satisfied. Desa Cibodas has been recognised as a national model village enterprise by the Indonesian Ministry of Villages. Its high-altitude temperate climate supports high-value vegetable cultivation, making it theoretically productive for rural agribusiness ecosystem research.

3.3. Quantitative Data Collection

A structured questionnaire was administered to 95 agricultural SME actors in Desa Cibodas, comprising farmers, BUMDes staff, and packaging facility operators. Eligible participants were adults who were actively involved in agricultural or agribusiness-related activities in Desa Cibodas and had direct experience with the local agribusiness ecosystem. Farmers were eligible if this study were actively engaged in agricultural production, BUMDes staff if this study were directly involved in BUMDes operations or agricultural business coordination, and packaging facility operators if this study were directly involved in post-harvest handling, packaging, inventory, or distribution activities. Participants were recruited from the three stakeholder categories according to these eligibility criteria. The final quantitative sample comprised 95 respondents. The original study records available for the manuscript did not preserve the category level respondent counts. Therefore, the exact proportions of farmers, BUMDes staff, and packaging facility operators cannot be retrospectively verified and are not reported to avoid introducing unsupported figures.

Four constructs were measured with five-point Likert scales (1 = strongly disagree, 5 = strongly agree), digital adoption readiness (7 items, $\alpha = 0.83$), institutional support quality (6 items, $\alpha = 0.79$), smart farming capability (5 items, $\alpha = 0.77$), and SME competitiveness (8 items, $\alpha = 0.85$). The instrument was piloted with 20 respondents and refined prior to full deployment.

3.4. Qualitative Data Collection

Semi-structured interviews were conducted with 14 key informants representing four stakeholder groups, village government, BUMDes management, farmer group leaders, and packaging facility operators. The informants comprised six village government representatives, including the Village Secretary, one BUMDes Director, four farmer group leaders, and three packaging facility managers, resulting in a total of 14 informants. Each interview lasted 45–90 minutes and was conducted in Indonesian, audio-recorded, and transcribed verbatim.

Table 1. Qualitative Informant Distribution by Stakeholder Group

Stakeholder Group	n	%
Village government	6	42.9
BUMDes management	1	7.1
Farmer group leaders	4	28.6
Packaging facility operators	3	21.4
Total	14	100.0

Documentary data, including the village business innovation proposal, BUMDes annual reports, and regional agricultural statistics were also analysed.

3.5. Analytical Procedures

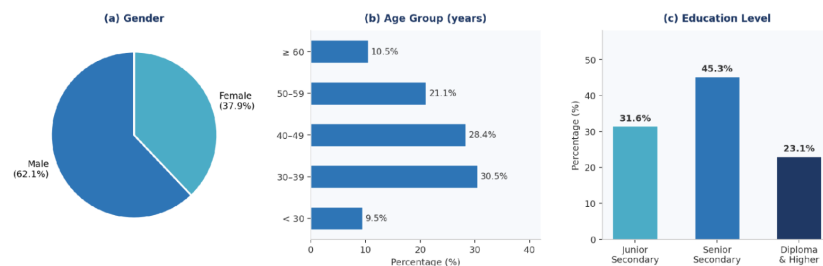
Quantitative data were analysed using IBM SPSS Statistics 26. Descriptive statistics, reliability analysis, and multiple linear regression were performed, with SME competitiveness as the dependent variable and digital adoption readiness, institutional support quality, and smart farming capability as predictors, controlling for respondent age, education, and farming experience.

Qualitative data were analysed using thematic analysis, data familiarisation, initial coding, theme generation, review, definition, and reporting. NVivo 14 managed qualitative data organisation [22]. Four primary themes were constructed deductively, aligned with the conceptual framework, supplemented by inductively emerging sub-themes. Integration was achieved through a weaving narrative in the Discussion, where statistical patterns are explained and qualified through interview evidence.

4. RESULTS

4.1. Respondent Profile

Of the 95 respondents, 62.1% were male and 37.9% were female. Educational attainment was mixed, with 45.3% completing senior secondary education and 23.1% holding a diploma or higher qualification. Mean farming experience was 11.4 years ($SD = 6.2$). Figure 2 summarizes the respondent profile.



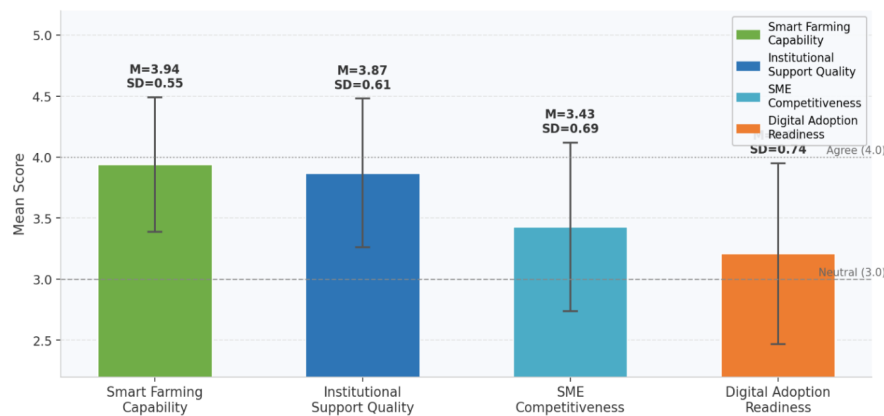
Note: Panel (a) shows gender distribution; panel (b) shows age group distribution; panel (c) shows educational attainment. The sample reflects the village's predominantly male, middle-aged farming population with mixed educational backgrounds.

Figure 2. Demographic Profile of Survey Respondents (n = 95)

As shown in Figure 2, the demographic distribution reflects the socioeconomic structure of a transitional rural community a predominantly working-age farming population with mixed educational levels [23]. The relatively high proportion of senior secondary educated respondents (45.3%) suggests baseline digital literacy potential that may not yet be fully leveraged within current agricultural practices a finding that carries implications for digital transformation programme design.

4.2. Descriptive Statistics for Study Constructs

Figure 3 shows that smart farming capability had the highest mean score ($M = 3.94$, $SD = 0.55$), followed by institutional support quality ($M = 3.87$, $SD = 0.61$), while digital adoption readiness had the lowest mean score ($M = 3.21$, $SD = 0.74$).



Not: Error bars represent ± 1 standard deviation. Reference lines indicate the Neutral midpoint (3.0) and the Agree threshold (4.0). Higher scores on production and institutional dimensions contrast with lower digital adoption readiness, indicating an ecosystem gap between production maturity and digital capability.

Figure 3. Mean Scores of Study Constructs with Standard Deviation Error Bars (5-Point Likert Scale)

Figure 3 reveals a structural asymmetry within the Desa Cibodas ecosystem, the production layer (smart farming capability) and the institutional layer (institutional support quality) are already well-developed and approach the agree level, while the digital layer (digital adoption readiness) remains the lowest scoring dimension. This asymmetry aligns with the conceptual framework's identification of digital transformation as the missing link in the ecosystem, and with the wider literature on rural digital transformation barriers [24]. Notably, the relatively wider standard deviation for digital adoption readiness ($SD = 0.74$) compared to smart farming capability ($SD = 0.55$) indicates more heterogeneous digital readiness across actors, a finding explored further in Section 4.4.

4.3. Multiple Regression Analysis

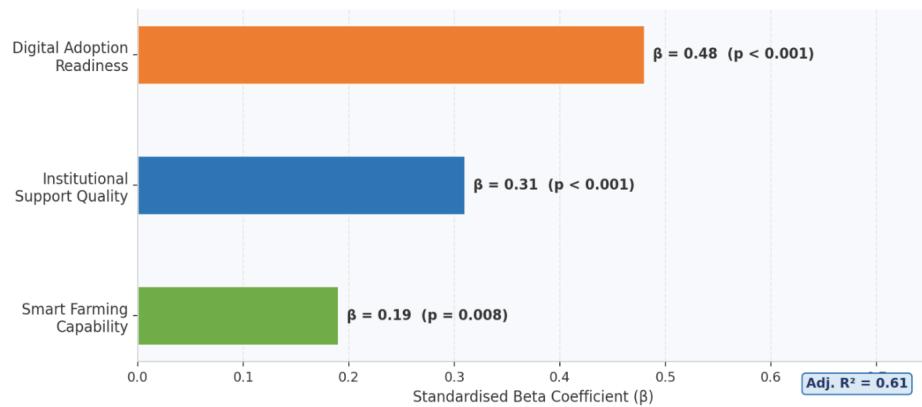
Table 2 presents the full multiple regression model predicting SME competitiveness [25]. The model simultaneously includes three focal predictors, digital adoption readiness, institutional support quality, and smart farming capability and three control variables age, education, and farming experience [26]. Accordingly, the full model contains six predictors. With 95 respondents, the corresponding degrees of freedom are 6 for the regression model and 88 for the residual, resulting in an overall test of $F(6,88)$. The model reports $R^2 = 0.64$ and adjusted $R^2 = 0.61$, indicating that the six-variable specification explains 64% of the variance in SME competitiveness, with the adjusted estimate accounting for model complexity. The three focal predictors are interpreted substantively, whereas the control variables are included to statistically adjust for respondent characteristics and are not interpreted as substantive predictors.

Table 2. Multiple Regression Results Predictors of SME Competitiveness

Predictor	β (Standardised)	SE	t-value	p-value	VIF
Digital Adoption Readiness	0.48	0.06	8.23	< 0.001	1.21
Institutional Support Quality	0.31	0.07	4.71	< 0.001	1.34
Smart Farming Capability	0.19	0.07	2.73	0.008	1.18
Age (control)	-0.08	0.05	-1.52	0.132	1.09
Education (control)	0.06	0.06	1.11	0.270	1.14
Farming Experience (control)	0.04	0.05	0.78	0.436	1.07
Model $F(6, 88) = 26.07$ $p < 0.001$ Adj. $R^2 = 0.61$ $R^2 = 0.64$ $n = 95$					

Note. Dependent variable: SME competitiveness (composite scale, $\alpha = 0.85$). VIF values all < 2.0 indicate no multicollinearity concern. SE = standard error. Controls are not interpreted substantively.

These findings directly address RQ1 by showing that digital adoption readiness, institutional support quality, and smart farming capability are associated with SME competitiveness within the Desa Cibodas entrepreneurial ecosystem.



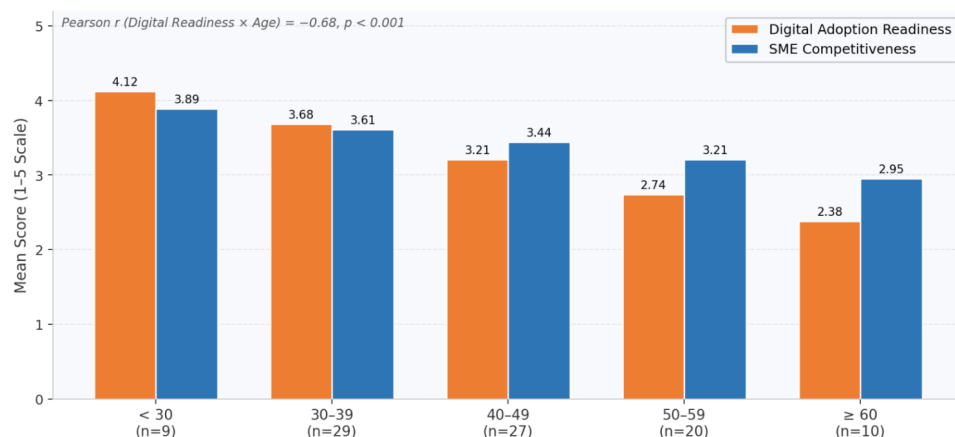
Note: All three predictors are statistically significant. Digital adoption readiness explains the largest unique variance in SME competitiveness ($\beta = 0.48$), demonstrating that digital capability not production technology alone is the primary driver of competitive differentiation among village SME actors.

Figure 4. Standardised Regression Coefficients (β) Predicting SME Competitiveness

Figure 4 confirms that digital adoption readiness is the strongest predictor of SME competitiveness. Institutional support quality ($\beta = 0.31$, $p < 0.001$) demonstrates the second-strongest predictive power, underscoring BUMDes and cooperative quality as ecosystem-level determinants of competitiveness that cannot be substituted by individual farmer effort alone. Smart farming capability ($\beta = 0.19$, $p = 0.008$), while statistically significant, has the smallest effect, consistent with its role as a necessary but insufficient foundation rather than the proximate driver of competitiveness.

4.4. Digital Adoption Readiness by Age Group

Figure 5 disaggregates digital adoption readiness and SME competitiveness scores by age group, revealing a strong negative relationship between age and digital readiness (Pearson $r = -0.68$, $p < 0.001$). Respondents under 30 scored highest on digital adoption readiness ($M = 4.12$), while those aged 60 and above scored lowest ($M = 2.38$). A parallel but less steep gradient was observed for SME competitiveness scores, suggesting that age is associated with both digital adoption readiness and SME competitiveness, while the present analysis does not establish a formal mediation relationship.



Note: Pearson r (Digital Readiness $\times$ Age group) = -0.68 , $p < 0.001$. The younger cohorts' higher digital readiness and competitiveness scores support a generational diffusion model of digital transformation in the village, where young BUMDes staff and farmer group members may serve as digital change agents for older cohorts.

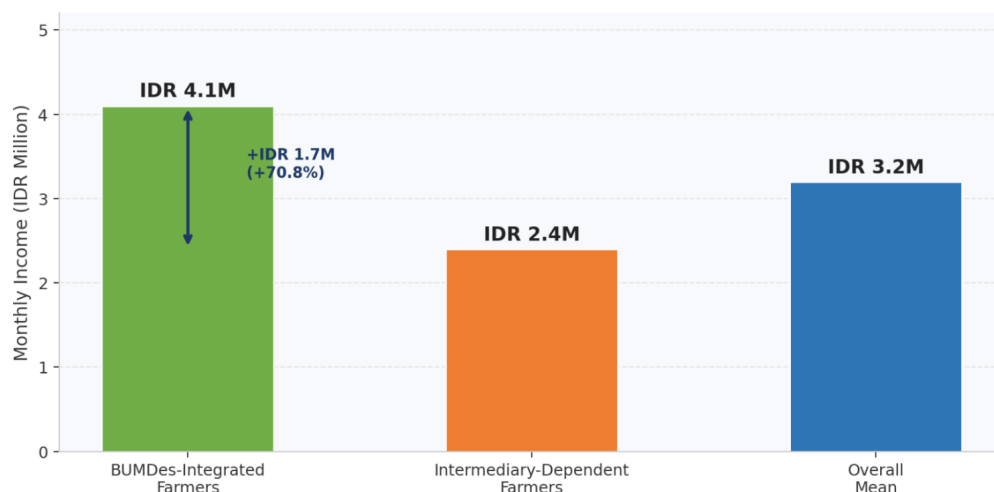
Figure 5. Digital Adoption Readiness and SME Competitiveness by Age Group

These findings carry important practical implications [27]. The strong generational gradient in digital readiness suggests that a simple platform provision approach to digital transformation will be insufficient to close the competitiveness gap for older farmers [7]. Targeted, age-differentiated training programmes potentially leveraging younger village members as peer educators will be necessary to achieve ecosystem-wide digital adoption. This is consistent with [28], finding that knowledge sharing and participatory learning approaches are more effective than technology provision alone in urban SME digital adoption contexts.

These findings address RQ3 by indicating that digital adoption capability is an important condition for strengthening farmer and SME participation in digitally mediated market channels and supporting greater market autonomy [29].

4.5. Income Gap Analysis

Figure 6 presents a descriptive comparison of monthly household income between BUMDes-integrated and intermediary-dependent farmers. The BUMDes-integrated group ($n = 41$) reports an average monthly income of IDR 4.1 million, compared with IDR 2.4 million among intermediary-dependent farmers ($n = 54$), representing an observed difference of IDR 1.7 million, or approximately 70.8%. This descriptive difference indicates substantial variation in household income across market access groups. It should not be interpreted as evidence that BUMDes integration or direct market access caused the observed income difference.



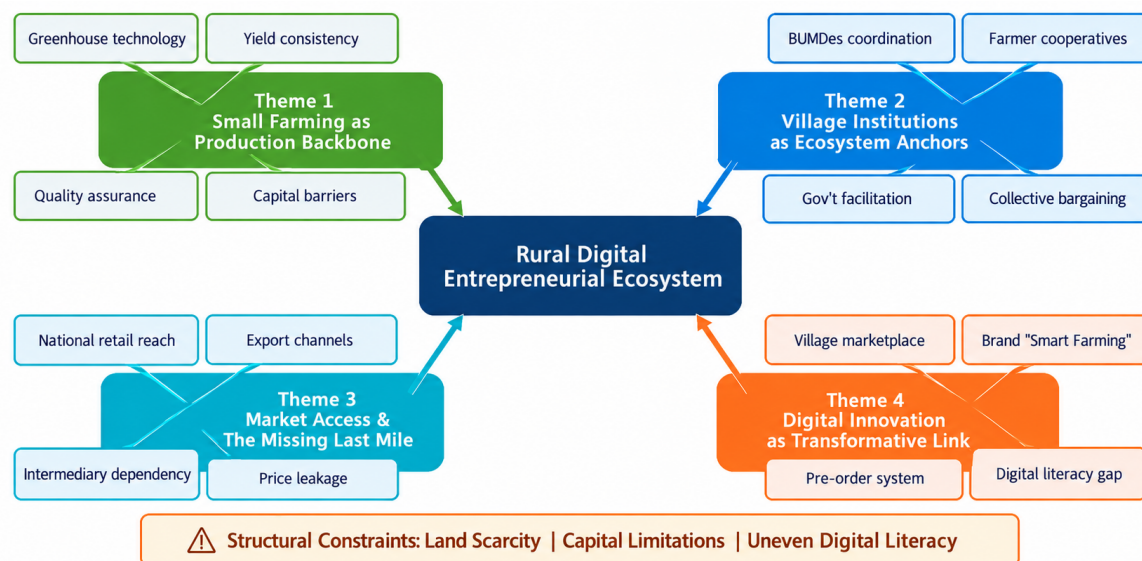
Note: BUMDes-integrated farmers ($n = 41$) versus intermediary-dependent farmers ($n = 54$). The 70.8% income gap (IDR 1.7 million per month) represents approximately eight months of additional income per year for BUMDes-integrated farmers, underscoring the economic magnitude of institutional integration and the direct market access that BUMDes channels enable.

Figure 6. Monthly Household Income by Market Access Channel (IDR Million)

The income difference shown in Figure 6 is economically notable in the context of rural West Java, where the reported regional minimum wage is approximately IDR 2.0 million per month [30]. Nevertheless, because the study does not employ formal between-group inferential testing or control for potential confounding factors, the observed difference should be interpreted as an association rather than a causal effect of BUMDes integration [31]. Factors such as farmer characteristics, production capacity, farm scale, market relationships, and access to other resources may also contribute to the difference between the two groups. Accordingly, the finding provides descriptive evidence of income variation associated with different market access arrangements and motivates further research using controlled comparative or longitudinal designs to examine whether BUMDes integration contributes independently to income improvement [16].

4.6. Qualitative Findings Thematic Analysis

Thematic analysis of 14 semi-structured interviews and documentary data identified five themes structured around the conceptual framework. Figure 7 presents the thematic map integrating these themes, sub-themes, and their structural relationships within the rural entrepreneurial ecosystem.



Note: The thematic map illustrates five major themes and their associated sub-themes, arranged around the central construct of the rural digital entrepreneurial ecosystem. The constraint ribbon at the base represents structural factors that operate as boundary conditions on ecosystem performance. Connections between themes and sub-themes were identified through iterative thematic analysis of 14 informant interviews and supporting

Figure 7. Thematic Map of Qualitative Findings Rural Entrepreneurial Ecosystem Dynamics in Desa Cibodas

- **Theme 1: Smart Farming as Production Backbone** All informants identified smart farming and greenhouse technology as the cornerstone of Desa Cibodas' competitive foundation [32]. The BUMDes Director described the greenhouse system as the engine that lets us guarantee volume and quality consistently, which is what modern retailers require. Farmer group leaders confirmed that greenhouse adoption increased average vegetable yields by an estimated 30–40% compared to open-field cultivation and significantly reduced weather-related production risk [33]. However, capital barriers to greenhouse adoption were repeatedly identified. Smallholders without BUMDes credit support cannot access greenhouse infrastructure independently.
- **Theme 2: Village Institutions as Ecosystem Anchors** BUMDes emerged as the central coordinating institution [34]. The Village Secretary stated that BUMDes provides collective bargaining power, packaging access, and emerging online-market access. Farmer cooperatives managed the mobilisation of smallholder production into aggregated supply, while village government provided regulatory legitimacy and facilitative support [35]. This institutional architecture is consistent with analysis of BUMDes as multi-functional institutional anchors addressing capital access, market linkage, and farmer capacity development simultaneously.
- **Theme 3: Market Access Strength and the Missing Last Mile** Informants described the paradox of wide market reach combined with limited direct market control [36]. While Cibodas vegetables reach national modern retail and international export markets, most access is mediated through packaging houses and distributors. One farmer group leader articulated the core problem, the resulting value leakage, noting that vegetables sold through intermediaries generated substantially higher retail prices than the returns received by producers. This structural dependency quantitatively manifests in the IDR 1.7 million income gap observed in the quantitative data, confirming the mixed methods integration point that institutional integration is the proximate mechanism connecting market access to income outcomes.
- **Theme 4: Digital Transformation as the Transformative Intervention** The village's business innovation proposal includes a digital marketplace, vegetable pre-order system, collective branding, and direct-to-consumer and direct-to-reseller channels through social media and e-commerce platforms. Informants supported this vision but highlighted uneven digital literacy among farmers. Younger BUMDes staff were viewed as potential peer-learning facilitators for older farmers, consistent with the observed negative association between age and digital adoption readiness ($r = -0.68$).

- Theme 5: Structural Constraints as Boundary Conditions Three structural constraints emerged consistently, land scarcity (residential and infrastructure expansion is reducing agricultural land), capital limitations (most smallholders lack collateral for formal credit), and digital literacy gaps (particularly among farmers aged 45+). These constraints are not unique to Cibodas and represent systemic challenges documented across Indonesian rural SME research. This Study function as boundary conditions on ecosystem performance. The ecosystem's transformative potential is real but bounded by these structural realities, which must be addressed through policy intervention if digital transformation gains are to be equitably distributed.

Taken together, the qualitative findings address RQ2 by demonstrating the interdependent roles of smart farming, village institutions, packaging infrastructure, and market-access mechanisms in strengthening value creation within the rural agribusiness ecosystem. These findings indicate that value creation is not generated by technological adoption alone, but through the coordinated integration of digital capabilities, institutional support, operational infrastructure, and market connectivity. To further align the proposed ecosystem with the domain of cyber and IT service management, the digital marketplace can be conceptualized as a secure and resilient agribusiness information infrastructure that integrates smart-farming data, digital service delivery, and market intelligence. Within this architecture, IoT-enabled farming systems can continuously capture production and environmental data, while cloud-edge computing facilitates distributed data processing, system responsiveness, and service continuity under the connectivity limitations commonly encountered in rural environments.

The resulting information can be integrated with BUMDes coordination mechanisms, packaging and inventory systems, and marketplace transactions to establish an end-to-end information flow across the production-to-market value chain. Building on this infrastructure, AI-driven data intelligence can transform aggregated production, inventory, order, and sales data into actionable insights for demand forecasting, production planning, resource allocation, and market decision making. Given the sensitivity of farmer profiles, production records, pricing information, and transaction data, the proposed digital service architecture should also embed robust cybersecurity and privacy mechanisms, including authentication, role-based access control, secure data exchange, and privacy-preserving data governance. Accordingly, AI, IoT, cloud-edge computing, cybersecurity, and privacy should be treated as mutually reinforcing components of an integrated digital service ecosystem rather than as isolated technological solutions, thereby supporting a more secure, intelligent, and resilient rural agribusiness environment.

5. DISCUSSION

5.1. A Four-Layer Rural Entrepreneurial Ecosystem

The integrated analysis identifies four interdependent layers in the Desa Cibodas rural entrepreneurial ecosystem, production, institutional, market, and digital. Production and institutional capabilities provide the operational and coordinating foundations of the ecosystem, while the market layer connects agricultural output to external buyers but also exposes value leakage through intermediaries. The digital layer remains the principal intervention gap, linking existing production and institutional capabilities with more autonomous and market-oriented value creation.

The asymmetry between production layer maturity (high) and digital layer development (low) is the defining structural challenge of the Cibodas ecosystem. This pattern sophisticated production coupled with underdeveloped digital market access has been identified as a common bottleneck in rural agribusiness transformation across Southeast Asia. The policy implication is clear, investment in additional smart farming technology in the absence of commensurate digital adoption capacity will yield diminishing competitiveness returns.

This integrated four-layer interpretation addresses RQ4 by positioning the Cibodas case as a rural digital entrepreneurial ecosystem model in which production, institutional, market, and digital capabilities operate as interdependent components.

5.2. Digital Transformation as the Missing Link

The study's central theoretical contribution is the identification of digital transformation as the missing link in the Cibodas ecosystem, the intervention connecting a mature production system to a more autonomous, value-capturing market position. Unlike previous studies examining digital transformation as an isolated variable, this study demonstrates ecosystem-mediated effects, digital adoption's impact on competitiveness is amplified by strong institutional support and high production capability. Respondents with high scores on all three

predictors demonstrated disproportionately higher competitiveness scores, suggesting multiplicative rather than merely additive ecosystem dynamics consistent with complex adaptive systems framework. This finding extends Bandung SME research, which found digital marketing effectiveness contingent on broader organizational and institutional readiness, to a rural agribusiness context. It also resonates with the conceptualisation of digital entrepreneurial ecosystems as collective intelligence systems in which individual digital capability is amplified by shared infrastructure and institutional embedding.

From a technical IT perspective, the proposed digital transformation can be operationalised through a village digital marketplace architecture that connects smart-farming production, BUMDes coordination, packaging and inventory activities, and downstream buyers. Production and product availability information can flow from farmers and smart farming activities to BUMDes as the institutional coordination node, where it can be aligned with packaging and inventory information before being presented through marketplace services. The platform can provide product catalogues, availability information, vegetable pre-orders, order coordination, and direct-to-consumer or direct-to-reseller transactions, consistent with the digital marketplace initiatives identified in the study. The resulting production, order, inventory, and sales data can support basic analytics to identify demand patterns and inform production and distribution decisions. Interoperability among these components can connect production information, institutional coordination, inventory status, marketplace transactions, and buyer information within a continuous information flow. Accordingly, the proposed digital marketplace is conceptualised not merely as an online sales channel but as an integrated information system layer that connects smart-farming and institutional capabilities with digitally coordinated market services.

5.3. Rural Digital Ecosystem Development Implications

Several concrete policy recommendations follow from these findings. National and provincial rural development programmes should integrate digital marketing capacity building with smart farming and BUMDes strengthening, rather than treating these as separate streams. Village government should invest in digital infrastructure, including stable internet access and shared computing facilities in community centres, to reduce capital barriers for individual smallholders. BUMDes governance frameworks should explicitly incorporate digital marketplace management as a core function. Export promotion agencies should partner with BUMDes networks to provide direct-to-buyer digital linkages, reducing intermediary dependence in international trade. Finally, digital training programmes should be age-differentiated and peer-learning-oriented, leveraging younger digital native community members as change agents.

These implications address RQ4 by translating the Cibodas case into practical lessons for rural digital entrepreneurial ecosystems, particularly through integrated digital marketplace development, institutional strengthening, digital capacity building, and infrastructure support. The findings also demonstrate the study's relevance to several Sustainable Development Goals (SDGs). The study contributes indirectly to SDG 2 (Zero Hunger) through smart farming capability, agricultural productivity, and improved market connectivity, which strengthen the capacity of rural agribusiness actors to participate in more stable food value chains. The findings support SDG 8 (Decent Work and Economic Growth) through enhanced SME competitiveness, institutional coordination, market access, and opportunities for greater value capture within agricultural value chains. The proposed integration of smart farming, digital marketplace development, and supporting digital infrastructure is aligned with SDG 9 (Industry, Innovation and Infrastructure) by promoting technology-enabled innovation and rural digital infrastructure. The study also supports SDG 12 (Responsible Consumption and Production) through more coordinated production, post-harvest handling, packaging, distribution, and market linkage practices that can improve value-chain efficiency. These contributions should be understood as areas of alignment with the SDGs rather than as directly measured SDG outcomes.

6. MANAGERIAL IMPLICATIONS

The findings provide several actionable implications for managers and operational actors within the Desa Cibodas rural agribusiness ecosystem. First, BUMDes managers should position digital marketplace coordination as an extension of existing aggregation and market-linkage functions by establishing clear procedures for product listing, order consolidation, pricing information, and direct buyer communication. Second, farmer cooperative leaders should strengthen collective participation in digital channels by coordinating production schedules, standardising product information, and supporting peer-based digital learning among members. Third, packaging facility managers should improve integration between post-harvest handling and digital orders by synchronising inventory information, product availability, packaging schedules, and delivery

coordination. Fourth, SME owners and farmer entrepreneurs should develop basic digital marketing capabilities, including product presentation, customer communication, order management, and the use of social media and e-commerce channels to reduce dependence on fragmented intermediary arrangements. Finally, digital marketplace administrators should establish clear platform governance procedures for user access, product information, transaction recording, order tracking, and service coordination across farmers, BUMDes, packaging facilities, and buyers. Collectively, these actions can strengthen coordination between the production, institutional, market, and digital layers identified in the four-layer rural entrepreneurial ecosystem.

7. CONCLUSION

This study examined the structure and dynamics of the rural entrepreneurial ecosystem in Desa Cibodas, West Java, and its relationship to SME competitiveness through a sequential explanatory mixed-methods design. Quantitative findings demonstrate that digital adoption readiness, institutional support quality, and smart farming capability jointly explain 61% of variance in SME competitiveness, with digital adoption as the dominant predictor ($\beta = 0.48$). The IDR 1.7 million monthly income gap between BUMDes-integrated and intermediary-dependent farmers quantifies the economic stakes of ecosystem integration. Qualitative findings reveal how these patterns are enacted through the daily interactions of farmers, BUMDes managers, village government, and packaging facility operators within a four-layer ecosystem.

The central conclusion is that rural SME competitiveness in Desa Cibodas is neither a function of natural endowment alone nor of individual entrepreneurial effort, but emerges from the systemic integration of production infrastructure, institutional embedding, market connectivity, and digital marketing capability. Digital transformation, currently the weakest ecosystem layer, represents both the most significant gap and the greatest opportunity for value recapture. Closing this gap requires not technology provision alone but an ecosystem-level intervention integrating platform development, institutional support, peer-learning programmes, and infrastructure investment.

Limitations include single-site scope (limiting generalizability), cross-sectional design (precluding causal inference), and self-report competitiveness measures (potential social desirability bias). Future research should pursue multi-village comparative studies testing the four-layer model across agribusiness, village tourism, and creative industry contexts, longitudinal quasi-experimental designs tracking BUMDes digital marketplace interventions over time, and international comparative research with rural digital agribusiness ecosystems in comparable Southeast Asian settings to enable cross-national theory building and policy learning.

8. DECLARATIONS

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8.2. Author Contributions

Conceptualization: DA and YS; Methodology: DA and YS; Software: AA; Validation: DA and AA; Formal Analysis: YS and AA; Investigation: DA and YS; Resources: DA; Data Curation: YS and AA; Writing Original Draft Preparation: DA and YS; Writing Review and Editing: DA, YS, and AA; Visualization: AA; Supervision: DA; Project Administration: DA; All authors, DA, YS, and AA, have read and agreed to the published version of the manuscript.

8.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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8.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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