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Technological adaptation and ethnic entrepreneurship: A cluster-based study in Northern Vietnam

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Abstract: This study explores the heterogeneous patterns of technological adaptation among ethnic minority entrepreneurs in Northern Vietnam. Using survey data from 230 ethnic businesses across four provinces, we adopt a bagged clustering algorithm to classify entrepreneurs into distinct groups based on their digital literacy, technology use, and attitudes toward digital transformation. The analysis reveals three clusters: (1) Digitally skilled but cautious users, who possess digital competence but underutilize technology in business operations; (2) Low digital engagement, characterized by limited skills and minimal digital integration; and (3) Tech-driven practitioners, who actively use digital tools despite lower formal education. Our findings thus highlight the need for cluster-specific policies that recognize the diversity among ethnic entrepreneurs, recommending tailored support such as digital literacy training for low-engagement groups, business application coaching for digitally skilled but cautious users, and scale-up assistance for tech-driven practitioners.

Keywords: Ethnic entrepreneur, Northern Vietnam, technological adaptation, cluster analysis, digital literacy.

1. Introduction

Ethnic entrepreneurship has become an increasingly important topic in contemporary economic discourse due to its role in fostering cultural diversity and contributing to local economies. Ethnic minority communities often face poor living conditions and limited economic opportunities; however, entrepreneurship allows them to strive and create economic value through culturally significant products and services. In Vietnam, there has been a growing trend of entrepreneurship among individuals from ethnic minority backgrounds. This trend has been supported by government initiatives and programs aimed at promoting local start-ups,

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such as the *2023 Women's Start-up*, *Promoting Indigenous Resources*, and *The Business Incubator* programs, which provide platforms for ethnic minority groups to showcase their products and innovations (CEMA, 2018).

In the era of Industry 4.0, digital transformation has emerged as a pivotal driver of economic growth, fundamentally altering business models, production processes, and market dynamics. For developing countries like Vietnam, the adoption of advanced technologies offers tremendous opportunities to accelerate economic development, enhance productivity, and foster innovation (Ngo, 2023; Pham et al., 2023). Particularly in Northern Vietnam, where diverse ethnic minority communities engage in entrepreneurial activities, technological adaptation holds significant promise for promoting inclusive economic growth and reducing regional disparities. However, despite government efforts, ethnic entrepreneurs in Northern Vietnam face significant challenges in integrating technology into their business operations. Limited access to financial resources, insufficient technological infrastructure, and inadequate digital skills can potentially hinder their ability to fully capitalize on digital transformation (Can & Dang, 2024; Vo et al., 2023).

Moreover, research on ethnic entrepreneurship in Vietnam has predominantly focused on socio-cultural and economic aspects, with limited attention to technological adaptation. Early studies emphasized financial constraints, discrimination, and historical inequalities as primary barriers to business growth among ethnic entrepreneurs (Bewaji et al., 2015; Carter et al., 2015). Within the context of Northwest Vietnam, determinants such as attitudes toward entrepreneurship, government policies, and entrepreneurial education have positively impacted ethnic minority businesses (Phan et al., 2022). However, these studies have not fully captured the influence of emerging factors such as Artificial Intelligence, digital networks, and the rise of e-commerce. Despite the potential benefits of digital transformation, ethnic entrepreneurs in Northern Vietnam remain constrained in leveraging technology for business development. Barriers such as financial limitations, low digital literacy, and insufficient government support continue to impede effective technological adoption (Prasannath et al., 2024; Nguyen et al., 2024; Neumeyer et al., 2020).

To address this gap, this study applies a cluster analysis approach to explore the heterogeneity among ethnic minority entrepreneurs in Northern Vietnam in terms of their digital literacy, technological adaptation, and business behavior. The use of cluster analysis enables the identification of distinct profiles of entrepreneurs based on shared characteristics and behaviors, allowing for more nuanced insights than a one-size-fits-all policy framework. This research thus contributes to the growing literature on digital transformation in developing economies and sheds light on how ethnic entrepreneurs navigate technological change. The findings aim to inform targeted strategies to empower ethnic communities, bridge the rural digital divide, and foster inclusive innovation.

2. Literature review and theoretical framework

Ethnic entrepreneurship, defined as business activities undertaken by individuals from minority ethnic groups, has been widely studied in various contexts. Previous scholars have examined numerous determinants of ethnic entrepreneurship, including social capital (Galbraith et al., 2007), access to financial resources (Appiah, 2019; Bewaji et al., 2015), cultural factors (Tehseen et al., 2023), and market conditions (Horváth & Zhang, 2022).

While research has extensively examined socio-cultural and economic factors influencing ethnic entrepreneurship, the role of technological innovation remains underexplored. Technological innovation - the adoption and implementation of new technologies - is critical in modern entrepreneurship as it improves efficiency, market reach, and product innovation. Schumpeter (1934) identifies innovation as the primary driver of economic development, and recent studies (Beliaeva et al., 2019; Tran, 2022) emphasize the importance of digital innovations for creating competitive advantages and driving economic growth. Recently, a rising number of authors have raised their voice that technological adaptation is essential for SMEs to maintain competitiveness in rapidly evolving markets. This is particularly salient in the post-pandemic economy, where digital transformation has become essential for competitiveness (Quaye et al., 2024; Shahadat et al., 2023; Indrawati, 2020).

However, studies largely focus on mainstream entrepreneurship, neglecting how ethnic entrepreneurs engage with technological innovations.

Internal factors such as limited financial capital, management capacity, and low digital literacy (Tran & Vu, 2018), as well as external pressures like market volatility and customer expectations (Zhu et al., 2006), constrain their technological adaptation. Furthermore, infrastructural inadequacies in rural and mountainous areas continue to widen the digital divide (Le & Nguyen, 2021).

To understand the complexity of digital engagement among ethnic entrepreneurs, this study draws on three complementary theoretical frameworks. The Technology Acceptance Model (TAM) (Davis, 1989) explains how perceived usefulness and ease of use influence technology adoption, especially relevant for evaluating digital tools in sales, marketing, and customer engagement. Diffusion of Innovation Theory (Rogers, 2003) helps contextualize the spread of new technologies among peer groups and local communities, emphasizing the roles of early adopters and social learning. Additionally, the Resource-Based View (RBV) (Barney, 1991) highlights how internal capabilities—such as digital skills, access to infrastructure, and social capital—shape firms' ability to leverage technology as a competitive advantage.

3. Research design

3.1. Research design and data collection

This study adopts a quantitative, cross-sectional survey design to examine patterns of technological adaptation and digital transformation among ethnic minority entrepreneurs in Northern Vietnam. A structured questionnaire was administered to a sample of entrepreneurs across selected provinces, including Ha Giang, Lao Cai, and Son La. The questionnaire consisted of items related to digital literacy, technology use, perceived opportunities, and barriers to digital transformation. Respondents rated their experiences on five-point Likert scales, while demographic as well as business-related information was also collected. After data cleaning and pre-processing, a final dataset of 230 responses was used for empirical analysis.

Given the study's aim to identify naturally occurring subgroups of entrepreneurs based on their digital behavior and attitudes, cluster analysis, which is best suited for this purpose was therefore used in this study. To enhance the stability and robustness of the clustering results, we applied a bagged clustering approach (Leisch, 1999) combining a hierarchical algorithm using Ward's minimum variance method and K-means clustering algorithm.

3.2. Bagged clustering algorithm

Given a data set X_N of size N, the algorithm consists of 5 steps as follows.

Step 1: Construct B bootstrap training samples $X_N^1, \dots, X_N^B$ of size N by drawing with replacement from the original sample X_N.

Step 2: Run the base cluster method (K-means) on each set, resulting in $B \times K$ centers $c_{11}, c_{12}, \dots, c_{1K}, c_{21}, \dots, c_{BK}$ where K is the number of centers used in the base method and c_{ij} is the j-th center found using X_N^i.

Step 3: Combine all centers into a new data set $C^B = C^B(K) = \{c_{11}, \dots, c_{BK}\}$.

Step 4: Run a hierarchical cluster algorithm on C^B, resulting in the usual dendrogram.

Step 5: Let $c(x)C^B$ denote the center closest to point *x*. A partition of the original data can now be obtained by cutting the dendrogram at a certain level, resulting in a partition $C_1^B \dots, C_m^B, 1 \le m \le BK$, of set C^B. Each point x is now assigned to the cluster containing $c(x)$.

4. Empirical results

4.1. Demographic characteristics

The demographic characteristics of the sample are reported in Table 1. First, the gender distribution was relatively balanced, with 119 female respondents (51.7%) and 111 male respondents (48.3%). Regarding ethnic composition, the sample includes four major ethnic groups with the H'Mong group accounting for the largest proportion (28.3%), followed by Tay (26.5%), Dao (24.4%), and Thai (20.8%). In terms of educational attainment, no formal education and vocational/college-level education each accounted for 18.7%, primary school education was the most common level, with 21.3%, while university or higher education was reported by 16.5%. Notably, 12.2% only completed secondary school, and 12.6% finished high school. This suggests that while a considerable number of respondents have limited formal education, a notable segment has accessed higher education or vocational training, which could influence their digital readiness and business innovation capacity.

Geographically, the distribution of respondents across the provinces was relatively even. The largest share came from Yen Bai (30.9%), followed by Son La (29.1%), Lao Cai (21.3%), and Ha Giang (18.7%). This regional balance enhances the representativeness of the sample in reflecting the diversity of conditions across Northern Vietnam. Regarding the type of business, the most common sector was handicrafts (37.4%), followed by agriculture and

manufacturing (23.9%), retail (21.3%), food and beverages (13.9%), and services and other activities (3.5%).

Finally, in terms of business form, the most dominant category was household businesses (30.0%), followed by individual enterprises (27.4%), cooperatives (26.5%), and microenterprises (16.1%).

Table 1: Socio-demographic characteristics of the profiled clusters

Information	Whole sample		CL1	CL2	CL3	*p*-value
	Frequency	Percentage				
Gender of ethnic business owners						1.435
- Male	111	48.3	47.76	40	53.03	
- Female	119	51.7	52.24	60	46.97	
Ethnic group of ethnic business owners						7.535
- H'Mong	65	28.3	27.61	36.67	25.76	
- Dao	56	24.4	25.37	6.67	30.3	
- Tay	61	26.5	24.63	36.67	25.76	
- Thai	48	20.8	22.39	20	18.18	
Education background of ethnic business owners						12.444
- No formal education	43	18.7	17.91	10	24.24	
- Primary school	49	21.3	18.66	36.67	19.7	
- Secondary school	28	12.2	14.18	10	9.09	
- High school	29	12.6	11.94	6.67	16.67	
- Vocational/College	43	18.7	17.91	16.67	21.21	
- University or above	38	16.5	19.40	20	9.09	
Province of ethnic business						1.394
- Ha Giang	43	18.7	18.66	23.33	16.67	
- Lao Cai	49	21.3	21.64	23.33	19.70	
- Son La	67	29.1	28.36	30.01	30.30	
- Yen Bai	71	30.9	31.34	23.33	33.33	
Type of business						10.151
- Agriculture and manufacturing	55	23.9	21.64	36.67	22.73	
- Handicrafts	86	37.4	33.58	30	48.48	
- Retail	49	21.3	25.37	20	13.64	
- Food & Beverages	32	13.9	16.42	10	10.61	
- Services and Others	8	3.5	2.99	3.33	4.55	
Form of business						6.619
- Individual	63	27.4	29.1	30	22.73	
- Household	69	30.0	23.88	33.33	40.91	
- Cooperative	61	26.5	29.1	23.33	22.73	
- Microenterprise	37	16.1	17.91	13.34	13.64	
Number of employees						4.739
- 1			20.15	20	21.21	
- 2-5			28.36	26.67	21.21	
- 6-10			34.33	26.67	28.79	
- >10			17.16	26.66	28.79	
Age of ethnic business owners			44.87	45.3	46.74	1.12
Years of operation			8.39	7.77	8.69	0.51
Business revenues						9.388*
- < 5 million VND			34.33	16.67	30.31	
- 5-20 million VND			34.33	23.33	36.36	
- > 20 million VND			31.34	60	33.33	

Note: Chi-square test was used for qualitative variables and ANOVA test was used to test whether the mean values of quantitative variables significantly differ among the clusters identified. All test results are not significant unless indicated otherwise. *, **, and *** denote significance at 0.1, 0.5 and 0.01.

Source: Output from R.

4.2. Clustering results

This study performs the bagged clustering algorithm on the survey items concerning the digital literacy capacity as well as technological adaptation and use of ethnic business owners. These are factors including digital confidence, information skills, social media, digital training,

Fintech skills, device use, online sourcing, digital marketing, online sales, sales tracking, and adoption willingness. Each item used a 5-point Likert scale (qualitative answer in which 1 means "Strongly Disagree" and 5 means "Strongly Agree"). These segmentation variables were used to calculate the dissimilarity matrix, for which the matrix of centers was hierarchically clustered using Ward's linkage method. The results are displayed in Figure 1.

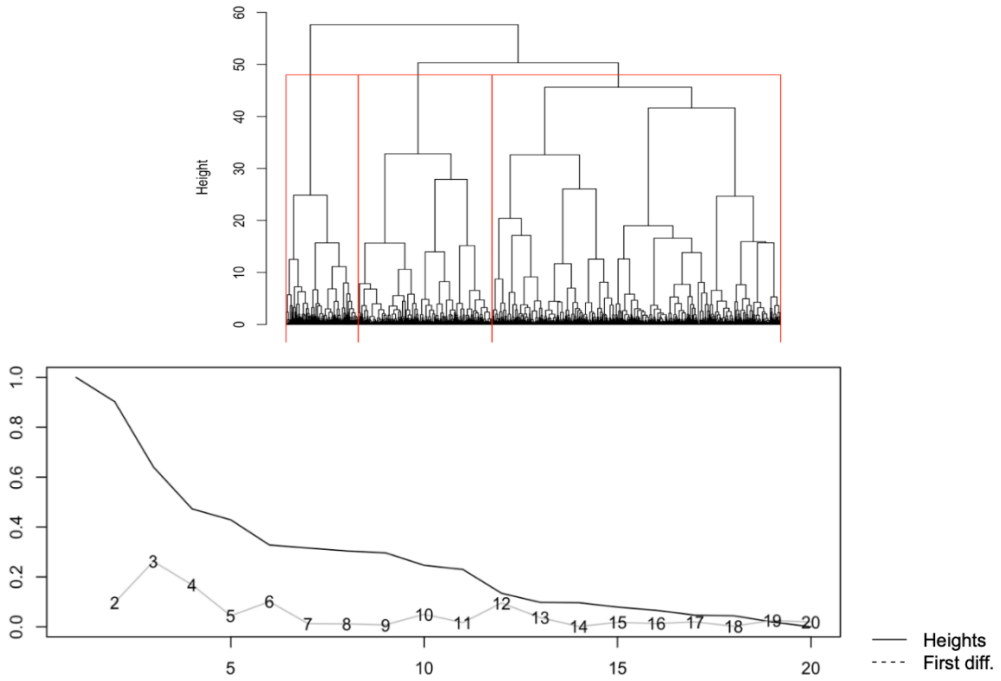

Figure 1: Dendrogram [top panel] and relative heights of aggregation (solid line) and first differences of relative heights (dashed line) [bottom panel]
Source: Output from R.

The top panel of Figure 1 displays the dendrogram derived from the bagged clustering procedure. The plot under the dendrogram shows the standardized heights at which each cluster is aggregated (solid line), and the first differences of these heights (dashed line). Local peaks in the dashed line, which correspond to the longest distances between two consecutive aggregations in the dendrogram, motivate the selection of the number of clusters. The peaks in the bottom panel of Figure 1 suggest that the ethnic business owners can be divided into three groups. In order to better understand and describe the digital readiness and behavior of ethnic entrepreneurs, the clusters are profiled in Figure 2 based on the considered factors.

As can be seen from Figure 2, each cluster reflects unique patterns in the way entrepreneurs engage with digital tools and platforms in their business operations. First, entrepreneurs in Cluster 1 (134 entrepreneurs, 51.5% of sample) exhibit high levels of digital literacy, particularly in areas such as social media usage, participation in digital training, and proficiency in using fintech applications. They also show a relatively strong sense of willingness to adopt new technologies. However, despite their capabilities, their actual usage of digital tools in business operations—including device use, digital marketing, online sales, and sales tracking—remains only moderate or below average. This cluster is therefore labelled "*Digitally skilled but cautious users*". The characteristics of this cluster suggests a disconnect between digital readiness and digital application, potentially stemming from contextual constraints such as infrastructure, cost concerns, or perceived risks. These entrepreneurs are digitally prepared but may lack confidence, resources, or incentives to fully integrate digital tools into their business models. Targeted interventions that showcase tangible business benefits of technology and offer localized support could therefore help activate this group's latent potential.

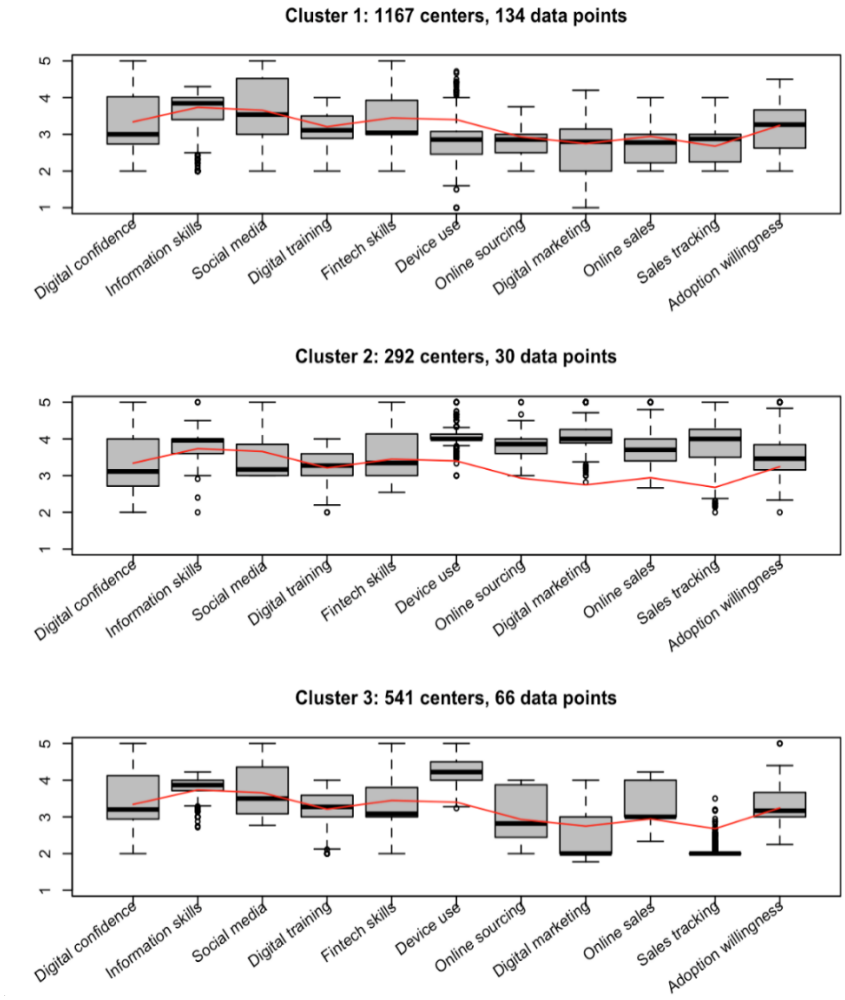

Figure 2: Boxplot for the three clusters using the factors concerning digital literacy capacity and technological usage in business
Source: Output from R.

Cluster 2 (30 entrepreneurs, 11.5%) represents entrepreneurs who are minimally engaged with digital technology. They report the lowest levels of digital confidence, training access, and use of digital tools across all business functions. Particularly low scores were observed in device use, sales tracking, and online transactions, indicating a traditional mode of operation with limited exposure to or interest in digital transformation. This cluster is thus labelled "*Low digital engagement*". These entrepreneurs may face multiple entry-level barriers, including limited education, poor digital infrastructure, and a lack of awareness about the benefits of technology adoption. As such, this cluster can be characterized as digitally excluded and may require foundational digital literacy programs, basic ICT infrastructure access, and community-led digital inclusion efforts.

Cluster 3 (66 entrepreneurs, 25.4%) includes those who demonstrate high levels of technological application, particularly in device use, online sourcing, digital marketing, and online sales. Interestingly, their scores on digital literacy indicators such as training received or social media proficiency are moderate rather than high, suggesting a more pragmatic, hands-on approach to technology. These individuals may have learned through peer experience, experimentation, or necessity, rather than formal training. Despite their technological engagement, this group reports relatively lower scores in sales tracking and adoption willingness, implying that while they are active users of digital tools, they may be selective or cautious about integrating more complex technologies. This segment reflects a practical, business-oriented user group that would benefit from scalable tech solutions and peer-led

capacity-building programs. This cluster is named "*Tech-driven practitioners*".

Further, the last four columns of Table 1 report the main characteristics of the clusters obtained, i.e. the mean values of the continuous variables and the percentages of the categorical variables. Each variable is verified if there are significant differences between clusters with the Chi-square test for qualitative variables, and with the ANOVA test for the continuous variables. In the last column, the p-values of the tests are reported.

The demographic profiles of the three identified clusters show notable differences in education, business type, and revenue, while variables such as gender, age, and province show limited variation.

Cluster 1 (Digitally Skilled but Cautious) includes a balanced gender mix and diverse ethnic representation. This group has the highest proportion of university-educated respondents (19.4%) and a strong presence of vocational/college-trained entrepreneurs, aligning with their higher digital literacy. Their businesses are spread across retail, food & beverages, and cooperatives, with moderate revenues and employee sizes, suggesting stable yet cautious tech engagement.

Cluster 2 (Low Digital Engagement) is more likely to include primary-educated entrepreneurs (36.67%), many from Tay and H'Mong groups, and businesses focused on agriculture and manufacturing (36.67%). Surprisingly, this group has the highest percentage of respondents earning over 20 million VND/month (60%), despite minimal digital usage. This indicates traditional, possibly large-scale businesses with limited digital integration.

Cluster 3 (Tech-Driven Practitioners) has the highest share of entrepreneurs with no formal education (24.24%), yet demonstrates strong use of digital tools in business operations. These entrepreneurs are concentrated in handicrafts (48.48%) and household businesses (40.91%), reflecting grassroots innovation and peer-driven digital adaptation. Revenue levels vary, with a notable portion still earning below 5 million VND/month, suggesting early-stage or lower-margin enterprises.

The membership of each cluster is further analyzed in deep using the multinomial logit model in order to identify which socio-demographic characteristics significantly influence the likelihood to be part of one of the groups with respect to a baseline group, i.e. Cluster 2. Table 2 presents the multinomial logit coefficients estimating the likelihood of ethnic entrepreneurs belonging to Cluster 1 (Digitally Skilled but Cautious) and Cluster 3 (Tech-Driven Practitioners), with Cluster 2 (Low Digital Engagement) serving as the reference group.

The results indicate that Dao ethnic group entrepreneurs are significantly more likely to be in both Cluster 1 ($\beta = 1.605$, $p < 0.1$) and Cluster 3 ($\beta = 1.865$, $p < 0.05$) compared to Cluster 2. This suggests that Dao entrepreneurs are more engaged in digital transformation behaviors, whether in terms of skill-building (Cluster 1) or active technology use (Cluster 3), relative to other ethnic groups.

Table 2: Multinomial logit coefficients of the clusters

Variables	**CL1**	**CL3**
Gender of ethnic business owners		
- Female	-0.254 (0.424)	-0.487 (0.467)
Ethnic group of ethnic business owners		
- Dao	1.605* (0.817)	1.865** (0.853)
- Tay	-0.048 (0.504)	0.152 (0.569)
- Thai	0.431 (0.577)	0.364 (0.653)
Education background of ethnic business owners		
- Primary school	-1.225* (0.721)	-1.39* (0.765)
- Secondary school	-0.297 (0.894)	-0.911 (0.975)
- High school	-0.069 (0.981)	-0.083 (1.01)
- Vocational/College	-0.648 (0.806)	-0.739 (0.843)
- University or above	-0.622 (0.774)	-1.704* (0.873)
Age of ethnic business owners	-0.017 (0.025)	0.014 (0.028)
Years of operation	0.024 (0.051)	0.049 (0.056)

Note: Base = CL2. Robust standard errors are in brackets. *, **, *** denote significance at 0.1, 0.5 and 0.01.
Source: Output from R.

In terms of education, having only a primary school education significantly decreases the likelihood of being in Cluster 1 ($\beta = -1.225$, $p < 0.1$) and Cluster 3 ($\beta = -1.390$, $p < 0.1$), indicating that limited formal education may be a barrier to digital adoption or even to

developing basic digital skills. Additionally, university-educated individuals are significantly less likely to be in Cluster 3 ($\beta = -1.704$, $p < 0.1$), possibly reflecting a counterintuitive trend where highly educated entrepreneurs may opt for more formal, less grassroots-driven models of business operation or prefer to work in sectors requiring less digital experimentation.

5. Discussion of research results and policy recommendations

This study investigates the degree of digital literacy capacity and technological adaptation among ethnic minority entrepreneurs in Northern Vietnam using a cluster analysis approach. Cluster results reveal three distinct groups: Digitally Skilled but Cautious Users (Cluster 1), Low Digital Engagement (Cluster 2), and Tech-Driven Practitioners (Cluster 3).

Cluster 1 consists of entrepreneurs with high digital literacy—especially in social media and fintech—but only moderate application of technology in business operations such as digital marketing, sales tracking, and e-commerce. This finding aligns with previous research indicating that digital readiness does not automatically translate into active usage without clear value perception or contextual support (Tran & Vu, 2018; Shahadat et al., 2023).

Cluster 2 includes the least digitally engaged entrepreneurs, with low levels of education, minimal training, and limited access to digital tools. Interestingly, this group includes the highest proportion of respondents earning over 20 million VND/month, mostly from traditional sectors like agriculture and manufacturing. This confirms earlier observations that higher income in rural contexts may stem from sectoral strengths rather than digital engagement (Vo Thai et al., 2023).

Cluster 3 demonstrates high levels of technological use despite average digital literacy. These entrepreneurs actively engage in online sourcing, marketing, and e-commerce. Their behavior suggests a learn-by-doing approach to technology adoption, consistent with grassroots innovation models (Neumeyer et al., 2020). Many operate household-based handicraft businesses and are likely to benefit from peer learning and practical mentorship rather than formal training.

From the findings of our research emerge several policy implications.

First, policy design should recognize the heterogeneity among ethnic entrepreneurs. Government programs must adopt a segmented approach that tailors support mechanisms to distinct behavioral profiles. For example, Cluster 1 (Digitally Skilled but Cautious) would benefit from programs that demonstrate the practical business value of technology—such as e-commerce pilots, digital storytelling of success cases, and personalized coaching—to convert digital potential into active usage.

Second, for Cluster 2 (Low Digital Engagement)—those with limited education and minimal tech use—foundational digital literacy training is essential. These programs should focus on basic ICT skills, mobile banking, and digital identity registration, delivered in local languages and through trusted community-based intermediaries such as women's unions, youth associations, and village leaders. Partnering with NGOs and vocational schools can expand reach and build trust.

Third, for Cluster 3 (Tech-Driven Practitioners)—who actively apply technology despite lower formal education—policy efforts should shift toward scale-up support. This includes access to affordable digital tools, marketing training, peer mentoring networks, and micro-grants to invest in platforms or logistics. These entrepreneurs can serve as digital champions and peer educators within their communities.

Finally, recognizing the high representation of women and youth in entrepreneurial activities, gender- and youth-sensitive programs—such as digital apprenticeships, seed funding, and mentorship networks—can create inclusive pathways for long-term empowerment and innovation in ethnic communities.

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