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Regional Heterogeneity in Livelihood Strategies and Its Implications for Household Welfare: A Panel Data Analysis of Rural Vietnam

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Abstract

This study undertakes a meticulous examination of the Livelihood Strategy Diversity Index (LSDI) and its nuanced implications on household welfare in heterogeneous regions of rural Vietnam. Employing a unique panel dataset derived from the Vietnam Access to Resources Household Survey (VARHS) spanning from 2010 to 2018, the study employs both Ordinary Least Squares (OLS) and instrumental variable (IV) methods to investigate the intricate relationship between LSDI and household welfare, with a specific focus on income and dietary diversity. The empirical findings reveal compelling evidence of pronounced regional heterogeneity, highlighting the distinctive impacts of the LSDI on household welfare across diverse geographical areas. This study underscores the importance of region-specific strategies, advocating for a tailored and diversified approach to agricultural activities aligned with the unique context of each region. Furthermore, the findings emphasize the pivotal role of consolidating small plots as a strategic measure to alleviate agricultural land fragmentation, offering valuable insights into region-specific interventions for the enhancement of household well-being, encompassing both income and nutritional diversity.

Keywords

Livelihood diversity, welfare impact, regional disparities, Vietnam.

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Introduction

In Vietnam, economic development relies heavily on the agricultural sector, which provides substantial income for a significant proportion of rural households (Phan et al., 2022; Ngo et al., 2022). Following trade liberalization and agricultural reforms in the 1980s, Vietnam transformed into a net exporter of crucial agricultural products, such as rice, coffee, pepper, and cashew nuts. As of 2021, the agriculture, forestry, and fishing sectors constitute 12.36 percent of the Gross Domestic Product (GDP) (GSO, 2022). The agricultural sector has made commendable progress in both scale and production, restructuring the industry towards achieving national food security and increasing exports. However, the vulnerability to market fluctuations, natural disasters, and epidemics poses a threat to the sustainable development of the sector, impacting the welfare of farmers.

The role of smallholders in Vietnam's agricultural system is pivotal, yet their susceptibility to risks and uncertainties creates instability in farmers' welfare. To address this, effective livelihood strategies have become imperative for enhancing household welfare and promoting sustainable agricultural development in rural areas. A household livelihood strategy is defined as an organized set of economic actions undertaken by that household and its members, considering the social context and available resources (Lingam, 2016). In rural areas, farmers have various options for their agricultural production activities to increase their income based on their resources. Diversifying operations is a strategy employed by farmers to manage risk, cope with economic and climate

shocks, and escape stagnation in agriculture (Zhao and Barry, 2014). Both on-farm production systems and off-farm livelihood sources contribute to mitigating climate-induced production and market uncertainties, thereby enhancing farm households' resilience (Asfaw et al., 2019). The complex interaction between push and pull pressures affecting family capital, labor, and land allocation has major consequences for understanding diversification's welfare effects (Atamanov and Van den Berg, 2012; Habib et al., 2022; Musumba et al., 2022; Rahman and Mishra, 2020).

Livelihood diversification strategies are heavily influenced by off-farm and on-farm revenue, agricultural markets, infrastructure, and information (Sisay, 2024). A full examination is needed to understand how these components interact across national settings, strategic approaches, and household conditions. Acknowledging country variety is crucial because economic structures, policy contexts, and institutional frameworks shape household opportunities and limits (Mehraban and Ickowitz, 2021). In regions with strong agricultural markets, crop demand may affect diversification decisions more. Push factors like restricted traditional farming alternatives may prevail in underdeveloped markets. Household strategies play a key part in diversification, offering vertical integration or horizontal expansion into unrelated industries and these decisions affect the environment, society, and economy (Zhao and Barry, 2014). Households can better respond to market signals and grab opportunities in places with advanced infrastructure and knowledge, while diversification may be harder in areas with inadequate infrastructure and knowledge. Diversification has different welfare consequences on households because education, risk tolerance, and household resources are important socioeconomic determinants (Asfaw et al., 2019). Understanding the complex dynamics of push and pull variables in families' capital, labor, and land allocation is essential to understanding alternative diversification approaches' welfare effects. Also, recognizing differences across regions, techniques, and households helps create customized policies that maximize diversification advantages while avoiding risks and injustices.

While studies in Vietnam have documented the widespread adoption of diversified livelihood strategies by farmers, primarily focusing on income diversification and employing the Simpson's index to assess income source diversity (Minot et al., 2006; Giller, 2020; Tran and Vu, 2020), a critical knowledge gap remains regarding the broader impacts of this diversification on household well-being. Specifically, the influence on dietary diversity across diverse regional contexts in rural Vietnam remains largely unexplored. Previous studies have often relied heavily on Simpson's index to measure income diversification, neglecting the inherent complexities of livelihood strategies in rural Vietnam. This index fails to capture the full spectrum of agricultural activities, which can significantly impact dietary diversity through self-produced food consumption (Leroy et al., 2015). Additionally, the existing literature lacks a regionalized perspective, overlooking the diverse ecological, cultural, and socio-economic contexts that can influence the relationship between diversification and dietary diversity (Abeje et al., 2019).

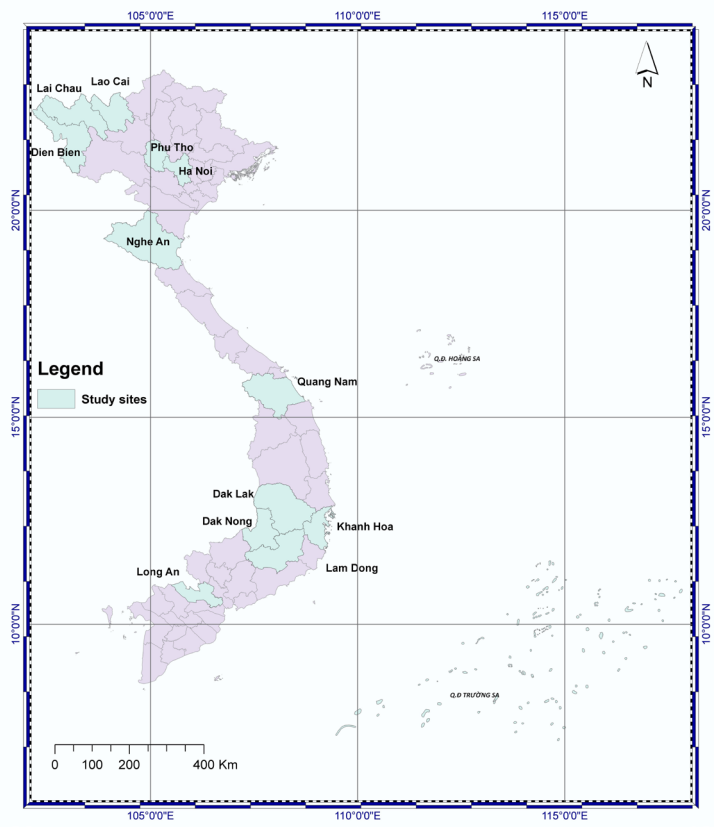
This study aims to address this gap by delving into the intricate relationship between livelihood strategy diversification and household income and dietary diversity, employing a nuanced approach that accounts for regional heterogeneity. We used the Livelihood Strategy Diversity Index (LSDI), derived from a count index of household activities in agricultural fields. Using a unique panel dataset spanning from 2010 to 2018 and covering households across Vietnam, our study explores the influence of LSDI on household welfare, considering both income and dietary diversity. Filling a significant gap in the literature, this study delves into the multidimensional impact of livelihood strategy diversity on household welfare, emphasizing the interconnected dimensions of income and food diversification. Notably, our findings reveal regional heterogeneity in the effects of LSDI on household welfare across diverse geographical areas. This highlights the need for region-specific strategies, emphasizing the importance of tailored and diversified agricultural approaches aligned with the unique contexts of each region. As Vietnam experiences economic growth similar to that seen in other developing nations across Asia and Africa, the insights gleaned from this study can serve as vital guidance for addressing issues such as poverty reduction, income generation, and food security. These findings hold significance beyond Vietnam, as they recognize the shared challenges and opportunities faced by developing countries worldwide. The lessons drawn from the livelihood strategies employed by small-scale farmers in Vietnam can serve as a valuable reference for their counterparts in different regions around the world.

Materials and methods

Data

Five-round surveys were conducted as part of the Vietnam Access to Resource Households (VARHS) project from 2010 to 2018 (2010, 2012, 2014, 2016, and 2018). The surveys covered 12 provinces across the country (Figure 1), including the northern region (Ha Tay, Lao Cai, Phu Tho, Lai Chau, and Dien Bien), central region (Nghe An, Quang Nam, and Khanh Hoa), highland region (Dak Lak, Dak Nong, and Lam Dong) and southern region (Long An). VARHS collected data biannually from rural households in these provinces, resulting in a dataset comprising 1,345 households each year and totaling 6,725 observations after merging the data.

This study delves into the relationship between livelihood strategy diversity and household welfare. Drawing from a comprehensive review of prior research (Musumba et al., 2022; Nguyen et al., 2021; Asfaw et al., 2019; Lafevor and Pitts, 2022; Pratiwi et al., 2018; Chilimo and Ngulube, 2011; Zhao and Barry, 2014; Mahama and Nkegbe, 2021; Ciaian et al., 2018), we have carefully selected a set of independent variables to construct our estimation model. These variables encompass a range of crucial elements, including the education level of the household head, family size (Habib et al., 2022; Li et al., 2020; Mahama and Nkegbe, 2021; Nguyen and Tran, 2018; Shekuru et al., 2022), access to rural credit, investment in agricultural activities, time allocated to agricultural extension services, presence of an irrigation system, willingness to invest in crop insurance, and access to the Internet (Asfaw et al., 2019; Musumba et al., 2022; Nguyen and Tran, 2018; Wu et al., 2017). Additionally, we consider critical household head characteristics, including age, gender, and education (Beyene et al., 2023; Habib et al., 2022; Sisay, 2024). To provide a holistic perspective, we also integrate land-related factors such as the number of plots, total agricultural areas, and the land fragmentation index (Asfaw et al., 2019; Nguyen and Tran, 2018; Sisay, 2024). A comprehensive overview of the descriptive statistics for these variables is available in Table 1.



Source: Authors

Figure 1: Study area indicating the data collection sites in Vietnam.

Variable	2010		2012		2014		2016		2018	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Household income[1]	10.93	0.76	10.95	0.76	11.17	0.79	11.29	0.81	11.47	0.89
Household food diversity index	6.26	1.82	6.26	1.64	6.03	1.74	6.19	1.79	6.33	1.68
Livelihood strategy diversity index	1.18	0.61	1.07	0.61	1.06	0.58	1.01	0.64	0.98	0.59
Crop Index	0.13	0.12	0.10	0.10	0.11	0.11	0.07	0.08	0.13	0.14
Livestock	0.81	0.39	0.76	0.43	0.75	0.43	0.71	0.45	0.68	0.47
Non-farm index	0.24	0.43	0.21	0.41	0.20	0.40	0.23	0.42	0.17	0.38
Investing to agricultural activities (1 = yes)	0.60	0.49	0.36	0.48	0.18	0.38	0.21	0.41	0.28	0.45
Visiting agricultural extension services (times)	1.24	1.77	1.32	2.08	1.68	2.60	2.44	1.79	2.10	2.52
Irrigation system (% of plots irrigated)	0.89	0.31	0.93	0.26	0.94	0.24	0.95	0.21	0.97	0.17
Accessing to rural credit (1 = yes)	0.55	0.50	0.44	0.50	0.39	0.49	0.33	0.47	0.27	0.44
Willingness to pay for crop insurance (Million VND)	0.15	0.14	0.70	13.71	0.24	0.43	0.07	0.42	0.16	0.43
Accessing to the internet (1 = yes)	0.21	0.41	0.44	0.50	0.44	0.50	0.45	0.50	0.58	0.49
Number of the family member (persons)	4.63	1.67	4.57	1.69	4.49	1.71	4.37	1.74	4.28	1.82
Gender of household head (1 = Male)	0.84	0.37	0.83	0.37	0.82	0.39	0.81	0.39	0.79	0.41
Age of household head (years)	50.80	11.84	52.31	11.62	53.92	11.59	55.49	11.60	57.02	11.42
Education of household head (years)	7.88	3.20	8.04	3.15	8.61	3.00	8.77	2.85	8.04	3.23
Number of land plots	5.30	2.98	5.10	2.79	4.54	2.67	4.20	2.53	3.88	2.32
Total area for agricultural production1 (m^2)	8.34	1.14	8.34	1.15	8.27	1.18	8.25	1.16	8.17	1.27
Land fragmentation index	0.60	0.25	0.60	0.25	0.56	0.26	0.54	0.26	0.50	0.27

Note: [1] in log
Source: Calculated by authors from VARHS

Table 1: Summary statistics of variables in the study.

Methods

Definitions of livelihood strategy diversity index and household dietary diversity index

Livelihood diversification, the reliance on various income sources for household sustenance, has emerged as a crucial indicator of community resilience and vulnerability in an increasingly dynamic world. In this context, the LSDI serves as a valuable tool for quantifying the extent of this diversification, providing insights into the overall well-being and adaptability of households and communities. The indicator is essential for quantifying the extent of livelihood diversification among households and communities. Livelihood diversification refers to the range of activities and sources of income that individuals or communities engage in. A greater diversity index indicates a broader range of livelihood strategies. Furthermore, the diversity index provides vital insights into the overall welfare of households and communities. The presence of diverse livelihood methods indicates the ability to withstand economic shocks, natural disasters, and other difficulties. The presence of many income sources inside families indicates that they have diverse sources of income, which in turn decreases their vulnerability to external risks. Furthermore, the index functions as a good instrument for evaluating the flexibility of households and communities. In dynamic socio-economic and environmental contexts, the ability to adjust to changes is crucial. A higher diversity index signifies that households possess greater adaptability, as they participate in a wider range of income-generating endeavors. However, while its strengths are undeniable, a critical examination of the index reveals limitations that require consideration for its effective application. The focus on quantifying diversification may overlook the quality of livelihoods and the well-being of individuals within the households. Furthermore, the LSDI's reliance on income data alone may not account for non-monetary aspects of livelihoods, such as access to education, healthcare, or social capital. A comprehensive understanding of community resilience requires a more holistic approach that considers both economic and non-economic dimensions.

Variables	Description
Household dietary diversity index (HDDS)	Sum up the scores for all food groups to obtain the total HDDS score. For each food group, determine whether the household consumed any food items belonging to that group during the reference period (1 = yes, 0 = no).
Livelihood strategy diversity index (LSDI)	An index to capture diversity as the number of livelihood activities conducted (from 1 to 3). The livelihood is the sum of the crop, non-farm, and livestock indexes.
Crop activities	If the household has any activity related to crop farming (rice, maize,…) during the study period (1 = yes, 0 = no).
Non-farm activities	If the household has any activity related to non-farm activities during the study period (1 = yes, 0 = no).
Livestock activities	If household have relate to livestock activities during the study period (1 = yes, 0 = no).

Source: Adopted from Cholo et al.(2019); Musumba et al., (2022)

Table 2: Definitions of key indexes used in the study.

The LSDI's key strength lies in its simplicity, utilizing accessible income data and employing measures like Simpson's or Herfindahl Index for quantifying diversification. This enables cross-context comparisons (Adato and Meinzen-Dick, 2002; Ellis, 2000), aiding in monitoring development goals for poverty reduction and food security (Niehof, 2004). In our study, LSDI, represented by the count of income sources from crop, non-farm, and livestock activities (Table 2), indicates livelihood diversification. A higher LSDI signifies greater resilience to shocks, as diversified income sources buffer against declines in specific areas. By identifying households with limited income sources, interventions can be targeted to promote diversification and enhance resilience (Matsuura et al., 2023). To assess LSDI's impact on household welfare, the HDDS metric was used. HDDS measures the diversity of consumed food groups, providing a comprehensive evaluation of the household diet's breadth and nutritional adequacy (Cholo et al., 2019), surpassing a focus solely on calorie intake (Smith and Subandoro, 2007).

The effect of the livelihood strategy diversity index on household welfare

In this study, we delve into the intricate relationship between livelihood strategy diversity and household welfare using full sample, as captured by the following equation:

$$Y_{it} = \alpha LSDI_{it} + \beta X_{it} + \delta \bar{X}_{it} + \chi HID_i + \lambda location_i + \varepsilon_{it} \quad (1)$$

Here, Y_{it} represents household welfare, encapsulating dimensions such as income and the HDDS of household i in year t. X_{it} is a set of control variables. HID_i is the household fixed effect. $\bar{X}_{it}$ are within-household averages for the time-varying independent variables capturing unobserved heterogeneity. Notably, LSDI is employed as an explanatory variable in this study. The IVs methods include two stages: first stage show the linking between LSDI with explanation variables and instrumental variable (result show in appendix 1) and the second stage show the causal effect of LSDI on household welfare (Table 5 and 6) based on Equation (1).

Regional heterogeneity in the effect of the livelihood strategy diversity index on household welfare

To capture regional heterogeneity using Equation (2), we separate the estimations for the effect of LSDI on household welfares based on different regions (r), including Northern, Central, Highland, and Southern regions (Table 7 and 8). The results from Table 7 and 8 provide how difference about the casual effect of LSDI on household welfares in various regions.

$$Yitr = \alpha LSDI_{itr} + \beta X_{itr} + \delta \bar{X}_{itr} + \chi HID_i + \varepsilon_{itr} \quad (2)$$

Here, Y_{itr} represents household welfare, encapsulating dimensions such as income and the HDDS of household i in year t at region r. X_{itr} is a set of control variables. HID_i is the household fixed effect. $\bar{X}_{itr}$ are within -household averages for the time-varying independent variables capturing unobserved heterogeneity. Again, LSDI is employed as an explanatory variable. After consider the Hausman test and reduce the potential biases, the study only provides the casual relationship between LSDI and household welfare based on the Instrumental variable and fixed effect. The estimation also includes two stage as previous presentation: first stage shows the linking between LSDI with explanation variables and instrumental variable by various region (result show in appendix 2) and the second stage show the causal effect of LSDI on household welfare by various region (Table 7 and 8) based on Equation (2).

Dealing with potential endogeneity and unobserved heterogeneity

The simultaneous determination of LSDI and household welfare introduces potential biases, leading to inconsistent estimates when using the Ordinary Least Squares (OLS) method based on Equation (1) and (2). To address this, instrumental

variables (IVs) are incorporated to ensure the creation of consistent estimators. The LSDI itself is characterized by three dummy variables, each representing distinct household production types: crops, livestock, and non-farms. The selection of these categories is informed by observed variations in LSDIs across different groups, as detailed in Table 4. The close association between these dummy variables and LSDI aligns with the criterion of instrumental relevance. To validate the strength of the instruments, the study employs the F-statistic form, specifically the Cragg-Donald Wald F statistic. This statistical measure, as advocated by Stock and Yogo (2005), serves to assess the weakness of instrumental variables. Notably, the F-statistic for the Cragg-Donald Wald test records a substantial value of 88,923.6 (Table 5 and 6), significantly surpassing the critical threshold of 22.30. This outcome attests that the instruments are robust, meeting the requisite criteria for relevance in the estimation process.

Unobserved heterogeneity is the term used describe these unobservable variables, which include farmers' management skills and their individualized perspectives on the adoption of conservation measures. These are hard to quantify or extract, but they have an impact on a farmer's decision-making process to choose livelihood activities. We can, however, appropriately account for time-invariant unobserved variability among respondent farmers thanks to the panel character of our data. By permitting correlated random effects (CRE), Mundlak (1978) presents a strategy for controlling for unobserved heterogeneity. Wooldridge (2005) has further refined this technique. By including the vectors of within-household averages for the time-varying independent variables, $\bar{X}_{it}$, we used the CRE technique in Equation (1) for estimation in both the random effect (RE) and fixed effect (FE) settings for Table 5 and 6.

Results and discussion

Livelihood strategies of surveyed households

Table 3 provides an overview of the livelihood strategies adopted by households for income generation spanning the years 2010 to 2018. Notably, a trend toward production specialization emerges over this period. In terms of agricultural production, there is a general increase in the number of households specializing in crops. Specifically, the count rose from 192 households in 2010 to 322 in 2018. However, it is noteworthy that the proportion of households engaged in crop production constitutes only around 20% of the total dataset.

Similarly, households combining crop production with non-agricultural activities increased from 60 in 2010 to 112 in 2018, but this still represents less than 10% of the total. Examining households involved in both crop and livestock production, a significant proportion embraced this dual model. Nevertheless, there is a decline observed, from 62.01% in 2010 to 58.88% in 2018. Moreover, households participating in all three areas - crop production, animal husbandry, and non-profit agricultural activities - decreased from 19.26% in 2010 to 8.85% in 2018.

There is a noticeable increase in households exclusively involved in crop production, accompanied by a decrease in those engaged in multiple agricultural activities (refer to Table 4). This evolving landscape is reflected in the decreasing livelihood diversification index for rural Vietnamese households over the years. Notably, the Mekong and Red River areas exhibit the lowest and highest diversification indices, respectively. This trend toward reduced diversification is attributed to the growing inclination of households in rural Vietnam towards production specialization. The decision to diversify can pose challenges as it requires additional

Livelihood activities	2010		2012		2014		2016		2018	
	No.	%	No.	%	No.	%	No.	%	No.	%
Only crops	192	14.28	254	18.88	245	18.22	305	22.68	322	23.94
Crops and livestock	834	62.01	802	59.63	837	62.23	732	54.42	792	58.88
Crops and non-farm	60	4.46	75	5.58	90	6.69	88	6.54	112	8.33
Crops and livestock and non-farm	259	19.26	214	15.91	173	12.86	220	16.36	119	8.85
Total	**1,345**	**100**	**1,345**	**100**	**1,345**	**100**	**1,345**	**100**	**1,345**	**100**

Source: Calculated by authors from VARHS

Table 3: The number of households participating in the different livelihood activities.

financial, temporal, and labor resources. When these resources cannot be effectively managed, there may be negative implications for household well-being.

Livelihood strategy diversity index	2010	2012	2014	2016	2018
Northern area	1.30	1.20	1.19	1.16	1.06
Central area	1.19	1.05	1.08	1.02	1.02
Highland area	1.02	0.99	0.86	0.79	0.98
Southern area	0.86	0.57	0.71	0.64	0.62
Mean	**1.09**	**0.96**	**0.96**	**0.90**	**0.92**

Source: Calculated by authors from VARHS

Table 4: Livelihood diversification index by regions from 2010 to 2018.

The effect of livelihood strategy diversity index on household welfare

This study concentrates on evaluating the impact of LSDI on household welfare, encompassing factors like income and food diversity. Recognizing the limitations of OLS estimation in handling endogeneity concerns, the IV method is employed to uncover the intricate relationship between LSDI and household welfare components, such as income (refer to Table 5) and food diversity (refer to Table 6) (Tran and Vu, 2019). In Table 5, we present the results using both Random Effects (RE) and Fixed Effects (FE) for OLS and IV estimators. To guide our choice between RE and FE, we conduct a Hausman test, yielding a p-value below 1%. Consequently, we accept the fixed effect for further discussion.

Our findings reveal a consistently positive and statistically significant coefficient for the livelihood strategy diversity index across all estimators. Notably, the effective coefficient on household income in the (IV estimator is slightly lower than that in the OLS estimator by the fixed effects estimation, registering values of 0.048 and 0.035, respectively. While this study is not the initial exploration of household livelihood diversity's impact on income, it pioneers the development of a specific diversity index tailored to production activities in rural Vietnam. This unique index contributes to our understanding of how livelihood diversity influences household income, with results indicating that as the livelihood strategy diversity index increases, household income also rises - a trend mirrored in previous studies by Asfaw et al. (2019) and Mahama and Nkegbe (2021). In addition, some previous research also show the similar result that imply that there was a positive and statistically significant relationship between livelihood diversification and the outcome variables indicated, including welfares (Sisay, 2024; Sun et al., 2023). Furthermore, our investigation into investments in agricultural activities, particularly those related to irrigation, soil, and water conservation in household land plots, yields intriguing insights. Surprisingly, both estimators by fixed effects reveal negative coefficients at -0.053, suggesting that these investments do not positively impact household income. The financial resources required for these activities contribute to increased total agricultural production costs, resulting in a reduction in household income. Our study underscores the significant role of agricultural extension services, revealing a positive correlation between time invested in visiting these services and household income. With a statistically significant coefficient of 0.023 at a p-value of 1% for both model estimators by fixed effects, participating in agricultural extension services emerges as a pathway to improving household income by enhancing access to better-quality inputs and effective production processes. The finding is similar to the previous research (Pan et al., 2018) since the author indicated records of success for access to agricultural extension services.

Additionally, our investigation into the relationship between household income and irrigation systems indicates a positive correlation, with a statistically significant link at a p-value of 10%, aligning with findings by Tesfay (2021) and Adetoro et al. (2022). Surprisingly, our results suggest a decrease in household income associated with access to rural credit, with a coefficient of -0.087 and a p-value of 1%. This unexpected outcome could be attributed to the informal nature of rural credit, resulting in less effective utilization by households due to reduced regulations and supervision by credit providers. Moreover, our research highlights the positive and significant impact of Internet access on household income, supporting this correlation with a coefficient of positive significance at a p-value of 1%. Access to the Internet proves beneficial as households can leverage information related to input and output markets, along with technological advancements, thereby expanding their output markets for agricultural products.

Our study highlights key findings on family size, age of household heads, and land fragmentation's impact on household income. A positive and statistically significant coefficient of 0.109

Variables	CRE estimation			
	OLS estimator		IV estimator	
	RE	FE	RE	FE
Livelihood strategy diversity index	0.050***	0.048**	0.052***	0.035*
	(0.018)	(0.021)	(0.018)	(0.021)
Investing in agricultural activities	-0.053***	-0.054***	-0.053***	-0.053***
	(0.020)	(0.020)	(0.020)	(0.020)
Times for visiting agricultural extension services	0.024***	0.023***	0.024***	0.023***
	(0.005)	(0.005)	(0.005)	(0.005)
Irrigation system	0.078*	0.087**	0.078*	0.086**
	(0.040)	(0.040)	(0.040)	(0.040)
Accessing rural credit	-0.090***	-0.088***	-0.090***	-0.087***
	(0.022)	(0.022)	(0.022)	(0.022)
Willingness to pay for crop insurance	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Accessing to internet	0.165***	0.164***	0.165***	0.163***
	(0.020)	(0.021)	(0.020)	(0.021)
Number of family members	0.108***	0.109***	0.108***	0.109***
	(0.010)	(0.010)	(0.010)	(0.010)
Gender of household head	0.038	-0.084	0.039	-0.084
	(0.035)	(0.065)	(0.035)	(0.065)
Age of household head	0.020***	0.019***	0.020***	0.019***
	(0.002)	(0.002)	(0.002)	(0.002)
Level education of household head	0.001	0.000	0.001	0.000
	(0.004)	(0.004)	(0.004)	(0.004)
Number of land plots	-0.009	-0.031***	-0.009	-0.031***
	(0.006)	(0.009)	(0.006)	(0.009)
Total area for agricultural production1	0.022	0.104***	0.022	0.104***
	(0.016)	(0.020)	(0.016)	(0.020)
Land fragmentation index	-0.191***	-0.144*	-0.191***	-0.147*
	(0.073)	(0.081)	(0.073)	(0.081)
Northern area	-0.271***	-	-0.272***	-
	(0.057)	-	(0.057)	-
Central area	-0.457***	-	-0.458***	-
	(0.058)	-	(0.058)	-
Highland area	-0.105*	-	-0.105*	-
	(0.060)	-	(0.060)	-
Constant	9.398***	8.899***	9.404***	8.912***
	(0.206)	(0.219)	(0.206)	(0.219)
Hausman Test (p-value)	0.000		0.000	
Weak identification test (Cragg-Donald Wald F-statistics)			88923.6	
Stock-Yogo weak ID test critical value at 10%			22.30	
Endogeneity test of LSDI (p-value)			0.00	

Note: Standard errors in parentheses; Household income in the log; *** p<0.01, ** p<0.05, * p<0.1
Source: Calculated by authors from VARHS

Table 5: Effect of the diversification index on household income.

(at the 1% level) suggests that larger family sizes contribute to higher household incomes, aligning with the reliance on family labor in the agricultural sector. Additionally, the positive correlation between the age of household heads and income supports the idea that experience helps navigate

production and market risks, leading to higher incomes. Regarding land fragmentation, an IV estimation with fixed effects shows a significant coefficient of -0.147 (at a 10% significance level), indicating that increased land fragmentation is associated with a decrease in household income, consistent with previous research by Tran and Vu (2019).

In Table 6, the findings are presented using both Random Effect (RE) and Fixed Effect (FE) models for OLS and IV estimators. The Hausman test, revealing a p-value below 1%, prompts the acceptance of the fixed effect for further discussion. Across all models, the coefficient associating LSDI with the HDDS index is consistently positive and statistically significant at a 1% p-value. This indicates that higher livelihood diversification is linked to an elevated HDDS index, reflecting improved food security. Notably, IV estimator coefficients are slightly lower than OLS estimator coefficients by 0.139 and 0.132, respectively, aligning with findings by Kassegn and Endris (2021), Endiris et al., (2021) and Abera et al. (2021). These studies showed that households with individuals engaged in activities outside of farming had a greater likelihood of being food-secure compared to those without such individuals. Additionally, the results show a positive correlation between family size and HDDS, with statistical significance at a 1% p-value in the IV estimator with fixed effects. The increase in family size corresponds to an increase in HDDS, suggesting a direct connection between household size and food consumption—a pattern consistent with studies by Cordero-Ahiman et al. (2021), Mehraban and Ickowitz (2021), Abera et al. (2021), and Christian et al. (2019).

The age of the household head is positively correlated with food diversity (coefficient = 0.014, p-value < 0.01), reflecting greater agricultural experience among older household heads, leading to increased food sources, consistent with Sambo et al. (2022). In terms of land characteristics, factors like the number of plots, total area, and land fragmentation index significantly impact Household Dietary Diversity Score (HDDS) across different estimators. Specifically, in IV estimation with fixed effects, only the total area for agricultural production is significant at a 10% level (coefficient = 0.94). This suggests that expanding the agricultural production area positively influences household food security, aligning with Phan et al. (2022).

Variables	**CRE estimation**			
	OLS estimator		IV estimator	
	RE	FE	RE	FE
Livelihood strategy diversity index	0.132***	0.139***	0.139***	0.137***
	(0.041)	(0.052)	(0.042)	(0.052)
Investing in agricultural activities	0.052	0.069	0.052	0.069
	(0.050)	(0.051)	(0.050)	(0.051)
Times for visiting agricultural extension services	-0.003	-0.004	-0.003	-0.004
	(0.012)	(0.011)	(0.012)	(0.011)
Irrigation system	0.098	0.116	0.099	0.116
	(0.100)	(0.102)	(0.100)	(0.102)
Accessing rural credit	0.014	0.019	0.014	0.019
	(0.055)	(0.056)	(0.055)	(0.056)
Willingness to pay for crop insurance	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Accessing to internet	0.080	0.080	0.080	0.079
	(0.051)	(0.052)	(0.051)	(0.052)
Number of family members	0.120***	0.125***	0.120***	0.126***
	(0.024)	(0.025)	(0.024)	(0.025)
Gender of household head	-0.034	0.127	-0.034	0.126
	(0.073)	(0.164)	(0.073)	(0.164)

Note: Standard errors in parentheses; Household income in the log; *** p<0.01, ** p<0.05, * p<0.1
Source: Calculated by authors from VARHS

Table 6: Effect of the Livelihood strategy diversity index on household dietary diversity. (To be continued).

Variables	CRE estimation			
	OLS estimator		IV estimator	
	RE	FE	RE	FE
Age of household head	0.017***	0.014**	0.017***	0.014**
	(0.006)	(0.006)	(0.006)	(0.006)
Level education of household head	-0.012	-0.018	-0.012	-0.018
	(0.011)	(0.011)	(0.011)	(0.011)
Number of land plots	0.072***	0.003	0.072***	0.003
	(0.013)	(0.021)	(0.013)	(0.021)
Total area for agricultural production[1]	-0.202***	0.094*	-0.202***	0.094*
	(0.036)	(0.051)	(0.036)	(0.051)
Land fragmentation index	-0.293*	-0.087	-0.292*	-0.087
	(0.176)	(0.205)	(0.176)	(0.205)
Northern area	-1.558***	-	-1.561***	-
	(0.114)	-	(0.114)	-
Central area	-1.412***	-	-1.415***	-
	(0.116)	-	(0.116)	-
Highland area	-0.921***	-	-0.921***	-
	(0.119)	-	(0.119)	-
Constant	6.183***	0.139***	6.186***	3.917***
	(0.434)	(0.052)	(0.433)	(0.551)
Hausman Test (p-value)	0.000		0.000	
Weak identification test (Cragg-Donald Wald F-statistics)			88923.6	
Stock-Yogo weak ID test critical value at 10%			22.30	
Endogeneity test of LSDI (p-value)			0.00	

Note: Standard errors in parentheses; Household income in the log; *** p<0.01, ** p<0.05, * p<0.1
Source: Calculated by authors from VARHS

Table 6: Effect of the Livelihood strategy diversity index on household dietary diversity. (Continuation).

Regional heterogeneity in the effect of livelihood strategy diversity index on household welfare

This study explores the regional variations in the impact of LSDI on household well-being in rural Vietnam (Table 7). Results reveal significant positive coefficients for LSDI in the Mekong River delta (Southern area) at a 5% p-value. Particularly noteworthy is the Northern region, showing the highest impact on household income with a substantial coefficient of 0.146. Additionally, the study identifies the statistical significance of visiting agricultural extension services in the Northern region and Mekong River areas, with coefficients of 0.036 and 0.032, respectively.

The study reveals significant factors influencing household income across different provinces. Agricultural production investment significantly impacts income in Coastal, Highland, and Southern provinces, with the Southern area experiencing the most substantial negative influence (-0.231) and the Highland provinces having the lowest impact (-0.094). Rural credit access negatively affects income in the Mekong Delta (-0.188) and to a lesser extent in the Northern area (-0.080) and coastal provinces (-0.130). The irrigation system shows a significant effect only in the highland area (0.162). Internet access has a noteworthy impact on household income, particularly in coastal provinces, where the coefficient is highest at 0.222. Both the number of family members and the age of the household head have significant impacts on income across all study areas, with the highest age coefficient (0.027) recorded in the highland region. Regarding land characteristics, an increase in the number of plots decreases household income in the Northern and coastal areas, while expanding the total agricultural production area proves beneficial, suggesting that reducing land fragmentation can uplift household incomes (Phan et al., 2022; Tran and Vu, 2019).

Variables	IV estimator by CRE with fixed effect			
	Northern area	Central area	Highland area	Southern area
Livelihood strategy diversity index	0.045	-0.008	-0.019	0.146**
	(0.031)	(0.043)	(0.049)	(0.058)
Investing in agricultural activities	0.025	-0.113***	-0.094**	-0.231***
	(0.030)	(0.038)	(0.044)	(0.073)
Times for visiting agricultural extension services	0.036***	0.010	0.011	0.032***
	(0.008)	(0.007)	(0.013)	(0.010)
Irrigation system	0.050	-0.009	0.162***	-0.033
	(0.077)	(0.083)	(0.061)	(0.142)
Accessing rural credit	-0.080**	-0.130***	-0.019	-0.188***
	(0.032)	(0.043)	(0.052)	(0.072)
Willingness to pay for crop insurance	-0.000	-0.000	-0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
Accessing to internet	0.168***	0.222***	0.155***	0.010
	(0.031)	(0.039)	(0.048)	(0.067)
Number of family members	0.106***	0.139***	0.066***	0.158***
	(0.014)	(0.021)	(0.023)	(0.041)
Gender of household head	-0.153	0.156	-0.011	-0.294
	(0.093)	(0.120)	(0.167)	(0.234)
Age of household head	0.015***	0.019***	0.027***	0.019***
	(0.003)	(0.005)	(0.006)	(0.007)
Level education of household head	-0.007	0.018*	-0.005	0.008
	(0.006)	(0.010)	(0.010)	(0.014)
Number of land plots	-0.038***	-0.049***	0.120***	-0.049
	(0.011)	(0.017)	(0.034)	(0.059)
Total area for agricultural production	0.107***	0.181***	-0.070	0.013
	(0.033)	(0.033)	(0.055)	(0.057)
Land fragmentation index	-0.182	0.043	-0.431*	-0.110
	(0.118)	(0.151)	(0.220)	(0.286)
Constant	9.212***	7.727***	10.100***	9.950***
	(0.343)	(0.397)	(0.569)	(0.661)

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: Calculated by authors from VARHS

Table 7: Effect of the Livelihood strategy diversity index on household income by regions.

Table 8 provides valuable insights into the regional variations in the impact of LSDI on HDDS using IV with FE. The findings reveal a positive relationship between increased LSDI and heightened HDDS in different regions. Notably, the results attain statistical significance for the Northern and Southern areas, underscoring the robustness of these associations. Specifically, the Mekong River Delta stands out with the highest effective coefficient of LSDI on HDDS, registering at 0.316. Furthermore, certain region-specific factors exhibit statistical significance, including the number of visits to agricultural extension services, irrigation systems, willingness to pay for agricultural insurance, and access to rural credit. Interestingly, positive correlations with HDDS are observed for the number of family members and the age of the household head in distinct regions such as the Northern, Coastal, and Highland areas. These nuanced findings contribute to a comprehensive understanding of the intricate dynamics between livelihood strategy diversity and dietary diversity across diverse geographical contexts.

Variables	IV estimator by CRE with fixed effect			
	Northern area	Central area	Highland area	Southern area
Livelihood strategy diversity index	0.190***	0.039	-0.077	0.316*
	(0.072)	(0.116)	(0.125)	(0.177)
Investing in agricultural activities	0.004	0.211**	0.124	0.007
	(0.070)	(0.104)	(0.112)	(0.222)
Times for visiting agricultural extension services	-0.005	0.029	0.038	-0.074**
	(0.019)	(0.020)	(0.033)	(0.031)
Irrigation system	0.170	-0.187	0.341**	-0.690
	(0.180)	(0.224)	(0.157)	(0.431)
Accessing rural credit	0.031	-0.247**	0.234*	0.043
	(0.076)	(0.117)	(0.133)	(0.219)
Willingness to pay for crop insurance	-0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Accessing to internet	0.055	0.153	0.134	-0.086
	(0.072)	(0.106)	(0.124)	(0.204)
Number of family members	0.151***	0.097*	0.216***	-0.164
	(0.032)	(0.057)	(0.060)	(0.124)
Gender of household head	-0.295	0.774**	0.910**	-0.367
	(0.218)	(0.325)	(0.428)	(0.707)
Age of household head	0.014*	0.025**	0.032**	-0.035*
	(0.008)	(0.013)	(0.015)	(0.021)
Level education of household head	-0.024*	-0.044*	-0.003	0.046
	(0.015)	(0.026)	(0.026)	(0.043)
Number of land plots	0.009	0.022	-0.072	0.181
	(0.026)	(0.047)	(0.087)	(0.179)
Total area for agricultural production	0.003	0.116	0.152	0.143
	(0.078)	(0.088)	(0.140)	(0.174)
Land fragmentation index	-0.082	0.047	-0.008	-0.158
	(0.277)	(0.409)	(0.564)	(0.865)
Constant	4.607***	3.151***	1.167	8.870***
	(0.803)	(1.073)	(1.458)	(2.001)

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: Calculated by authors from VARHS

Table 8: Effect of the Livelihood strategy diversity index on the household dietary diversity by regions.

Conclusion

In recent years, Vietnam has made remarkable progress in agricultural development, transitioning from a traditional agricultural country to a significant player in the regional and global commodity agriculture landscape. Rural households have played a pivotal role in this transformation by engaging in various agricultural activities to improve their well-being. This study aims to uncover the factors that influence the Livelihood Strategy Diversity Index (LSDI) and assess its impact on household welfare, particularly in terms of income and the Household Dietary Diversity Scale (HDDS) index.

Findings from the period between 2010 and 2018 reveal a declining trend in livelihood strategy diversity, with the Red River Delta showing the highest diversity index. The study identifies positive associations between LSDI and various factors such as agricultural investments, access to rural loans, family size, gender of the household head, and the number of plots. To evaluate the influence of LSDI on household welfare, robust methodologies including Instrumental Variables and Ordinary Least Squares with fixed effects were employed. Results affirm that an enhanced LSDI is positively correlated with increased household income and improved HDDS scores. Regional differences are evident, with LSDI

significantly enhancing well-being in the Red River and Mekong Delta regions. The study underscores the importance of diversifying farming strategies strategically to increase income. Encouraging crop and livestock diversification not only enhances agricultural production diversity but also reduces input costs through efficient resource utilization, such as recycling cattle-derived fertilizers.

Despite its contributions, this study also highlights areas for further exploration. Longer-term analysis, spanning multiple decades, is crucial to understanding how the influence of LSDI on household welfare evolves over time. This would entail capturing dynamic changes in factors like farm productivity, market access, and government policies. Additionally, unanticipated negative impacts from seemingly beneficial factors, such as increased agricultural investment in certain regions, particularly those with land constraints or water scarcity, warrant further investigation. Exploring these nuances, along with household-level risk-mitigation strategies, such as the willingness to pay for agricultural insurance in high-risk areas, can provide valuable insights into enhancing both well-being and resilience in the agricultural sector. Addressing these gaps will pave the way for more effective strategies that promote sustainable agricultural development, improve rural livelihoods across diverse regions of Vietnam, and foster greater resilience in the face of evolving challenges.

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Appendix

Variables	RE		FE	
	Coefficient	P-value	Coefficient	P-value
Investing in agricultural activities	0.019	0.001	0.01908	0.001
Times for visiting agricultural extension services	0.001	0.614	0.00096	0.441
Irrigation system	0.004	0.695	-0.0026	0.811
Accessing rural credit	0.014	0.027	0.01391	0.021
Willingness to pay for crop insurance	0.000	0.399	2.80E-07	0.448
Accessing to internet	-0.006	0.303	-0.0049	0.399
Number of family members	-0.008	0.003	-0.0082	0.002
Gender of household head	0.035	0.001	0.03062	0.082
Age of household head	-0.001	0.300	-0.0009	0.232
Level education of household head	0.001	0.253	0.00146	0.230
Number of land plots	0.024	0.000	0.02461	0.000
Total area for agricultural production1	0.032	0.000	0.01116	0.041
Land fragmentation index	-0.070	0.001	-0.0362	0.100
Production types	0.602	0.000	0.60753	0.000
Constant	-0.674	0.000	-0.3786	0.000

Source: Calculated by authors from VARHS

Table A1: The factors linking between LSDI and explanation variables (First stage of instrumental variable method for Table 5 and 6).

Variables	Northern area		Central area		Highland area		Southern area	
	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P-Value
Investing in agricultural activities	0.026	0.001	0.023	0.058	-0.003	0.828	0.025	0.297
Times for visiting agricultural extension services	-0.002	0.274	0.004	0.025	0.007	0.075	0.003	0.392
Irrigation system	-0.010	0.593	0.027	0.229	-0.027	0.129	0.057	0.205
Accessing rural credit	0.015	0.061	0.029	0.013	0.002	0.886	-0.002	0.936
Willingness to pay for crop insurance	0.000	0.426	0.000	0.412	0.000	0.339	0.000	0.063
Accessing to internet	-0.018	0.023	-0.010	0.353	-0.004	0.767	0.001	0.950
Number of family members	-0.006	0.078	-0.014	0.018	-0.003	0.684	-0.014	0.263
Gender of household head	0.019	0.412	0.022	0.504	0.076	0.104	0.014	0.849
Age of household head	-0.002	0.016	0.000	0.731	0.003	0.199	0.000	0.999
Level education of household head	0.001	0.589	0.002	0.430	0.003	0.348	-0.002	0.675
Number of land plots	0.023	0.000	0.024	0.000	0.048	0.000	0.050	0.007
Total area for agricultural production1	0.027	0.001	0.012	0.188	-0.020	0.204	-0.023	0.202
Land fragmentation index	-0.027	0.350	-0.083	0.042	0.027	0.659	-0.040	0.655
Production types	0.568	0.000	0.620	0.000	0.685	0.000	0.706	0.000
Constant	-0.316	0.000	-0.439	0.000	-0.596	0.000	-0.444	0.039

Source: Calculated by authors from VARHS

Table A2: The factors linking between LSDI and explanation variables by regions (First stage of instrumental variable method for Table 7 and 8).