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Integrated Model for the Sustainable Development of the Arabica Java Ijen Raung Specialty Coffee Agroindustry: A Two-Stage Approach

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ABSTRACT

Indonesian coffee, particularly from East Java, has gained worldwide recognition as an export commodity due to its distinctive flavor in the international market. East Java Coffee is renowned globally as a specialty coffee, with Arabica Ijen Raung, known as Java Coffee, holding this prestigious reputation. However, the coffee agroindustry faces multidimensional challenges. The objective of this study is to design an integrated model for the sustainable development of the Arabica Java Ijen Raung specialty coffee agroindustry. The research was conducted in Bondowoso Regency. The sampling method employed was snowball sampling, consisting of 302 Arabica coffee farmers and 32 micro, small, and medium-sized enterprises (MSME) in the coffee sector. The research methodology applies a two-stage approach within the Structural Equation Modeling–Partial Least Squares (SEM-PLS) framework. In the first stage, the sustainability models of coffee farming and MSME were analyzed. In the second stage, the sustainability of the agroindustry was examined by integrating latent variable scores aggregated based on partnerships with MSME. This approach enables a comprehensive integration of upstream and downstream analyses. The findings reveal that the integration between farm-level sustainability and MSME sustainability plays a mutual role in supporting overall agroindustry sustainability. Policies at both the upstream and downstream levels significantly affect agroindustry sustainability, both directly and indirectly, through the mediating role of agroindustry development. These results indicate that enhancing agroindustry sustainability requires integrated strategies across the value chain, with a particular focus on strengthening agroindustry development as the key mediator. Furthermore, policy improvements should be combined with agroindustry development initiatives to produce tangible impacts on long-term sustainability.

1. INTRODUCTION

Coffee is one of Indonesia's leading agricultural commodities, holding high economic and social value, and serving as a key driver in global trade [1]. Indonesian coffee has become a prominent national commodity with a strong global presence as an export product due to its distinctive flavor in international markets. Beyond serving as a source of foreign exchange, coffee also provides livelihoods for approximately 1.5 million farmers in Indonesia [2]. In 2023, the coffee plantation area in Indonesia was estimated at 1.266 million hectares, representing a 0.07% increase compared to previous years. However, Indonesia's coffee production reached 760.2 thousand tons in 2023, marking a decline of about 1.9% from the previous year [3].

East Java Province is among the key regions in Indonesia recognized as a center of coffee cultivation [4]. East Java Province ranks as the fourth-largest contributor to national coffee production on the island of Java, with a total plantation area of 92,185 hectares and a total output of 47,109 tons [5]. East Java Province has several regencies that serve as key coffee-producing areas, one of which is Bondowoso Regency [6]. East Java Coffee has long been recognized internationally for its distinctive flavor, with Arabica Ijen Raung earning the designation of specialty coffee, widely known abroad as Java Coffee [7]. The superior Arabica coffee production from Bondowoso Regency is not matched by its processing industry. Approximately 80% of exported coffee is in the form of beans, while only 20% is exported as ground coffee, instant coffee, or blended coffee [8].

The development of the smallholder coffee agroindustry in Bondowoso faces challenges such as traditional cultivation practices and inconsistent processing, resulting in product quality that does not meet market demands. Additionally, the income of the local coffee agroindustry heavily depends on the sale of coffee beans [9]. This situation may affect the sustainability of the smallholder coffee agroindustry, as the sector is increasingly moving toward the development of processed coffee products. According to Reytar et al. [10] as part of sustainable development, the development of the coffee agroindustry should be guided by sustainable development criteria based on five dimensions: economic, social, ecological (environmental), technological, and institutional.

The sustainability of the agroindustry cannot be separated from the roles of two main groups: farmers, as raw material producers, and MSME, as actors in the downstream processing of specialty coffee products [11]. These two groups face distinct challenges across environmental, economic, social, technological, and institutional aspects. Therefore, the development of the specialty coffee agroindustry needs to systematically consider the integration among actors, using an analytical approach capable of accommodating the multidimensional structures and relationships of each group.

Research on the variables influencing the development of agroindustry sustainability remains very limited. Designing model for the development of sustainable small coffee agroindustry at the agropolitan area of Ijen employs an exponential comparison approach [12]. The study by Wibowo et al. [13] highlighted the importance of developing the downstream agroindustry to increase the added value of arabica specialty coffee production in Java Ijen Raung. Their study indicates that the development of ground coffee products holds significant potential. The aim of this research is to design an integrated model for the sustainable development of the arabica specialty coffee agroindustry in Java Ijen Raung. The novelty of this study goes beyond the application of the Two-Stage SEM-PLS approach. It lies in constructing an integrative sustainability model that merges two distinct actors farmers and MSMEs into a single agroindustry sustainability construct. A key innovative element is the aggregation mechanism based on MSME farmer partnerships, where farmers' sustainability scores are integrated according to their business and supply-chain relationships with MSMEs. This approach allows the contribution of MSMEs to be assessed not only through their internal performance but also through their influence on partner farmers' sustainability. The focus on the Java Ijen Raung specialty Arabica coffee system further reinforces the substantive novelty of this study compared with prior work.

2. MATERIALS AND METHOD

2.1 Research location

Bondowoso Regency was selected as the research location because it is the only regency where arabica specialty coffee Java Ijen Raung can grow as an endemic crop. Most of the Bondowoso Regency area consists of highlands with elevations ranging from 900 to 2,000 mdpl [14]. The study was conducted in five sub-districts: Sumberwringin, Botolinggo, Ijen/Sempol, Sukorejo, and Cerme (Figure 1). The research respondents consisted of two groups: farmers and MSME. Farmer respondents were selected using snowball sampling, totaling 302 arabica coffee farmers. The total farmer population in the study area was recorded as 1,327 individuals. Snowball sampling was chosen because the target population Arabica coffee farmers was relatively difficult to identify individually in formal administrative records, and many respondents were more accessible through community networks and farmer group referrals. This method was therefore appropriate for reaching dispersed farmer populations and ensuring adequate representation in the study. The sub-district with the largest farmer population was Sumberwringin (571 farmers, with 132 respondents selected), followed by Sempol/Ijen (324 farmers, 76 respondents), Botolinggo (185 farmers, 42 respondents), Cerme (149 farmers, 29 respondents), and Sukosari (98 farmers, 23 respondents). This respondent distribution represents the variation in social, economic, and technical conditions of Arabica coffee cultivation in the study area. Meanwhile, 32 MSME respondents were included in the study, and due to the limited population size, a census approach was applied. Although the number of MSMEs is relatively small for SEM-PLS based on the general guideline of 10 respondents per indicator the sample remains acceptable because PLS-SEM is well known for its high tolerance to small sample sizes and is specifically designed to handle prediction-oriented models with complex structures. This methodological characteristic allows the model to remain stable even with limited observations. Nevertheless, the small number of MSME respondents is acknowledged as a limitation, and the interpretation of Model 2 results is conducted with appropriate caution. Data collection techniques included surveys, interviews, and observations [15].

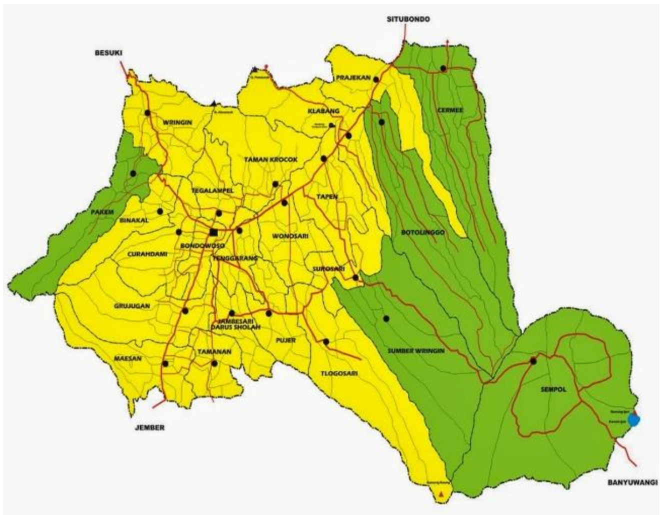

Figure 1. Research location (indicated in yellow)

2.2 Data analysis

This study employed a Two-Stage SEM-PLS approach because the model was developed from two different respondent groups: farmers and MSME. This approach refers to the Two-Stage SEM-PLS method proposed by Ringle et al. [16] and Fassott et al. [17] which states that a two-stage approach can be used to integrate models from different respondent groups by using latent construct scores as inputs for the subsequent model. In the first stage (Tables 1 and 2), SEM modeling was conducted for each group to obtain the latent construct scores of K_HU (farming sustainability) from the upstream sector and K_HI (MSME sustainability) from the downstream sector. The scores obtained in stage one, i.e., the construct scores of K_HU and K_HI, were used as input exogenous variables in the second-stage integrated model (Table 3) [18]. The latent variable scores from stage one for the farming sustainability model were aggregated according to the partnership between farmers and MSME, as shown in Figure 2.

Table 1. Latent variables of model 1 farming sustainability

Variable	Indicator	Refs.
Environmental dimension (DL)	DL1, DL.2, DL.3, DL.4	[19, 20]
Economic dimension (DE)	DE.1, DE.2, DE.3, DE.4	[21]
Social dimension (DS)	DS.1, DS.2, DS.3, DS.4, DS.5	[22]
Technological dimension (DT)	DT.1, DT.2, DT.3, DT.4	[23]
Institutional dimension (DK)	DK.1, DK2, DK.3, DK.4	[24]
Policy (K_HU)	K_HU.1, K_HU.2, K_HU.3, K_HU.4	[25]
KEB_HU (Farming sustainability)	KEB_HU.1, KEB_HU.2, KEB_HU.3, KEB_HU.4, KEB_HU.5, KEB_HU.6, KEB_HU.7, KEB_HU.8, KEB_HU.9, KEB_HU.10, KEB_HU.11, KEB_HU.12	[26-28]

Table 2. Latent variables of model 2: MSME sustainability in the downstream sector

Variable	Indicator	Refs.
Environment dimension (DL)	DL 1, DL.2, DL.3, DL.4, DL.5, DL.6	[22]
Economic dimension (DE)	DE.1, DE.2, DE.3, DE.4, DE.5, DE.6	[29]
Social dimension (DS)	DS.1, DS.2, DS.3, DS.4, DS.5, DS.6, DS.7	[1]
Technological dimension (DT)	DT.1, DT.2, DT.3, DT.4, DT.5, DT.6	[30]
Institutional dimension (DK)	DK.1, DK.2, DK.3	[12]
Policy (K_HI)	K_HI.1, K_HI.2, K_HI.3, K_HI.4	[31]
MSME Sustainability (KEB_HI)	KEB_HI.1, KEB_HI.2, KEB_HI.3, KEB_HI.4, KEB_HI.5, KEB_HI.6, KEB_HI.7, KEB_HI 8, KEB_HI.9, KEB_HI.10, KEB_HI.11, KEB_HI.12, KEB_HI.13, KEB_HI.14, KEB_HI.15, KEB_HI .16, KEB_HI.17, KEB_HI.18	[32, 33]

Table 3. Latent variables of the integrated agroindustry sustainability model

Variable	Indicator	Reference
Farming Sustainability (KEB_HU)	Latent variable scores from Model 1, aggregated based on farmer-MSME partnerships	[34-36]
MSME Sustainability (KEB_HI)	Latent variable scores from Model 2	[34-36]
Agroindustry policy (K_INT)	K_INT.1, K_INT.2, K_INT.3, K_INT.4	[32]
Agroindustry development (PA)	PA1, PA2, PA3, PA4, PA5, PA6, PA7	[12]
Agroindustry sustainability (KA)	KA1, KA2, KA3, KA4, KA5	[12]

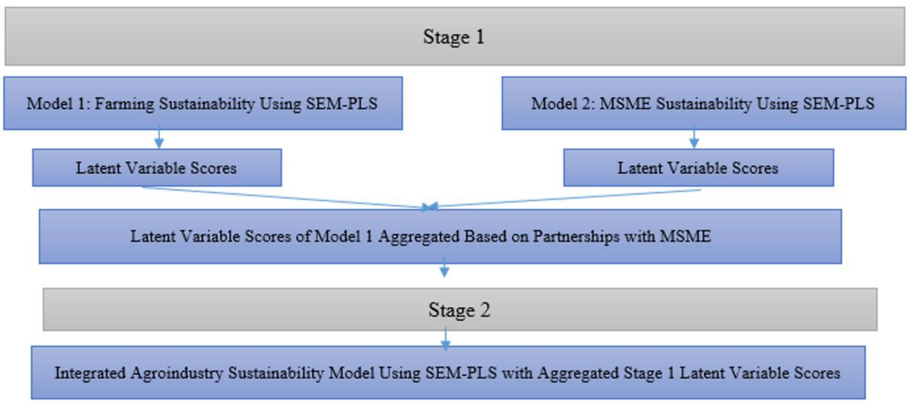

Figure 2. Conceptual research design
Source: Modified from Liu et al. [36]

2.3 Aggregation laten variable score

The latent variable scores obtained from the first-stage SEM-PLS models were aggregated to represent group-level constructs for the integrated model. For the upstream sector, the farm sustainability scores (KEB_HU) were aggregated based on the partnership between each farmer and the corresponding MSME in the downstream sector. The aggregation was performed by computing the mean of the latent scores of farmers linked to the same MSME. These aggregated scores were then used as exogenous variables in the second-stage integrated SEM-PLS model, allowing for the evaluation of contributions from both upstream and downstream actors to overall agroindustry sustainability [36].

2.4 Testing measurement model (outer model)

The research instruments were tested for validity and reliability using the PLS-SEM approach in the SmartPLS application. Indicators were considered valid if they had an outer loading ≥ 0.70 and an AVE value ≥ 0.50 [37]. Indicators K_HI 6, K_HI 14, and K_HI 16 in the downstream sustainability variable were removed because they did not meet the convergent validity criteria [38]. Eliability tests showed that both Composite Reliability and Cronbach's Alpha values were > 0.70, indicating that the instruments were reliable. All constructs also satisfied discriminant validity based on the Fornell-Larcker criterion and HTMT < 0.90 [31].

Table 4. Hypothesis

Direct Effect	Hypothesis
Model 1	
DE -> KEB_HU	H1 DE positively affects farming sustainability
DE -> K_HU	H2 DE positively affects policy
DK -> KEB_HU	H3 DK positively affects farming sustainability
DK -> K_HU	H4 DK positively affects policy
DL -> KEB_HU	H5 DL positively affects farming sustainability
DL -> K_HU	H6 DL positively affects policy
DS -> KEB_HU	H7 DS positively affects farming sustainability
DS -> K_HU	H8 DS positively affects policy
DT -> KEB_HU	H9 DT positively affects farming sustainability
DT -> K_HU	H10 DT positively affects policy
K_HU -> KEB_HU	H11 Policy positively affects farming sustainability
Indirect Effect	
DL -> K_HU -> KEB_HU	H12 Environmental Dimension (DL) indirectly affects farm sustainability through policy
DS -> K_HU -> KEB_HU	H13 Social Dimension (DS) indirectly affects farming sustainability through policy
DT -> K_HU -> KEB_HU	H14 Technological Dimension (DT) indirectly affects farming sustainability through policy
DE -> K_HU -> KEB_HU	H15 Economic Dimension (DE) indirectly affects farming sustainability through policy
DK -> K_HU -> KEB_HU	H16 Institutional Dimension (DK) indirectly affects farming sustainability through policy
Model 2	
Direct effect	
DE -> KEB_HI	H17 DE affects MSME sustainability
DE -> K_HI	H18 DE affects policy
DK -> KEB_HI	H19 DK affects MSME sustainability
DK -> K_HI	H20 DK affects policy
DL -> KEB_HI	H21 DL affects MSME sustainability
DL -> K_HI	H22 DL affects policy
DS -> KEB_HI	H23 DS affects MSME sustainability
DS -> K_HI	H24 DS affects policy
DT -> KEB_HI	H25 DT affects MSME sustainability
DT -> K_HI	H26 DT affects policy
K_HI -> KEB_HI	H27 Policy affects MSME sustainability
Indirect effect	
DL -> K_HI -> KEB_HI	H28 DL indirectly affects MSME sustainability through policy
DS -> K_HI -> KEB_HI	H29 DS indirectly affects MSME sustainability through policy
DT -> K_HI -> KEB_HI	H30 DT indirectly affects MSME sustainability through policy
DE -> K_HI -> KEB_HI	H31 DE indirectly affects MSME sustainability through policy
DK -> K_HI -> KEB_HI	H32 DK indirectly affects MSME sustainability through policy
Model 3	
Direct effect	
KEB_HI -> KA	H33 MSME sustainability affects agroindustry sustainability
KEB_HI -> K_INT	H34 MSME sustainability affects policy
KEB_HI -> PA	H35 MSME sustainability affects agroindustry development
KEB_HU -> KA	H36 Farming sustainability affects agroindustry sustainability
KEB_HU -> K_INT	H37 Farming sustainability affects policy
KEB_HU -> PA	H38 Farming sustainability affects agroindustry development
K_INT -> KA	H39 Policy affects agroindustry sustainability
PA -> KA	H40 Agroindustry development affects agroindustry sustainability
Indirect effect	
KEB_HI -> PA -> KA	H41 MSME sustainability indirectly affects agroindustry sustainability through agroindustry development
KEB_HI -> K_INT -> KA	H42 MSME sustainability indirectly affects agroindustry sustainability through policy
KEB_HU -> PA -> KA	H43 Farming sustainability indirectly affects agroindustry sustainability through agroindustry development
KEB_HU -> K_INT -> KA	H44 Farming sustainability indirectly affects agroindustry sustainability through policy

2.5 Structural model testing (inner model)

Structural models are evaluated by looking at the values of the coefficients of determination (R^2) and predictive relevance (Q^2). The R-squared value is used to assess the influence of independent latent variables on dependent latent variables. The criteria for the value (R^2) are > 0.67, which indicates that the model is good, and > 0.33 is moderate and > 0.19 is weak. The next structural model evaluation is the measurement of how well the model produces the observation value, as well as the estimation of its parameters using the Q^2 value; if $Q^2 > 0$, then the model has predictive relevance, but if the value is less than 0, then the model lacks predictive relevance [39].

2.6 Hypothesis testing

Hypothesis testing based on PLS was conducted using bootstrapping, as shown in Table 4 [31, 40]. This study employed a 5% significance level. Hypotheses were tested through the estimation of path coefficients and significance testing, where a p-value ≤ 0.05 indicates that the hypothesis is supported.

3. RESULT AND DISCUSSION

3.1 Uji outer model

The data collected through questionnaires were subsequently tested for validity and reliability to minimize bias. The validity test results show that all latent variables have AVE square root values greater than the correlations between latent variables, as presented in Table 5, thus meeting the discriminant validity criteria [39]. The outer model includes convergent validity, discriminant validity, and reliability for reflective models [41].

The outer model test results indicate that all factor loadings meet the recommended threshold, being above 0.70, which is considered ideal as it explains more than 49% of the indicator variance (obtained from 0.70^2) by the latent construct. The Average Variance Extracted (AVE) values are above 0.5, indicating that the measurement model evaluation in terms of convergent validity has been fulfilled. Reliability testing, using Cronbach's Alpha, Rho A, and Rho C (Composite Reliability), also exceeds 0.7, confirming that the constructs are reliable [42].

This study measured discriminant validity using both the Fornell–Larcker criterion and HTMT. Discriminant validity assessment using HTMT is more sensitive than Fornell–Larcker in detecting discriminant validity issues and requires more empirical evidence to support its use [43]. The discriminant validity results are presented in Table 6.

Table 5. Convergent validity and reliability

Model 1: Farming Sustainability				
Latent Variable	**AVE**	**Rho C**	**Rho-A**	**Cronbach Alpha**
DE	0.868	0.963	0.954	0.949
DK	0.866	0.963	0.950	0.948
DL	0.922	0.979	0.978	0.972
DS	0.898	0.978	0.975	0.972
DT	0.915	0.977	0.969	0.969
KEB_HU	0.844	0.985	0.984	0.983
K_HU	0.903	0.974	0.966	0.964
Model 2: MSME Sustainability				
Latent Variable	**AVE**	**Rho C**	**Rho-A**	**Cronbach Alpha**
DE	0.715	0.938	0.987	0.921
DK	0.775	0.911	0.864	0.854
DL	0.890	0.980	0.989	0.976
DS	0.643	0.927	0.918	0.908
DT	0.633	0.912	0.898	0.885
KEB_HI	0.669	0.968	0.968	0.964
K_HI	0.733	0.916	0.882	0.878
Model 3: Integrated Agroindustry Sustainability				
AVE	**Rho C**	**Rho-A**	**Cronbach Alpha**	**AVE**
KA	0.717	0.927	0.906	0.901
K_INT	0.662	0.886	0.839	0.826
PA	0.682	0.937	0.935	0.920

Source: SmartPLS 4 Output, 2025

Table 6. Discriminant validity result

Model 1 (Farming Sustainability)							
	DE	**DK**	**DL**	**DS**	**DT**	**KEB_HU**	**K_HU**
DE	**0.932**	0.547	0.405	0.442	0.595	0.436	0.508
DK	0.522	**0.931**	0.327	0.430	0.620	0.544	0.512
DL	0.389	0.314	**0.960**	0.620	0.138	0.259	0.100
DS	0.426	0.415	0.601	**0.948**	0.310	0.520	0.372
DT	0.573	0.596	0.135	0.303	**0.956**	0.579	0.658
KEB_HU	0.423	0.528	0.254	0.510	0.566	**0.919**	0.625
K_HU	0.490	0.492	0.100	0.365	0.637	0.611	**0.950**
Model 2 (MSME Sustainability)							
	DE	**DK**	**DL**	**DS**	**DT**	**KEB_HU**	**K_HU**
DE	**0.846**	0.437	0.874	0.345	0.458	0.569	0.451
DK	0.385	**0.880**	0.576	0.410	0.429	0.437	0.897
DL	0.837	0.525	**0.944**	0.391	0.551	0.678	0.762
DS	0.347	0.362	0.394	**0.802**	0.589	0.702	0.559
DT	0.445	0.367	0.531	0.545	**0.796**	0.734	0.600
KEB_HI	0.587	0.4	0.681	0.671	0.702	**0.818**	0.831
K_HI	0.442	0.786	0.721	0.514	0.538	0.773	**0.856**
Model 3 (Integrated Agroindustry Sustainability)							
	KA	**K_INT**	**PA**				
KA	**0.847**	0.522	0.896				
K_INT	-0.450	**0.814**	0.683				
PA	0.833	-0.599	**0.826**				

Source: SmartPLS Output, 2025

Based on Table 6, all correlations between variables or constructs do not exceed the correlation of each variable with itself, indicating that the Fornell–Larcker criterion has been satisfied. The HTMT values for all variables are below 0.9, meaning that the average correlations among measurement items do not overlap. The accepted HTMT threshold is < 0.90 or < 0.85 [44]. As HTMT is the most sensitive criterion for assessing discriminant validity, the discriminant validity in this study has been confirmed.

3.2 Uji inner model

This study employed the bootstrapping method to test the inner model, using a subsample of 5,000 and the Bias-Corrected and Accelerated (BCA) bootstrap confidence interval method [39]. Structural model analysis began by examining the VIF values, as shown in Table 7. The p-values of all variables indicate no signs of multicollinearity, with all values below 10, confirming that construct reliability and validity requirements are met [18].

Table 7. Structural model and hypothesis testing

	Path	P-Value	VIF	H	The Role of Mediation
Direct Effect					
Model 1					
DE → KEB_HU	-0.060	0.299ns	1.873	H1	
DE → K_HU	0.158	0.006**	1.826	H2	
DK → KEB_HU	0.153	0.002**	1.821	H3	
DK → K_HU	0.115	0.069*	1.796	H4	
DL → KEB_HU	-0.009	0.861ns	1.771	H5	
DL → K_HU	-0.199	0.001**	1.695	H6	
DS → KEB_HU	0.295	0.000***	1.876	H7	
DS → K_HU	0.238	0.000***	1.768	H8	
DT → KEB_HU	0.218	0.000***	2.259	H9	
DT → K_HU	0.433	0.000***	1.901	H10	
K_HU → KEB_HU	0.320	0.000***	1.911	H11	
Indirect Effect					
DL → K_HU → KEB_HU	-0.064	0.004**		H12	Indirect only (Full mediation)
DS → K_HU → KEB_HU	0.076	0.003**		H13	Complementary (Partial mediation)
DT → K_HU → KEB_HU	0.139	0.000***		H14	Complementary (Partial mediation)
DE → K_HU → KEB_HU	0.05	0.015**		H15	Indirect only (Full mediation)
DK → K_HU → KEB_HU	0.037	0.086 ns		H16	Direct only (No mediation)
Model 2					
Direct effect					
DE → KEB_HI	0.538	0.003**	4.747	H17	
DE → K_HI	-0.462	0.011**	3.399	H18	
DK → KEB_HI	-0.592	0.000***	2.938	H19	
DK → K_HI	0.483	0.000***	1.462	H20	
DL → KEB_HI	-0.449	0.041**	7.796	H21	
DL → K_HI	0.748	0.001**	4.263	H22	
DS → KEB_HI	0.183	0.048**	1.662	H23	
DS → K_HI	0.161	0.235ns	1.498	H24	
DT → KEB_HI	0.222	0.017**	1.756	H25	
DT → K_HI	0.081	0.542ns	1.714	H26	
K_HI → KEB_HI	1.111	0.000***	6.317	H27	
Indirect effect					
DL → K_HI → KEB_HI	0.831	0.010**		H28	Competitive (partial mediation)
DS → K_HI → KEB_HI	0.179	0.193ns		H29	Direct only (No mediation)
DT → K_HI → KEB_HI	0.090	0.538ns		H30	No effect (No mediation)
DE → K_HI → KEB_HI	-0.513	0.037**		H31	Competitive (partial mediation)
DK → K_HI → KEB_HI	0.537	0.000***		H32	Competitive (partial mediation)
Model 3					
Direct effect					
KEB_HI → KA	0.067	0.899ns	8.237	H33	
KEB_HI → K_INT	0.873	0.000***	1.154	H34	
KEB_HI → PA	-0.430	0.006**	1.154	H35	
KEB_HU → KA	-0.234	0.071**	1.552	H36	
KEB_HU → K_INT	0.161	0.020**	1.154	H37	
KEB_HU → PA	-0.348	0.027**	1.154	H38	
K_INT → KA	0.080	0.887ns	9.356	H39	
PA → KA	0.800	0.000***	1.737	H40	
Indirect effect					
KEB_HI → PA → KA	-0.344	0.015**		H41	Indirect mediation (Full mediation)
KEB_HI → K_INT → KA	0.07	0.889ns		H42	No effect (No mediation)
KEB_HU → PA → KA	-0.278	0.03**		H43	Competitive mediation (Partial mediation)
KEB_HU → K_INT → KA	0.013	0.895ns		H44	Direct only (No mediation)

Source: SmartPLS Output, 2025

Notes: NS: Not significant; ***: Significant at the 1% level; **: Significant at the 5% level; *: Significant at the 10% level

Stage 1 Analysis Farming Sustainability Model for Arabica Coffee in Java Ijen Raung and MSME Sustainability Model

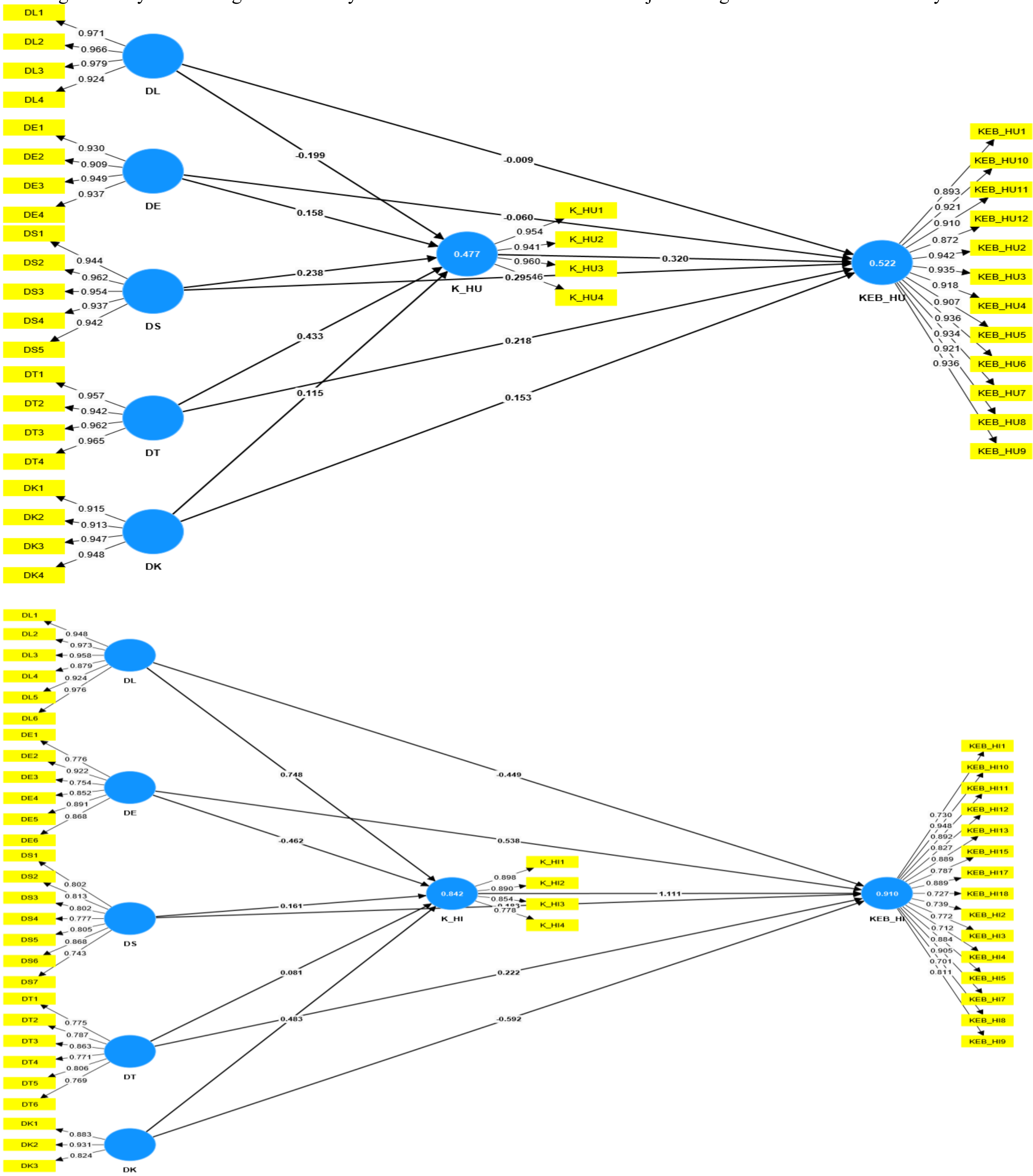

Figure 3. Step 1 model structure (farming sustainability and MSME sustainability)

Based on Table 8 and Figure 3, the R^2 value for farming sustainability (K_HU) is 0.477, which falls into the moderate category [39]. This indicates that the exogenous variables explain 47.7% of the variance in farming sustainability, while the remaining variance is attributed to factors outside the model. The R^2 value for upstream policy (KEB_HU) is 0.522, also in the moderate category, meaning that the exogenous factors together with farming sustainability explain 52.2% of the variance in upstream policy. The Q^2 values for these constructs are 0.424 (K_HU) and 0.436 (KEB_HU), both greater than 0, indicating good predictive relevance or this model, the R^2 value for MSME sustainability (K_HI) is 0.842, categorized as strong, and the R^2 value for downstream policy (KEB_HI) is 0.910, also very strong. This shows that the exogenous variables explain more than 80% of the variance in both MSME sustainability and downstream policy, indicating very high explanatory power. The Q^2 values for these constructs, 0.434 (K_HI) and 0.436 (KEB_HI), also demonstrate high predictive relevance. Therefore, this model is not only strong in explanation (R^2) but also highly relevant for prediction (Q²).

The integrative analysis based on Table 8 and Figure 4 results show that the R^2 value for agroindustry sustainability (KA) is 0.740, categorized as strong, while the R^2 value for intervention policy (K_INT) is 0.891, categorized as very strong. Meanwhile, the R^2 value for agroindustry productivity (PA) is 0.415, which falls into the moderate category. This indicates that intervention policy plays a dominant role in explaining the variation in agroindustry sustainability, whereas productivity is still influenced by other external factors outside the model. The Q^2 values in the integrative model are 0.480 (KA), 0.563 (K_INT), and 0.251 (PA), all greater than zero, demonstrating good predictive relevance. However, the predictive strength of productivity is relatively lower compared to agroindustry sustainability and intervention policy.

Table 8. R^2 and Q^2

Construct Prediction Summary			
	Q-square	R-square	Adj R-square
Step 1			
Model 1 Farming Sustainability			
KEB_HU	0.436	0.522	0.512
K_HU	0.424	0.477	0.468
Model 2 MSME Sustainability			
KEB_HI	0.436	0.910	0.889
K_HI	0.434	0.842	0.812
Step 2			
Model 3 Integrated Agroindustry Sustainability			
KA	0.480	0.740	0.701
K_INT	0.563	0.891	0.884
PA	0.251	0.415	0.375

Source: Outpt SmartPLS, 2025

Results of Stage 2 Integrative Analysis

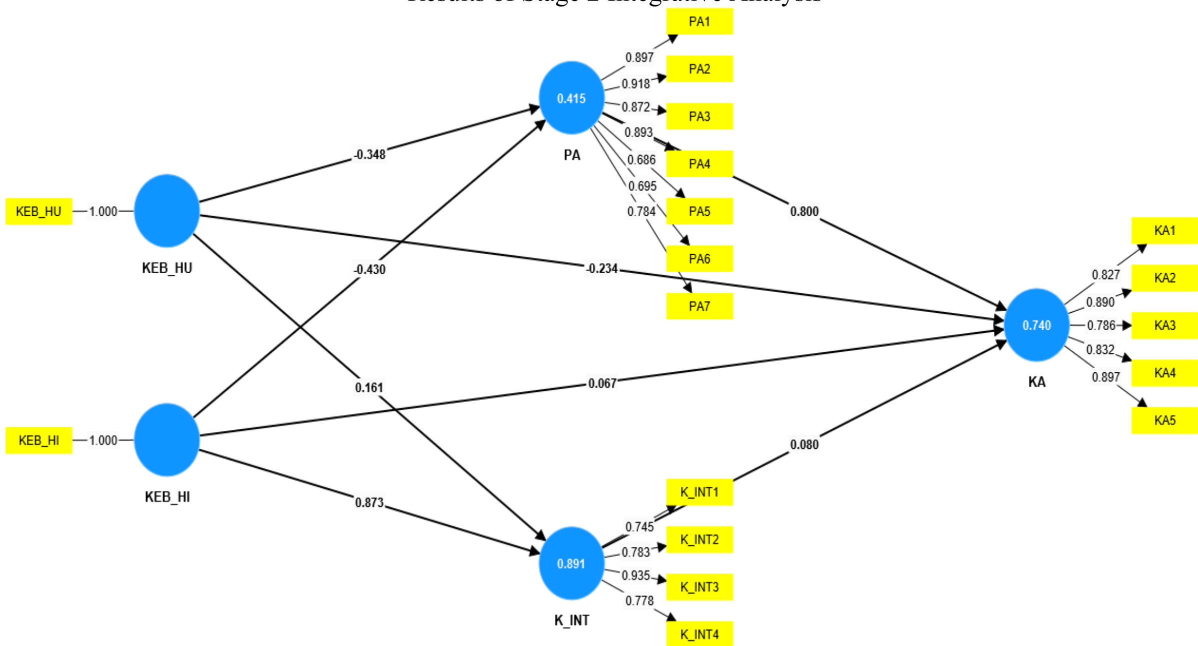

Figure 4. Integrated agroindustry sustainability model structure

3.3 Direct effect in the farming sustainability model for Arabica Coffee in Java Ijen Raung

Table 7 shows that the economic dimension does not significantly affect farming sustainability (H1 rejected). This is evident from the indicators—land area (DE.1), coffee production (DE.2), labor costs (DE.3), and coffee price (DE.4)—which empirically do not explain variations in sustainability. A larger land area may increase production capacity, but it does not necessarily translate to greater sustainability if not accompanied by efficient management and institutional support. Similarly, higher coffee production does not automatically improve sustainability, as yield fluctuations due to climate, pest attacks, and plant age often undermine farmers' economic stability. Labor costs also consume a significant portion of farming expenses, so wage increases without corresponding increases in selling prices can reduce farmers' profit margins [22]. On the other hand, coffee prices at the farmer level are strongly influenced by the global market, which tends to be volatile, and therefore cannot serve as a reliable foundation for long-term sustainability. This aligns with the findings of Sulewski et al. [45], which indicates that the impact of the economic dimension on sustainability is often inconsistent and context-dependent, including trade-offs between economic and other dimensions or the more dominant role of institutional and social factors in determining sustainability.

On the other hand, Table 7 shows that the economic dimension significantly affects policy (H2 accepted). Land area and coffee production serve as the basis for policies aimed at increasing productivity through land extensification and intensification [46]. High labor costs (DE.3) have prompted policies on mechanization and input subsidies, while fluctuating coffee prices (DE.4) have led to price stabilization policies and strengthened marketing institutions, as reflected in the Coffee Project Management Office (CPMO) program implemented through collaboration among stakeholders, including PTPN XII, the Ministry of State-Owned Enterprises, Perhutani, and local Arabica coffee farmers in Java Ijen Raung, to protect farmers' coffee prices. This finding aligns with Swart et al. [47] who reported that price and production costs are major drivers of policy direction.

The institutional dimension significantly affects Arabica coffee farming sustainability (H3 accepted), as shown in Table

7. Financial institutions (DK.1) play a crucial role in providing farmers with access to financing. The availability of credit and working capital enables farmers to rejuvenate crops, adopt technology, and manage farms more efficiently. Marketing institutions (DK.2) help strengthen farmers' bargaining power within the value chain, allowing them not to rely solely on middlemen and to access broader markets with fairer prices. Support from coffee certification institutions (DK.3) is strategic, as certifications—such as organic, fair trade, or geographical indication—can enhance coffee competitiveness in international markets [48]. These certifications also ensure environmental and social sustainability. The role of local institutions (DK.4), such as MPIG (Society for the Protection of Geographical Indications), contributes to strengthening regional coffee product identity, expanding networks, and increasing consumer trust. This finding aligns with Donovan and Poole [49], who reported that institutional support can enhance farmers' bargaining position in the coffee value chain.

The institutional dimension significantly affects policy (H4 accepted), as shown in Table 7. Access to financial institutions (DK.1) forms the basis for financing policies, marketing institutions (DK.2) drive policies to strengthen the value chain, certification support (DK.3) underpins policies facilitating sustainable certification, and local institutions (DK.4), such as MPIG, reinforce community-based policies. These findings align with Donovan and Poole [49], who emphasized the role of collective institutions in trade policy, Beuchelt and Zeller [50], who highlighted institutional support for coffee certification, and Sulewski et al. [45], who reported that institutions serve as a primary foundation for sustainable agricultural policies.

Table 7 shows that the environmental dimension does not significantly affect arabica coffee farming sustainability in Java Ijen Raung (H5 rejected). This indicates that water availability (DL.1) and soil fertility (DL.2) are relatively stable due to supportive agroclimatic conditions, and therefore do not serve as differentiating factors in determining farming sustainability. Environmental factors do not emerge as primary determinants. This finding is supported by Bhujel and Joshi [51], who reported that the homogeneity of agroecological conditions makes environmental factors less decisive compared to socio-economic and institutional factors in sustainable farming.

The environmental dimension significantly affects policy (H6 accepted), as shown in Table 7. Environmental aspects are key factors in formulating coffee farming management policies. Water availability (DL.1) and soil fertility (DL.2) determine productivity, highlighting the need to strengthen policies on water and land conservation and environmentally friendly cultivation practices Ulya et al. [52]. Est attack frequency (DL.3) also drives policies for ecologically based pest management to reduce reliance on chemical pesticides. Additionally, access to coffee plantation locations (DL.4) influences infrastructure development policies that support harvest transportation. These findings are supported by Arifin [53], who emphasized that coffee farming sustainability depends on policy support for environmental and natural resource management.

The social dimension significantly affects Arabica coffee farming sustainability in Java Ijen Raung (H7 accepted), as shown in Table 7. Support from research institutions encourages farmers to access cultivation technologies and post-harvest management innovations, thereby improving quality and productivity [54]. Individual factors such as age, education, human resource capacity, and experience also serve as important determinants. Highly educated farmers are more receptive to information and the adoption of sustainable practices [55]. Additionally, experience in coffee farming strengthens farm management capacity [56].

Based on Table 7, the social dimension significantly affects policy (H8 accepted). This finding aligns with Bacon et al. [55], who highlighted the role of research institutions in strengthening the competitiveness of coffee farmers. Social factors have been shown to influence policy effectiveness. In addition, human resource capacity and farming experience can enhance farm management. Therefore, the social dimension serves as an important foundation in formulating policies for sustainable coffee farming development.

The technological dimension significantly affects the sustainability of specialty arabica coffee farming in Java Ijen Raung (H9 accepted), as shown in Table 7. The adoption of modern cultivation technologies, such as pruning, balanced fertilization, and environmentally friendly pest control, has been proven to enhance coffee productivity and quality. This finding aligns with Cremaschi [57], who reported that sustainable agronomic practices strengthen production efficiency. Innovations such as producing organic fertilizers from agricultural waste also support soil fertility while reducing dependence on chemical fertilizers. In the post-harvest stage, technological standards, including washed and honey processes, have been shown to improve sensory quality and the market price of specialty coffee [58]. The application of modern storage technologies, such as hermetic storage, helps preserve bean quality and extend shelf life. Therefore, the implementation of technology from upstream to downstream is a key factor that strengthens competitiveness while ensuring the sustainability of arabica coffee farming in Java Ijen Raung in the global market.

The technological dimension significantly affects policy (H10 accepted), as shown in Table 7. This finding confirms that technological advancements at both the farm and post-harvest levels drive the emergence of policy interventions. Regarding cultivation technology (DT.1), the application of pruning techniques, the use of superior varieties, and agroforestry practices have been shown to improve productivity and quality, prompting the need for government policies in the form of extension programs and support for production facilities to broaden technology adoption [59]. Fertilizer technologies (DT.2), particularly organic and biofertilizers, not only enhance soil fertility but also contribute to environmental sustainability. However, limited access to capital and information often hinders their use, highlighting the need for policies that provide incentives, quality regulations, and training support to optimize these innovations [56]. Post-harvest technology standards (DT.3) are closely linked to value addition and market access. Differences in post-harvest processing methods significantly impact coffee sensory quality, making policies that regulate quality certification, facilitate joint processing, and establish national standard guidelines highly important. The application of post-harvest storage technologies (DT.4), including mechanical dryers and hermetic storage, effectively reduces losses and extends shelf life [60]. However, adoption requires institutional support and financing. Therefore, policies facilitating equipment provision, communal warehouse development, and farm credit access are essential to accelerate technology adoption [61]. These findings reinforce empirical evidence that strengthening the technological dimension directly stimulates the need for policies supporting farm modernization, post-harvest efficiency, and the sustainability of the arabica coffee agroindustry.

Policy significantly affects the sustainability of arabica coffee farming in Java Ijen Raung (H11 accepted), as shown in Table 7. Financing policies contribute to increased access to capital and farm stability [62] while institutional strengthening enhances farmers' bargaining power within the supply chain [63]. Additionally, environmental and waste management policies encourage the adoption of environmentally friendly practices and productive waste utilization [26] and export and market policies expand access to the global value chain through quality standardization and certification. Thus, policy not only serves as external support but also acts as a key catalyst linking farm management practices to economic, social, and environmental sustainability.

Based on these results, several operational policy recommendations can be proposed. First, to strengthen institutional effects, policymakers should provide direct facilitation to farmer groups such as training, mentoring, and cooperative strengthening rather than relying on top-down directives. Second, financing policies should be improved through simplified loan procedures and credit schemes tailored to smallholder coffee farmers. Third, environmental policies should include practical waste-handling technologies and incentives for composting, wastewater treatment, and organic farming practices. Finally, export and market policies should be supported by capacity-building programs that help farmers meet international standards, including training on coffee cupping, traceability, and certification requirements. These targeted interventions ensure that the positive policy effects identified in the analysis translate into measurable improvements in farming sustainability.

3.4 Indirect effect in the farming sustainability model for Arabica Coffee in Java Ijen Raung

Based on Table 7, the mediation test results indicate that the environmental dimension indirectly affects farming sustainability through policy (H12 accepted). This pattern is categorized as indirect-only (full mediation), meaning that the direct effect of the environmental dimension on sustainability is not significant, but becomes significant when mediated by policy. This mediation pattern is theoretically justified because environmental factors such as water availability, soil fertility, pest incidence, and the presence of protected areas are largely structural and external to farmers' control. According to sustainability theory and agricultural systems ecology, biophysical constraints cannot be effectively addressed at the farm level without institutional support, since they require collective action, regulation, and long-term resource governance. Therefore, policy acts as a necessary mechanism that translates environmental challenges into actionable interventions. Conservation and resource management policies help maintain ecosystem carrying capacity and enhance productivity [64]. While waste management policies promote the conversion of coffee waste into organic fertilizer, supporting farm efficiency [46]. This demonstrates that environmental factors, which are relatively difficult for farmers to control, can be addressed through policy instruments such as regulations, incentives, and support programs. These findings are supported by Khan et al. [65] who emphasized that ecological sustainability in coffee farming is more effectively achieved when environmental aspects are managed through adaptive, integrated policy frameworks that combine ecological, economic, and social considerations.

Based on the mediation test results in Table 7, the relationship between the social dimension and farming sustainability falls under the complementary (partial mediation) category. This indicates that the social dimension (DS) has a positive indirect effect on farming sustainability through policy (H13 accepted). Theoretically, this pattern occurs because social capital such as farmer group cohesion, participation, trust, and collaboration networks has a dual mechanism of influence. On one hand, strong social relations can directly enhance farming sustainability by facilitating knowledge sharing, collective action, and mutual support among farmers. On the other hand, the effectiveness of social capital is further amplified when supported by appropriate policies. Policies that strengthen farmer organizations, expand training and participation programs, and facilitate partnerships between farmers and institutions enhance the ability of social structures to function optimally. In agricultural development theory, social capital requires institutional reinforcement to translate informal networks into measurable improvements in productivity, resilience, and sustainability. Thus, policy acts as a formal mechanism that institutionalizes and scales up the benefits of social interactions. This finding supports Tambunan [66] who reported that sustainable agricultural development is strongly influenced by social support that is facilitated and amplified through government-driven empowerment programs and institutional strengthening.

Based on the mediation test results, the relationship between the technological dimension (DT) and farming sustainability falls under the complementary (partial mediation) category. This indicates that the technological dimension has a positive effect on sustainability both directly and indirectly through policy (H14 accepted). Theoretically, this mediation pattern can be explained by the dual nature of technology in agricultural systems: while technologies can directly enhance productivity, efficiency, and environmental performance, their widespread adoption often depends on institutional and policy support. At the technical level, cultivation technologies such as pruning, fertilization, and simple mechanization can increase coffee productivity while maintaining environmental quality [67]. However, technology adoption is often constrained by costs and knowledge gaps, making input subsidies or technical training policies crucial [68]. Fertilizer production technologies based on organic waste contribute to the principles of a circular economy and reduce reliance on chemical fertilizers, with policy interventions such as research support, equipment provision, and production incentives being critical to successful implementation [69]. In the post-harvest stage, technologies such as sorting, drying, and grading have been shown to improve product quality and market value. Studies in Ethiopia highlight that adopting post-harvest standards through extension policies and equipment facilitation can enhance coffee quality and competitiveness in the global market [70]. Furthermore, post-harvest storage technologies are essential for reducing losses and preserving bean quality. Recent research indicates that policy support for implementing modern drying and storage systems directly improves supply chain efficiency [53]. Overall, these findings reinforce the theoretical view that technology alone cannot fully drive sustainability; instead, its impact is amplified when embedded within supportive policy frameworks that reduce adoption barriers, institutionalize best practices, and promote technological diffusion.

The mediation test results presented in Table 7 indicate that the economic dimension (DE) also has a positive indirect effect on farming sustainability through policy, following an indirect-only (full mediation) pattern (H15 accepted). This means that the economic dimension does not exert a significant direct effect on sustainability, but its influence becomes significant when mediated by policy. Theoretically, this mediation pattern is expected because economic factors such as farm income, production costs, market access, and price stability are heavily shaped by institutional and policy environments rather than by farmers' individual actions. In agricultural sustainability literature, economic improvements often require structural interventions, such as market regulation, incentive schemes, and support programs, which can reduce systemic barriers and enhance farmers' economic resilience. Policies that promote agroforestry adoption, for example, enable farmers to increase land productivity while diversifying income sources. Likewise, coffee certification programs and inclusive supply chain policies help strengthen price stability, market access, and bargaining power, thereby improving farmers' income and long-term economic sustainability [63]. Without such policy support, economic constraints such as volatile prices, limited capital, and unequal market relationships cannot be effectively mitigated at the farm level. Therefore, the economic dimension influences sustainability primarily through policy mechanisms, explaining the indirect only (full mediation) pattern observed in this study.

The mediation test results in Table 7 indicate that the institutional dimension (DK) does not have an indirect effect on farming sustainability through policy (H16 rejected), but instead exerts a direct effect following a direct-only (no mediation) pattern. This suggests that farmer institutions play a more direct role through internal social mechanisms rather than through formal policy interventions. Theoretically, this pattern is consistent with the concept of endogenous institutional performance, which posits that the effectiveness of local institutions is shaped more by internal governance, trust, norms, and collective action than by external regulatory frameworks. In rural development studies, institutions often operate autonomously based on long-standing social practices, making their impact relatively independent of policy mediation. This finding aligns with Karyani et al. [71], who reported that local institutions often operate more effectively via internal socio-economic mechanisms than through government policy instruments. Financial and marketing institutions are not fully effective despite regulatory policies because farmers' access to formal financing remains limited due to administrative requirements and collateral constraints, leading them to rely on informal financial sources with higher interest rates [71]. Similarly, coffee marketing institutions are suboptimal as distribution chains are still dominated by intermediaries, leaving farmer institutions with weak bargaining power [72]. Consequently, although government policies aim to strengthen access to finance and markets, their implementation often does not align with the structural realities at the farmer level. The effectiveness of institutions is therefore more influenced by internal community dynamics and social networks than by formal policy [73]. This theoretical perspective explains why the institutional dimension exhibits a direct-only effect with no significant mediation through policy.

The study found that policy, as an intervention variable, plays a crucial role in determining the direction of farming sustainability. However, policy effectiveness largely depends on its content and implementation. Supportive policies, particularly in technological, social, and economic aspects, have been shown to strengthen sustainability, whereas restrictive policies especially those targeting environmental aspects without alternative support can hinder progress. Therefore, adaptive, participatory, and farmer centered policy design is necessary to function effectively as a lever for the sustainability of the arabica coffee agroindustry.

3.5 Direct effect in the MSME sustainability model for Arabica Coffee in Java Ijen Raung

Table 7 shows that the economic dimension (DE) has a positive effect on MSME sustainability (H17 accepted), but interestingly, it has a negative effect on policy (H18 accepted). This finding indicates that while the economic dimension of MSME can directly enhance sustainability, it is often not institutionalized into policies that favor MSME. This result aligns with Tambunan [66] who reported that many agribusiness MSME develop independently without adequate policy support.

The institutional dimension (DK) shows a contrasting result: it has a negative effect on MSME sustainability (H19 accepted) but a significant positive effect on policy (H20 accepted). This implies that institutional structures are more effective when channeled through policy rather than directly driving MSME sustainability. This finding is supported by previous study about that MSME associations in the food sector play a greater role in policy advocacy than in directly enhancing competitiveness [74].

The environmental dimension (DL) also has a direct negative effect on sustainability (H21 accepted) but a positive effect on policy (H22 accepted). This indicates that environmental indicators such as high quantities of coffee processing waste, poor waste management, lack of sanitation SOPs, low air quality in production, and uncontrolled chemical use directly increase costs and sustainability risks for MSMEs. However, these issues trigger government interventions through sanitation regulations, water efficiency policies, and monitoring of waste and chemicals. Coffee waste presents both environmental challenges and economic opportunities based on a circular economy, while water, sanitation, and food safety issues drive stricter regulations and government facilitation programs for MSME [75]. Thus, weaknesses in environmental practices suppress business sustainability but simultaneously strengthen formal policy attention and response.

The social dimension (DS) has a direct positive effect on MSME sustainability (H23 accepted). Support from the coffee community and involvement in business organizations strengthen partnership networks and facilitate access to market information. Social capital plays a crucial role in MSME resilience [76]. Individual factors, such as the age and education of business actors, also influence managerial capacity and decision-making quality [32]. The availability of capital and family participation serve as socio-economic resources supporting business continuity [77]. Additionally, local wisdom and cultural heritage contribute to strengthening product identity and enhancing added value in the specialty coffee market [52]. Thus, the social dimension serves as a key foundation integrating community, individual, and cultural aspects in sustaining MSME coffee enterprises.

The social dimension does not have a significant effect on MSME sustainability policy for arabica coffee in Java Ijen Raung (H24 rejected). Social factors, including community support, family participation, and local wisdom, primarily strengthen business resilience at the internal level but do not directly influence policy direction. Choong [78] found that social capital contributes to entrepreneurs' adaptive capacity, yet it is rarely incorporated into policy design. Community networks enhance MSME sustainability but are not strong enough to serve as a basis for policy formulation without formal institutional support.

The technological dimension has a significant effect on the sustainability of specialty arabica coffee MSME in Java Ijen Raung (H25 accepted). The application of coffee processing technology (DT.1) ensures product quality consistency and standardization, thereby strengthening the MSME position in the specialty coffee market. Furthermore, the alignment of technology with business scale (DT.2) is essential so that adoption does not create excessive costs but aligns with production capacity. Product and process innovations (DT.3) provide opportunities for diversification and added value, as noted by Setyowati and Wida Riptanti [79], who identified innovation as a key determinant of MSME sustainability. The use of information technology (DT.4) expands market access and improves supply chain efficiency [80]. Thus, the sustainability of specialty coffee MSME depends not only on technology availability but also on its appropriateness, innovation, and strategic utilization.

Based on Table 7, the technological dimension does not significantly affect MSME sustainability policy for arabica coffee in Java Ijen Raung (H26 rejected). Aspects such as coffee processing technology (DT.1), technology-business scale alignment (DT.2), product and process innovation (DT.3), and the use of information technology (DT.4) have not been the primary focus in policy formulation. MSME policies are more oriented toward financing and market access, while support for technology adoption remains partial. This finding aligns with Adam and Ghaly [22], who reported that technology only has a tangible impact when supported by synergistic policies that promote its diffusion and implementation at the MSME level.

Policy has a significant effect on the sustainability of specialty arabica coffee MSME in Java Ijen Raung (H27 accepted). Financing policies strengthen access to capital, which is a prerequisite for enhancing production capacity. Institutional support policies facilitate the formation of collaborative networks, improving the bargaining position of MSME. Furthermore, environmental and waste management policies (KEB_HI.3) encourage the adoption of eco-friendly practices, increasingly aligned with global market demands. In addition, export and market policies expand MSME' access to international trade opportunities with higher quality standards. These findings are consistent with Tohiroh et al. [81], who highlighted that consistent public policy support serves as a strategic instrument for enhancing sustainability and competitiveness in agribusiness MSMEs.

Based on these findings, several operational policy recommendations can be proposed. First, to strengthen institutional effects, policymakers should support farmer and MSME groups through direct facilitation such as training, mentoring, and cooperative strengthening rather than relying on top-down instructions. Second, financing policies should include simplified credit mechanisms and incentive schemes tailored to small-scale processing units. Third, environmental policies should incorporate practical waste-handling technologies and provide subsidies for eco-friendly equipment to ensure effective adoption. Lastly, export and market policies should be aligned with capacity-building programs that help MSME meet international standards. These concrete interventions ensure that the positive policy effects identified in the analysis can be translated into measurable improvements in MSME sustainability.

3.6 Indirect effect in the MSME sustainability model for Arabica Coffee in Java Ijen Raung

Mediation analysis indicates that the relationship among the environmental dimension (DL), policy (K_HI), and MSME sustainability (KEB_HI) follows a competitive (partial mediation) pattern. This suggests that the environmental dimension affects MSME sustainability both directly and indirectly through policy (H28 accepted), but the directions of these effects are opposite. The environment directly contributes positively to MSME sustainability; however, when policy acts as a mediator, the intervention produces a counteracting effect. These findings align with the competitive partial mediation theory and Porter's hypothesis, which posit that environmental regulations can stimulate innovation and efficiency, thereby enhancing business sustainability, but overly strict or misaligned regulations may become a burden for MSME [82]. This pattern is also consistent with institutional theory, which states that policy pressures can either enable or constrain firms, and with compliance cost theory, which explains why certain regulatory interventions may offset the benefits of environmental practices.

The analysis indicates that the social dimension has a direct effect on MSME sustainability, while the mediation pathway through policy is not significant (H29 rejected). This direct only pattern underscores that social factors such as support from coffee institutions, the age and education of MSME actors, availability of capital, family participation, and local wisdom/culture possess intrinsic strength in sustaining MSME operations without necessarily being facilitated through policy. These findings align with Achmad et al. [82] and Aisyah et al. [83], highlighting social capital as a critical asset for MSME in building resilience and business sustainability. Strengthening the social dimension should focus on network development, collaboration, and community support, while policy serves only as a supplementary rather than a primary mediating factor. This pattern is theoretically supported by social capital theory and the resource-based view, which posit that relational networks, trust, and community-based resources function as internal capabilities that directly enhance firm performance and are not dependent on external regulatory mechanisms. Therefore, strengthening the social dimension should focus on network development, collaboration, and community support, with policy serving only as a supplementary rather than a primary mediating factor.

The analysis shows that the technological dimension does not have a significant effect on MSME sustainability, either directly or through policy (H30 rejected). This no effect (no mediation) pattern indicates that the availability and application of technologies such as coffee processing technology, product innovation, information technology use, equipment completeness, and packaging have not yet become primary determinants of MSME sustainability. This condition may result from limited access, high implementation costs, and insufficient human resource capacity to adopt technology optimally. These findings align with Hadi et al. [84], who reported that the low capacity for technology adoption among coffee MSME limits the contribution of technology to improving sustainability. This pattern is also consistent with the Technology Acceptance Model and diffusion of innovation theory, which emphasize that technology affects performance only when users perceive clear benefits and possess adequate capability to adopt it.

The mediation test results indicate a competitive (partial mediation) pattern in the relationship among the economic dimension, policy, and MSME sustainability (H31 accepted). This finding suggests that improvements in economic aspects do not always directly enhance MSME sustainability and may even undermine it if not accompanied by adequate policy support. However, through the role of policy, the influence of the economic dimension can be redirected positively, contributing to the strengthening of sustainability. This aligns with previous research emphasizing the critical role of regulations, institutions, and public policy in mitigating potentially negative economic impacts and ensuring a strong linkage between business growth and sustainability principles [22]. This pattern is theoretically supported by institutional theory and the sustainable development governance perspective, which propose that economic incentives alone may create trade-offs or short-term optimization, but policy mechanisms such as regulation, facilitation, and oversight can reshape these incentives toward long-term sustainability goals.

The results indicate that the institutional dimension plays a significant role in promoting MSME sustainability, both directly and through policy as a mediator (H32 accepted). The observed competitive partial mediation pattern underscores that the presence of strong institutions such as regulations, legal frameworks, and organizational support can directly enhance sustainability, but their effectiveness is maximized when translated into concrete, actionable policies. This aligns with Anggraeni et al. [24] who found that institutions serve as a foundation for implementing sustainable development policies and emphasized the synergy between institutions and policies in strengthening the competitiveness of sustainable MSME. Policies thus function not only as technical instruments but also as channels linking institutional capacity to the achievement of MSME sustainability. This pattern is further supported by governance theory and policy implementation perspectives, which highlight that institutional arrangements only generate impact when supported by effective policy execution that converts strategic frameworks into operational outcomes. Policies thus function not only as technical instruments but also as channels linking institutional capacity to the achievement of MSME sustainability.

3.7 Direct effects in the integrated agroindustry sustainability model for Arabica Coffee in Java Ijen Raung

Based on Table 7, the integrated analysis of farm sustainability (KEB_HU) and MSME sustainability (KEB_HI) shows differing impacts on the sustainability of the coffee agroindustry (KA). In the direct pathways, KEB_HI → KA is not significant (H33 rejected), whereas KEB_HU → KA (H36 accepted) exhibits a negative effect. This indicates structural imbalances within the supply chain, where increased upstream productivity is not matched by downstream absorption capacity and quality standards. Consequently, oversupply of raw materials, price declines, and low added value can weaken agroindustry sustainability [12]. Conversely, the relatively limited impact of MSMEs, restricted export market access, and low technological innovation mean the downstream sector is not yet able to significantly drive sustainability. This finding aligns with Arifin [53] who emphasized that without integrated policies linking farmers and MSME, agroindustry sustainability is often hindered by mismatches between upstream production capacity and downstream absorption.

MSME sustainability positively affects policy (H34 accepted). The higher the level of MSME sustainability across managerial, financial, and marketing network aspects the greater the demand and impetus for supportive public policies [33]. In the context of the coffee agroindustry, MSME that maintain business sustainability through production efficiency, product innovation, and market access tend to be more responsive to government policies, driving the development of more adaptive and pro-small-business regulations. This aligns with Moachammad et al. [32] and Setyaningsih et al. [85], who noted that MSME sustainability depends not only on internal factors but also on external support through policies facilitating access to capital, institutional strengthening, and market development. This positive relationship reflects a policy feedback mechanism, whereby MSME success in maintaining sustainability stimulates the emergence of more inclusive policies oriented toward strengthening the coffee value chain from upstream to downstream.

MSME sustainability significantly affects agroindustry development (H35 accepted). This indicates that MSME continuity across production capacity, product innovation, and market connectivity is a key driver for expanding the agroindustry value chain. MSMEs that successfully maintain business sustainability not only increase added value through product diversification and process efficiency but also strengthen their bargaining position in both domestic and export markets. This finding aligns with Aisyah et al. [83], who emphasized that MSME sustainability plays a strategic role in integrating upstream and downstream sectors and acts as a catalyst for community-based agroindustry development. Strengthening MSME sustainability is thus a key strategy for transforming the coffee agroindustry toward a more competitive, inclusive, and long-term oriented system.

Farming sustainability influences policy (H37 accepted). Upstream sustainability including environmentally friendly cultivation practices, efficient input use, and stable farmer productivity serves as a critical foundation for formulating coffee agroindustry development policies [84]. In other words, the sustainability status of farming encourages the government and relevant institutions to design policies that are more adaptive to farmers' needs, covering financing, institutional strengthening, environmental management, and market access. This finding aligns with Gabriel [86] who emphasized that effective policies often stem from the dynamics and sustainability at the production level, as downstream success heavily depends on the consistency and resilience of upstream farming systems.

Table 7 shows that in the integrated model, farm sustainability has a significant effect on agroindustry development (H38 accepted). Sustainable farming practices including the adoption of environmentally friendly cultivation technologies, balanced pruning and fertilization, and land management with conservation considerations serve as the primary foundation for ensuring high-quality raw materials for downstream industries [52]. Without sustainability at the upstream level, agroindustry development faces serious challenges such as unstable supply, low product quality, and high production costs. This finding is supported by Nugroho [87], who emphasized that the success of national coffee industry development largely depends on consistent production at the farmer level, both in terms of quantity and quality. Farm sustainability acts as a key driver in the agribusiness value chain, which in turn strengthens the competitiveness of the agroindustry in both domestic and global markets. Therefore, upstream sustainability is not merely a production factor but also a strategic instrument in accelerating the transformation of the coffee agroindustry toward a more efficient and highly competitive system.

Table 7 shows that in the integrated model, policy does not have a significant effect on agroindustry development (H39 rejected). Regulations have not yet fully promoted the implementation of strategic indicators, including product downstreaming, upstream downstream integration, inter-institutional collaboration, postharvest technology investment, promotion and branding, cross-stakeholder socialization, or policy synchronization among agencies. The success of agroindustry development is more strongly determined by the initiative and collaboration of business actors rather than merely the existence of formal policies [88].

Based on Table 7, agroindustry development has a significant effect on agroindustry sustainability (H40 accepted). This indicates that strengthening product downstreaming, upstream–downstream integration, inter-institutional collaboration, postharvest technology investment, joint promotion, and policy synchronization are key factors in creating a competitive and sustainable agroindustry system. With a well directed development strategy, the agroindustry can not only increase product added value but also strengthen its position in the global supply chain and maintain economic, social, and environmental sustainability [84].

3.8 Indirect effects in the integrated agroindustry sustainability model for Arabica Coffee in Java Ijen Raung

The study found an indirect-only mediation (full mediation) pattern in the relationship between MSME sustainability and agroindustry sustainability through agroindustry development (H41 accepted). This means that MSME sustainability does not directly contribute to agroindustry sustainability but is entirely mediated by agroindustry development strategies. Although MSME have the potential to maintain sustainability, the impact becomes tangible when integrated into targeted development programs, including product downstreaming (PA1), upstream downstream integration (PA2), and joint promotion and branding (PA5). By strengthening agroindustry development, MSME sustainability can be transformed into systemic sustainability at the agroindustry level [84]. Theoretically, this mediation pathway indicates that sustainable MSME will only have a broad impact if supported by structured agroindustry development, encompassing postharvest technology investment (PA4) and inter-institutional policy synchronization (PA7). Adams and Ghaly [89] explained that value chain integration and downstreaming innovation are critical mechanisms for linking MSME capacity with agroindustry sustainability. Collaborative, technology-driven agroindustry development enhances resilience and the overall sustainability of the coffee sector.

The analysis results indicate that MSME sustainability does not have a significant effect on agroindustry sustainability through policy (H42 rejected). This no effect (no mediation) pattern suggests that achievements in MSME level sustainability are not yet strong enough to trigger the emergence of relevant policies or produce a tangible impact on agroindustry sustainability. This situation may occur because policies are often formulated top down and do not fully respond to dynamics at the MSME level. Although coffee processing MSME may be sustainable at the enterprise level, their impact is insufficient to enhance agroindustry sustainability if mediated only through policy instruments This is because policies remain general, partial, and do not fully address the specific needs of coffee-processing MSME, such as access to financing, market protection, and technology incentives. According to Tambunan et al. [66], the effectiveness of policies in supporting agribusiness MSME sustainability is strongly influenced by consistent implementation, cross-agency coordination, and the involvement of local actors in policy formulation. Without proper synchronization, policies tend to fail as an effective channel linking MSME sustainability to systemic agroindustry sustainability. This pattern is also supported by policy feedback theory and bottom-up policy implementation perspectives, which argue that policies generate meaningful outcomes only when informed by local input and grounded in the actual capacities of target groups. When this alignment is weak, policies do not function effectively as mediating mechanisms, resulting in the absence of both direct and mediated effects.

The integration analysis shows a competitive (partial mediation) pattern, indicating that the sustainability of coffee farming has an indirect effect on agroindustry sustainability through agroindustry development (H43 accepted). This suggests that sustainable cultivation practices will impact the agroindustry level only if accompanied by downstream processing, supply chain integration, and institutional collaboration. This finding aligns with Prakosa et al. [73] who emphasize the importance of governance and sustainability across the coffee value chain, as well as the role of business model innovation in strengthening upstream–downstream linkages. This mediation pattern is also supported by value chain theory and systems thinking, which posit that improvements at the production level create meaningful system-wide outcomes only when connected through coordinated development mechanisms that integrate upstream and downstream actors.

The study shows that the sustainability of coffee farming (KEB_HU) has a direct effect on agroindustry sustainability (KA) (H44 rejected), while the mediating role of policy (K_INT) is not significant. The direct-only (no mediation) pattern indicates that upstream sustainability—such as productivity, cultivation efficiency, and environmental management at the farm level—contributes directly to agroindustry sustainability without requiring policy facilitation. This finding aligns with previous studies emphasizing that sustainable practices at the production level form the primary foundation for the agroindustry value chain [48]. Enhancing farmers' capacity through sustainable upstream practices is a more decisive factor than policy interventions, although policies remain necessary as long-term support. This pattern is theoretically supported by production base theory and resource-dependency logic, which argue that the strength and stability of downstream industries depend fundamentally on the sustainability of input-producing sectors. When upstream resources are strong and consistent, their impact flows directly to downstream performance, even in the absence of policy mediation. Enhancing farmers' capacity through sustainable upstream practices is therefore a more decisive factor than policy interventions, although policies remain necessary as long-term support.

4. CONCLUSION

The integration of farm sustainability and MSME sustainability plays a mutually supportive role in promoting agroindustry sustainability. Policies in both upstream and downstream sectors influence agroindustry sustainability directly and indirectly through the mediating role of agroindustry development, and these effects are statistically significant. This indicates that enhancing agroindustry sustainability requires an integrated strategy from upstream (farmers) and downstream (MSME) actors, with a focus on strengthening agroindustry development as the primary mediator. Meanwhile, policy improvements should be combined with agroindustry development programs to achieve a tangible impact on overall agroindustry sustainability.

4.1 Study limitations and future research directions

This study has several limitations. The MSME sample size was small, and the use of snowball sampling for farmers may introduce selection bias. In addition, the study focused only on Kabupaten Bondowoso, limiting the geographical generalizability of the findings. Future research should involve larger and more diverse samples using probability based sampling. Comparative studies across multiple coffee producing regions and the use of longitudinal or mixed method approaches are recommended to provide deeper insights into sustainability dynamics and policy impacts.

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AUTHOR CONTRIBUTIONS

B. Durroh conducted the literature review, data collection, analysis, and comprehensive interpretation of the data. This article is part of the author's doctoral dissertation. Darsono, Heru Irianto, and Erlyna Wida Riptanti provided supervision and contributed critical insights to enhance the quality of the manuscript.

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