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The Well-Being of Small-Scale Farmers Post-COVID-19 Pandemic: A Mediation-Effect Approach

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ABSTRACT

Small-scale farmers are vulnerable to unpredictable threats, including climate disasters, price volatility, and health shocks. While the first two hazards occur frequently, farmers experienced both health crisis and market shock simultaneously during and post COVID-19 pandemic. Leveraging unique information of 461 rural households collected in the Vietnamese Mekong Delta in 2023, this research investigates the extent to which the COVID-19 pandemic hit farming household welfare as measured by income. Hence, the impacts of COVID-19 infection were analysed through two alternative proxies: (1) households with at least one infected member before vaccination; and (2) households' perceptions of COVID-19 seriousness. The findings reveal that household income was largely negated by the COVID-19 pandemic irrespective of the proxies used. Quantile regression models uncover that the COVID-19 infection hit wealthier households harder than those in lower income groups, whereas the perception of COVID-19 seriousness had more negative influences on the lower tail of the income distribution. Further, the mediation analysis model exhibits that the pandemic directly reduced household welfare and hampered on-farm diversification in household income as a mediator. Hence, this study provides useful insight into the effectiveness of the recovery policies and the preparedness for future inevitable dangers, especially in rural communities.

Keywords: COVID-19 Infection; Household Welfare; Mediation Analysis; Quantile Regression; Rural Communities

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1. Introduction

The agricultural sector is playing a more prominent role in alleviating poverty, improving income, and enhancing food security for people who depend on farming activities for their primary livelihood^[1]. Among Asian economies, Vietnam is an exemplar of a food security country since becoming a rice exporter in the 1990s. As such, most land in the Vietnamese Mekong Delta (VMD hereafter) region is used for agricultural production purposes. According to the General Statistic Office—GSO^[2], 25.74 out of 40.57 thousand km² (62.9%) of natural land area is used for crop production, animal husbandry, and fisheries. However, the Vietnamese economy is dominated by small-scale farming, with an average farmland size of less than one hectare (ha)^[3]. This small-scale feature limits farmers' capacities to enhance their yields and raise their voices in the market. Consequently, farmers often face an abundance of the same agricultural produce and price fluctuations after a good season. On the other hand, they may struggle with a poor harvesting season owing to unfavourable weather conditions (e.g., drought, heat shock, flood)^[4].

In 2019, the outbreak of COVID-19 disrupted diverse regions around the world, some regions experienced stronger impacts across social, health, economic, and construction sectors^[5, 6]. The shocks increase unearned income that partially compensates for the loss of earned income^[7]. Health shocks decrease food expenditure but expand health expenditure irrespective of possession of health insurance, in addition to housing and electricity bills^[8]. In Vietnam, the pandemic dramatically impacted economic activities, causing a serious decline in livelihoods across the country^[9–12]. Although the economic repercussions of the pandemic varied by region, all suffered the impact of those shocks. Thanks to the government's emphasis on 'leaving no one behind', Vietnam stood out as one of the exceptions in Asia, reporting minimal levels of human losses caused by the pandemic in 2020. Adopting powerful and prompt coping measures, this country successfully kept the disaster under control with only 415 infected individuals and zero human losses in 2020. Tung^[9] and the World Bank^[13] claimed that the government's fast and robust

response is a key to successfully controlling the pandemic. Nevertheless, as the pandemic intensified in the 2021–2022 period with 43,206 casualties, individuals suffered the loss of family members, a decline in health, and economic collapse despite the government's continuous and tireless efforts^[14]. Nearly one-in-three households reported a decrease in their income in 2021 compared with the previous year^[13].

In the case of rural areas in the VMD, households experienced fewer human losses incurred by COVID-19, which was largely attributed to their lower population density. Nonetheless, economic challenges were significant and enduring, as farmers faced income losses due to disruptions in the trading of agricultural produce and off-farm employment during lockdowns^[12]. These economic hardships were also evident in VMD. However, while a substantial body of current research has focused on the impacts of the COVID-19 pandemic, studies exclusively dedicated to rural communities are far from ample^[5, 12, 15]. In the Vietnamese context, most existing research on this issue is based on qualitative and now-casting methods, whereas this study stands out as one of the first to conduct a quantitative data-driven analysis.

Since the impact may be direct or indirect through an intermediary variable identified as a mediator, causal mediation models are needed to measure the impact of COVID-19 on household income. This provides the flexibility for the data analysis, allowing people to consider potential interactions between the mediator and the treatment^[16]. However, limited research so far discusses the integrations of the COVID-19 pandemic, household income, and on-farm diversification simultaneously. Hence, it is essential to examine the mechanism by which household income declines through direct and indirect channels related to the pandemic. The findings from this study are expected to contribute to the comprehensive understanding of the COVID-19 (as a health pandemic) – household welfare nexus in two ways.

First, it will provide evidence for the detrimental impact of the COVID-19 pandemic on rural household income. Second, this study pioneers in considering the pandemic as a direct causal factor as well as a mediator that intensifies the adverse effects of conventional impediments to household income after the

pandemic. Thus, this research intends to fill this gap of minimal focus on the literature and assess its significance in improving the livelihood of small-scale farmers. Also, limited studies found that poorer or wealthier households, and how much people suffer income loss due to the pandemic^[7, 12]. There is potential heterogeneity of the impacts across different quantiles of the income distribution due to differences in socio-demographic and economic factors. Specifically, this paper assesses whether households engaged in unique agricultural livelihoods or mixed agricultural livelihoods (so-called on-farm livelihood diversification) are more adversely affected by the pandemic.

Putting all these issues together, this study will help policymakers in developing strategies to provide aid in the future by taking into consideration the adoption decision of farmers as a research context. It is indeed essential for the relevant stakeholders to apply proper policy implementation.

The rest of the paper is structured as follows: Section 2 provides a concise review of the literature on the connection between household income and the COVID-19 pandemic, with a focus on the context of developing countries. Section 3 describes the study area, data, variables, and methodologies. In the subsequent section, research results are discussed. Finally, the paper concludes with a closing remark that includes policy implications.

2. Literature Review

The COVID-19 pandemic has had a widespread negative impact on the world in multiple dimensions^[5]. Focusing on the relationship between the health shocks, especially the COVID-19 crisis and household welfare, this section aims to review the current research outcomes in the developing countries, particularly in the context of the agrarian economy. Research has highlighted the disruptive effects of the COVID-19 outbreak on rural household welfare^[17-20]. The pandemic has led to a more enduring decline in household income in rural areas than in urban areas^[7, 21]. This negative impact is particularly pronounced for lower-income cohorts where household livelihoods are mainly based on daily and informal em-

ployment. Astonishingly, the health issues associated with COVID-19 seem to be less concerning than its negative economic consequences^[5]. Notably, even after the pandemic, livelihood resilience remains weak^[12].

COVID-19 dealt a severe blow to farming households on multiple fronts. It triggered an increase in the prices of staple foods but declined incomes, thereby causing economic hardships at different magnitudes depending on the household's wealth^[5, 22]. Kansiime et al.^[19] noted that, compared to non-farm households, farming households encountered less acute food security thanks to their self-subsistence characteristics. Huynh and Bui^[15] focused on the vulnerability to the COVID-19 pandemic of rural households in the central part of Vietnam. They argued that rural households lost their employment due to the widespread COVID-19 pandemic, thereby their income decreased tremendously. The vulnerability of the surveyed households to the pandemic was largely shaped by factors such as the household heads' limited education, their lack of stable employment, and restricted access to assistance from local government, grassroots organisations, and community groups.

Nevertheless, Guedegbe et al.^[23] found mixed effects of COVID-19 containment measures on on-farm and non-farm incomes. These effects were contingent on various factors related to households' resilience and vulnerability, including land size, wealth, income diversification, involvement in processing activities, and reliance on their labour force. This implies that male farmers are responsible for earning money and doing farm activities while female farmers use most of their time for taking care of their family. Further, despite limited research on the extent to which households effectively cope with this health crisis, results from previous identical research on health shocks are paramount^[5, 7, 24]. While households can smooth their non-health expenditure in the short term, they suffer from vulnerability-enhancing mechanisms (adults are unable to work, increased loans and sold assets) that pose risks to their income in the long-run. This consequence is more severe in rural areas than in urban areas, especially the female-headed ones^[25]. Nguyen et al.^[26] examined the role of land and labour diversification on the adaptation to covariate shocks (natural disasters for example)

and idiosyncratic shocks (health crisis) in Thailand and Vietnam. Farmers can only smooth their consumption when facing the idiosyncratic shocks, but not the covariate shocks. While Thai farmers can mitigate the losses caused by idiosyncratic shocks through land diversification, Vietnamese farmers can do so if they diversify their employment. Therefore, in Vietnam, promoting the development of non-farm sectors is helpful for rural households to overcome the shocks. Tran^[27] added that the recovery from shocks in Vietnam is determined by the ownership of physical assets rather than the household and individual characteristics. In addition, coping strategies probably assist the poor in recovering from the shocks.

Considering governmental responses to the pandemic, financial aid measures are more likely to buffer the economic fallout caused by COVID-19. Such measures assist households, particularly the poor, in smoothing their expenditure. Both immediate support (e.g., in-kind and in-cash subsidies) and long-term intervention strategies (e.g., through implementing social security programs, creating market linkage, and revolving finance mechanisms) are crucial to help farming families recover their production^[17]. Satchanawakul et al.^[28] emphasized the essence of financial relief schemes to underpin vulnerable groups' consumption of necessary goods in Thailand. Bui et al.^[29] found that financial subsidisation increases household spending on durable goods, fosters an optimistic view of economic recovery, builds trust in governmental policy, and contributes to overall individual well-being in Vietnam and Thailand.

Nevertheless, examining the role of social protection embracing unemployment insurance, social assistance and social services and mass organisations in response to the COVID-19 pandemic, Nguyen and Bui^[10] argued that despite the Government's attempts to minimise the adverse effects of the pandemic crisis, these measures have proven insufficient and failed to promptly meet the needs of the population, especially the impoverished. To fulfil these gaps, the contributions of the community via the mass organisations (the Women's Association, the Youth Union, the Red Cross and Vietnam Fatherland Front) and individuals' self-resilience are crucial to overcome the pandemic.

Regarding the COVID-19 pandemic in Vietnam, there exists a close interaction between animals and humans, which may create a significant concern about the emergence or recurrence of diseases that can be transmitted between them^[12]. Vietnam stands among the first countries that have reported cases of highly dangerous avian flu in poultry, with substantial human and economic consequences^[12, 30–32]. In recent years, the nation has witnessed a growing interest in the concept of 'One Health'. One Health is a strategy aimed at enhancing health and wellness by addressing and preventing risks, as well as reducing the impact of crises that arise when humans, animals, and their environments interact. This approach advocates for a collaborative and comprehensive approach across different sectors, encouraging a collective effort from the entire society to manage health hazards. It entails a fundamental shift in perspective towards risk management^[12, 30, 31, 33].

Overall, in addition to other health shocks the extant literature endeavours to assess the impacts of COVID-19 in the pandemic period and evaluate the government's response to cushion the human and economic losses. However, several studies lack reliable data sources due to restricted time and movement amid lockdowns and social distancing measures. As a result, the findings from these studies may be less robust owing to a dearth of rigorous empirical evidence. The current research aims to fill these gaps by addressing these limitations and providing comprehensive insights.

3. Data and Methodology

3.1. Data and Variables

3.1.1. Study Areas

Given the restricted theoretical foundation explaining the negative impacts of the pandemic on rural and agricultural income, a data-driven study was conducted. A single cross-sectional dataset collected in the rural areas of VMD—a major agricultural production region of Vietnam—was the primary data source in this current paper. In 2022, the total inhabitants of VMD were about 17.4 million (of which 12.8 million (73.27%) reside in rural areas), accounting for approximately 17.9% of the

national figure^[2].

In this study, the data were utilised from the rural household survey conducted from October to December 2023 in three locations of VMD, namely Can Tho, Dong Thap, and Vinh Long. Can Tho City is a centrally managed municipality that undergoes a rapid urbanisation; thereby stimulating a notable increase in the contribution of non-farm economic activities to household welfare. On the other hand, Dong Thap and Vinh Long are characterised by agriculture-based economies where rice farmers are increasingly diversifying into on-farm livelihoods (e.g., crops, livestock, and fisheries) rather than off-farm activities^[4]. In Dong Thap, farmers focus on the production of rice and horticulture (e.g., durian, star apple, dragon fruit, and pineapple), whereas coconut and citrus are more popular in Vinh Long. Especially, it is a community of three main ethnic groups, including Kinh, Khmer, and Hoa^[34].

The population in the three provinces in 2022 was 4,056,900^[2]. Following Yamane^[35], the minimum sample size was suggested as follows:

$$n = \frac{N}{1 + Ne^2} = \frac{4,056,900}{1 + 4,056,900 (0.05)^2} = 400 \quad (1)$$

where n denotes the minimum suggested sample size, N is the population, and e represents the margin of error (5%).

Due to limited time and budget, the number of participants in our research is limited; this might not allow us to access all perspectives and detailed information from the community regarding the impacts of the pandemic. In total, 469 household heads or representatives were interviewed in this household survey. After excluding inadequate responses, 461 valid responses from Can Tho (143), Vinh Long (159), and Dong Thap (159) were retained for analysis. This indicates a margin of error of 4.7%.

3.1.2. Data Collection

The two-stage sampling approach was adopted. The first stage of the sampling process was the purposive selection of Can Tho, Vinh Long, and Dong Thap. The second stage was the proportionate random sampling of rice farmers in these provinces, in view of the high concentration of farmers. The interviews were performed in the Vietnamese language and took about 45 minutes on average.

The original questionnaire was designed and pre-tested with 30 farmers in Vinh Long province to eliminate the uncertainties. Vinh Long was selected for pre-testing thanks to the density of farmers, especially ethnic communities such as Khmer and Chinese in this province. After the pre-test, the transparency of the questionnaire was improved by altering some words and including more guidelines, because some participants had a low level of education. The data were collected through face-to-face interviews using a multi-level questionnaire. The questionnaire was designed for collecting information on households' demographic characteristics, health status, and their livelihoods, with specific attention to the impacts of the COVID-19 pandemic in 2022. In the subsection of the health status, following the guidance from the One Health approach^[36], participants were asked about their understanding of the COVID-19 effects on their health status, and their awareness of the relationship between human health, animal well-being, and environmental well-being.

3.1.3. Variables

The dependent variable (y) is the natural logarithmic form of monthly household income per capita (measured in thousands of Vietnam Dong—1,000 VND) which captures farmers' welfare. As a principal indicator of rural inhabitants' economic well-being, household income is derived from three major income sources, namely, on-farm incomes, labour-wage income, and non-farm non-wage income^[37]. In addition, some households received transfer income in the form of state benefits and private remittances from their relatives. Instead of tracking the income pattern over time, we asked households about their income status in 2022 compared with 2021 when the COVID-19 pandemic severely impacted society.

The independent variables under consideration were established to investigate the impacts of the COVID-19 pandemic. The first variable is a dummy of COVID-19 infection (*infection*). This variable was obtained by asking participants whether they had been exposed to the COVID-19 virus since the onset of the pandemic (from early 2020). Perceiving that the severity of COVID-19 infection is contingent on vaccination status, those who reported being infected were further questioned about whether their infections occurred before or after receiv-

ing the first vaccination. Subsequently, a dummy of Covid infection without vaccine (*ad infection*) was generated. This takes a value of one for infections before the first vaccination and zero for the rest of the observations. One may concede that COVID-19 infected almost everyone, but most exposed cases may be less health-threatening for individuals who have been immunised. Hence, we only categorised the sample into two groups: those infected before vaccination and those infected after vaccination. Additionally, we conducted interviews with participants regarding their perceptions of the health damage related to COVID-19. A dummy of COVID-19 seriousness was created by taking a value of

one if they described it as harmful (and/or very harmful) and zero if they perceived it as harmless (or having a limited effect).

A vector of control variables captures the household production capacity and structure (resources such as education, age, land, and mixed agricultural livelihoods) and household characteristics (e.g., gender, marital status, religion, and smoking). In addition, internet access and smoking are considered in the analysis. While internet access is proven to spur income growth^[38], smoking cigarettes is an impediment to household income^[39]. **Table 1** provides a detailed description of all the variables used in this study.

Table 1. Description of variables.

Variable	Description	Measurement
<i>Monthly income per capita (y)</i>	Dependent variable: monthly household (HH) income per capita	Natural log of monthly household income per capita (1,000 VND)
<i>infection</i>	HH member experienced a COVID-19 infection	Dummy variable (1 if any household member was infected by COVID-19; 0 otherwise)
<i>Adjinfection</i>	Adjusted value of <i>infection</i> , HH member infected before the first vaccination	Dummy (1 if any household member was infected by COVID-19 before the first vaccination; 0 otherwise)
<i>Covid_seriousness</i>	The participant was aware that COVID-19 causes health problems	Dummy variable (1 if participant was aware that being infected by COVID-19 causes health problems; 0 otherwise)
<i>Education</i>	Educational level of household head (HHH)	Ordinal variable: 1 if completed primary or less; 2 if completed lower secondary; 3 if completed upper secondary; 4 if obtained a bachelor's degree; 5 if finished a master's degree or higher
<i>Age</i>	Age of HHH	years
<i>Arable_land</i>	The largest operated areas are used for the most prominent likelihood;	m ²
<i>Mixed_agricultural_livelihoods</i>	The household had more than one agricultural livelihood	Dummy variable (1 if the household has more than one agricultural livelihood, 0 otherwise)
<i>Gender</i>	Gender of HHH	Dummy variable (1 if HHH is male, 0 otherwise)
<i>Marriage</i>	Marital status	Dummy variable (1 if HHH is married, 0 otherwise)
<i>Internet_usage</i>	The household has internet access	Dummy variable (1 if a household has internet access, 0 otherwise)
<i>Smoking</i>	HHH is a smoker	Dummy variable (1 if HHH is a smoker, 0 otherwise)

3.2. Model Specification

3.2.1. Income–COVID-19 Infection Nexus

The study first aims to explore the relationship between the COVID-19 pandemic and household income in VMD. In order to compute the negative impacts of COVID-19 infection on household economic outcomes, a benchmark model is used in this study. The effects of the COVID-19 pandemic on household income are measured as follows:

$$y_i = \beta_0 + \beta_1 infection_i + X_i \beta_x + \varepsilon_i \quad (2)$$

where:

y_i is the natural logarithmic form of income per capita of household i ;

$infection_i$ is a dummy; equal to 1 if household i had any COVID-19 infected member;

X_i is a vector of control variables;

β_0 is the regression intercept;

β_1 is correlation coefficient of COVID-19 infection;

ε_i is the white noise error term.

Replacing $infection_i$ by $adjinfection_i$ yields Equation (3) as follows:

$$y_i = \gamma_0 + \gamma_1 adjinfection_i + X_i \beta \gamma_x + \zeta_i \quad (3)$$

where:

γ_0 is the regression intercept;

γ_1 is correlation coefficient of the adjusted COVID-19 infection;

ζ_i is the white noise error term.

In both Equations (2) and (3), the estimated parameters β_1, γ_1 are expected to be negative, indicating the reverse effects of COVID-19 on household welfare. Further, given the likelihood of COVID-19 infection is subject to individual behaviour to the pandemic, we used a dummy indicating an individual's perception of the danger of COVID-19 infection (*Covid_seriousness_i*) as follows:

$$y_i = \lambda_0 + \lambda_1 Covid_seriousness_i + X_i \lambda_x + \xi_i \quad (4)$$

where:

λ_0 is the regression intercept;

λ_1 is correlation coefficient of *Covid_seriousness_i*;

ξ_i is the white noise error term.

A rationale behind this choice is that COVID-19 infection, as a threat to their health, diminishes individuals' economic activities, consequently hindering income growth.

Additionally, the Durbin-Watson test was used to examine first-order autocorrelation in regression residuals. If Durbin-Watson values are in the range of 1–3, they are acceptable^[40]. According to Koenker and Bassett^[41], quantile regression, an alternative to OLS, estimates the conditional mean of quantile functions for a distribution. Provided heterogeneities in the impacts of COVID-19 infection on income, quantile regression techniques are applied for a holistic understanding of the differentials in income distribution owing to this health and economic shock.

3.2.2. Is COVID-19 Infection a Mediator?

It is evident that the likelihood of being exposed to COVID-19 is proportionate to various factors that also correlate with the household economic outcomes. Therefore, Ordinary Least Squares (OLS) models, as outlined in the above Equations (2)–(4) are far from perfect for drawing a comprehensive picture of the extent to which production structure, in addition to productive factors, determines economic outcomes in the case of 'new normal'. Despite the diverse sources of COVID-19 infection, a consensus is that the larger the variety of livelihoods, the higher the probability of being infected^[42]. Specifically, considering COVID-19 infection

as a mediating variable and the livelihood diversity as a treatment variable, the mechanism of these effects is simply depicted as in **Figure 1** as follows:

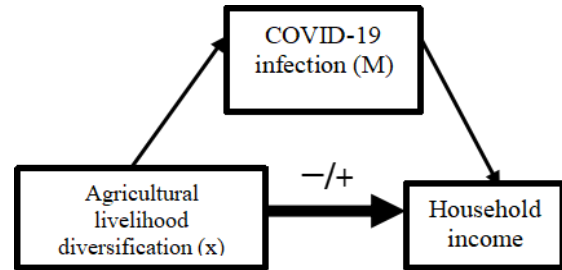


Figure 1. Determinants of household income in the new normal context.

The extant literature suggests that livelihood diversification is likely to boost household income^[4, 43]. However, this direction becomes ambiguous due to the distortion of the COVID-19 pandemic as a disaster^[44]. In fact, individuals involved in a broader range of economic activities bear a higher potential risk of infection, thereby reducing incomes due to the economic disruptions caused by COVID-19. Before delving into a further in-depth analysis of how the COVID-19 pandemic influenced household income, an OLS model addressing the correlation between agricultural livelihood diversification (*agri_diversity_i*) and household income is presented as in Equation (5):

$$y_i = \alpha_0 + \alpha_1 agri_diversity_i + Z_i \alpha_z + u_i \quad (5)$$

Then, a multiple mediator model is formulated as follows:

$$M_i = \delta_0 + \delta_1 agri_diversity_i + Z_i \delta_z + v_i \quad (6)$$

$$y_i = \theta_0 + \theta_1 agri_diversity_i + \theta_2 M_i + Z_i \theta_z + \psi_i \quad (7)$$

where:

M_i , COVID-19 infection, functions as a mediating variable;

Z_i is a vector of control variables;

δ_1 is correlation coefficient of *agri_diversity_i* on M_i ;

θ_1 is the correlation coefficient of *agri_diversity_i* on household income;

θ_2 is the correlation coefficient of M_i on household income;

θ_x is the vector of correlation coefficients of control variables on household income;

α_0 , δ_0 and θ_0 are the intercepts;

u_i , v_i , and ψ_i are residuals.

Regarding an independent variable of interest, we initially quantify a total effect of $agri_diversity_i$ on the household income per capita (y_i) without the mediator (M_i) as described in Equation (5). Equation (6) models the relationship between $agri_diversity_i$ and M_i while Equation (7), with θ_1 , computes the direct effect of $agri_diversity_i$ on y_i after taking into account the indirect effect of M_i . Particularly, the mediation effect is yielded by either subtracting θ_1 from α_1 or multiplying δ_1 by θ_2 .

Performing sensitivity analysis is crucial for assessing the robustness of empirical results in mediation effects^[45, 46]. In this regard, we conducted statistical and graphical analyses to evaluate the possible existence of an unmeasured confounder. This robustness check therefore indicates the degree of violation of the sequential ignorability assumption in the constructed mediator model. The 'rho' (ρ) parameter, ranging from -1 to $+1$, illustrates the correlation between the two error terms of the linear models for the mediator and outcome variables. The larger the absolute value of ρ , the higher the probability of the existence of conventional unobserved predictors for both the mediator and outcome.

In this study, STATA version 17 was used for data analysis.

4. Results and Discussion

4.1. Descriptive Statistics

In **Table 2**, among the 461 individuals, 154 (33.40%) were infected. Of these, 47 cases occurred without any dose of vaccination, 73 cases after the first dose, and 34 cases with unascertained infection periods. The monthly income per capita is approximately 4.6 million VND, which is consistent with the data informed by the General Statistics Office^[2]. In the VMD, the mean income in Can Tho, Dong Thap, and Vinh Long is 5.3, 4.1, and 3.7 million VND, respectively. 288 out of 461 farmers (62.47%) stated that their current economic status was better than during the COVID-19 period whereas only 60 farmers (13.02%) reported incurring more economic difficulties, and 28 participants (6.07%) said 'do not know'.

4.2. Income Impacts of the COVID-19 Pandemic

Results from Equations (2)–(4) demonstrate a consistent negative consequence of COVID-19 infection on household income irrespective of independent variable used (**Table 3**). It is noted that our findings relied primarily on the estimates derived from our preferred models, specifically those outlined in the two Equations (3) and (4) because the correlation coefficient on COVID-19 infection in the Equation (2) was statistically insignificant at the 5% level.

Table 2. Descriptive statistics for model variables.

Variable	Mean	SD	Min	Max
Monthly income per capita (mil. VND)	4.591	4.207	0.652	36.739
COVID-19 infection rate (%)	33.83	47.36	0	100
Adjusted COVID-19 infection rate (%)	10.19	30.29	0	100
COVID-19 seriousness dummy	0.475	0.499	0	1
Household head's education (level)	3.127	0.896	1	5
Age of household head (year)	52.31	13.08	19	85
Arable land (hectare)	0.697	0.692	0	8
Mixed agricultural livelihoods (dummy)	0.325	0.469	0	1
Gender (dummy)	0.540	0.498	0	1
Marriage (dummy)	0.746	0.435	0	1
Internet usage (dummy)	0.804	0.396	0	1
Smoking (dummy)	0.260	0.439	0	1
Observations	461			

In **Table 3**, the results reveal that education and age of household head, arable land, mixed agricultural livelihoods, and marriage significantly affected the monthly

income per capita. Especially, internet usage shows no effect in the case of model 1.3. Regarding independent errors, the Durbin-Watson statistic showed that the val-

ues of the residuals were slightly positively autocorrelated. However, the Durbin-Watson statistic value (approximately 1.7) fell in the range of 1–3, which was acceptable. Values below 1 and above 3 can cause concern and may invalidate the analysis^[40].

While education, land, and internet access show positive effects, age and marriage show negative impacts

on household welfare. The size of the household increased the intensity of the impact of the pandemic on small-scale farmers, perhaps because crowded families need more food and are involved in more activities for survival; thus, they struggled for food during lockdown to farm during the pandemic, leading to a reduction of yield, income and food insecurity^[5].

Table 3. Income model with the COVID-19 infection.

Variable	Model		
	1	2	3
Dependent variable: the natural log of monthly household income per capita (y_i)			
COVID-19 infection	-0.255* (0.132)		
Adjusted COVID-19 infection		-0.591*** (0.222)	
COVID-19 seriousness			-0.344*** (0.118)
Education of household head	0.135*** (0.047)	0.126*** (0.046)	0.138*** (0.046)
Age of household head	-0.019*** (0.004)	-0.019*** (0.004)	-0.017*** (0.005)
Arable land (m ²)	0.397*** (0.097)	0.393*** (0.095)	0.354*** (0.085)
Mixed agricultural livelihoods	-0.114* (0.059)	-0.110** (0.055)	-0.133** (0.050)
Gender	0.020 (0.117)	0.039 (0.118)	0.041 (0.117)
Marriage	-0.287** (0.123)	-0.274** (0.126)	-0.289** (0.123)
Internet usage	0.216* (0.112)	0.195* (0.113)	0.143 (0.112)
Smoking	-0.033 (0.110)	-0.047 (0.109)	-0.036 (0.110)
Constant	8.591*** (0.371)	8.586*** (0.370)	8.661*** (0.357)
Adj-R ²	0.184	0.198	0.194
Observations	461	461	461
Durbin-Watson d-statistic (10, 461)	1.750	1.745	1.731

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively; the SEs are given in parentheses; Modes 1, 2, 3 report the results from Equations (2), (3), and (4), respectively.

Compared to households with infections occurring post-vaccination, those having member(s) who experienced COVID-19 infection without any dose of vaccination suffered a marked decrease in income by 44.57%. Although this reverse effect was less pronounced when using the COVID-19 seriousness dummy, the impacts on household income remained substantial, at 29.04%. These findings align with the existing literature and the anticipation of dramatically negative impacts of COVID-19, irrespective of what variables are used to proxy for COVID-19^[7, 47]. This result coincides with previous studies that explain COVID-19 restriction measures reduced the supply of farm inputs and limited access to extension services. Previous studies suggest that COVID-

19 had restricted movement and transportation during lockdown in the northeastern region of Thailand; hence, it became more difficult for outsiders (e.g., sellers, visitors, and laborers) to enter the area, resulting in an increase in the price of farm inputs, such as seed and fertilizer^[7, 21]. There were shortages in labor to harvest and middlemen to bring the products to the marketplaces^[21]. Many people in Vietnam also lost their jobs as well as their main livelihood due to the restrictions and lockdown^[15]. These disruptions adversely affected rice production among rural poor households, significantly reducing the rice quantity in both domestic and international markets^[48]. This effect created disruptions of agricultural systems, in which rice was the crucial staple

crop grown to enhance income, food, and nutritional security, also influencing health outcomes of smallholder households^[7, 21].

A notable result is that on-farm diversification tends to diminish household income. A 10% reduction in income for households who practiced multiple agricultural activities, which is contradictory to an assertion of a positive relationship between livelihood diversification and farmers' resilience to shocks, and the probability of falling back into poverty^[24, 43, 49]. This is because farmers faced challenges in selling their produce during COVID-19; hence, there was a reduction in their welfare. Thereby they reported limited investment for the next crop after the pandemic was over^[2, 12]. On the other hand, it is consistent with results in Amfo et al.^[50] who underscored an adverse relationship between crop diversification and household welfare. It is feasible that crop diversification in the case of limited resources such as small-scale farming and financial problems, could prove inefficient^[12, 51].

The size of farmland positively correlates with household income ($p < 0.01$). Each additional 1,000 m² of farm size land induced a tremendous extension in income by 42–48%. In the case of small land fields in

Vietnam, this result aligns with the findings of Phan and O'Brien^[3] who observed that an increase in farmland is associated with an expansion of household income. As expected, every additional level of education completed by the household head was associated with around 13–14% of a rise in income. In the case of COVID-19, it is meaningful to farmers in Vietnam because they can adopt both crop intensification and crop diversification. They can adopt monoculture of staple crops (e.g., rice, maize, sweet potato, and bean) or integrate rice, vegetables, and fruits^[5].

Table 4 reports the impacts of COVID-19 infection on income at the 0.25, median, 0.75, and 0.9 quantiles respectively. By and large, the negative impacts of COVID-19 on household income were more considerable in the upper tail of the distribution than in the central and the lower quantiles. It means wealthier households incur a more significant loss of income than poorer households due to the impact of COVID-19 infection. On the other hand, many farmers are more focused on their health and food safety post-pandemic; hence, they invest more in crop diversification and farming practices for self-sufficiency to protect against future disruptions^[5].

Table 4. Quantile regression with the adjusted COVID-19 infection variable.

Variable	Quantile			
	25 th	50 th	75 th	90 th
Dependent variable: the natural log of monthly household income per capita (y_i)				
Adjusted COVID-19 infection	-0.438** (0.211)	-0.362** (0.151)	-0.561*** (0.128)	-0.640*** (0.205)
Education of the household head	0.151** (0.072)	0.095* (0.056)	0.134** (0.056)	0.197*** (0.072)
Age of household head	-0.029*** (0.004)	-0.017*** (0.003)	-0.016*** (0.003)	-0.012** (0.004)
Arable land (m ²)	0.536*** (0.118)	0.442*** (0.076)	0.322*** (0.069)	0.203* (0.107)
Mixed agricultural livelihoods	-0.168*** (0.072)	-0.111** (0.048)	-0.095** (0.043)	-0.086 (0.066)
Gender	-0.109 (0.180)	-0.022 (0.133)	0.069 (0.093)	0.107 (0.146)
Marriage	-0.456*** (0.133)	-0.317** (0.101)	-0.179* (0.100)	-0.021 (0.192)
Internet usage	0.161 (0.243)	0.388** (0.135)	0.281** (0.130)	0.084 (0.215)
Smoking	0.041 (0.174)	-0.100 (0.162)	-0.118 (0.109)	0.037 (0.172)
Constant	8.870*** (0.354)	8.620*** (0.336)	8.893*** (0.289)	9.044*** (0.412)
Pseudo R^2	0.175	0.181	0.151	0.128
Observations	461	461	461	461

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; SE in the bracket.

The quantile regression method, in comparison with OLS estimators, represents the relationship between COVID-19 infection and household income in more detail (Table 5). Given the heterogeneous effects of COVID-19 on household income, it relaxed the assumption of the equal slope coefficients derived from the different conditional quantiles. However, using the COVID-19 seriousness proxy revealed the reverse patterns, with a significant decrease in income observed only in the lower half of the income distribution. These differences motivated us to explore a novel approach for understanding the COVID-19—income linkage. Like our expectation, poorer households suffered more from the pandemic than wealthier

households. Delving into the intricacies of how COVID-19 undermined crop-based income, Mutegi et al.^[52] and Singh et al.^[53] proved that the poor are most vulnerable regarding food security as they tend to sell their properties to compensate for their income loss. Examining the interruption of farming activities due to COVID-19 in India, Kumar et al.^[54] claimed that three-fifths of vegetable farmers reduced their production while 80% of these reported a decline in consumption during the 2020–2021 period. Irawan et al.^[20] explained that COVID-19 shrunk the demand side more seriously than the supply side (labor supply), as it prevented households from accessing necessary goods and other commodities.

Table 5. Quantile regression with the COVID-19 seriousness variable.

Variable	Quantile			
	25 th	50 th	75 th	90 th
Dependent variable: the natural log of monthly household income per capita (y_i)				
COVID-19 seriousness	-0.313** (0.138)	-0.278*** (0.099)	-0.146 (0.099)	-0.096 (0.156)
Education of the household head	0.191*** (0.074)	0.136*** (0.049)	0.095 (0.058)	0.165** (0.071)
Age of household head	-0.025*** (0.005)	-0.015*** (0.003)	-0.017*** (0.003)	-0.014*** (0.004)
Arable land (m ²)	0.516*** (0.099)	0.384*** (0.075)	0.312*** (0.062)	0.283*** (0.108)
Mixed agricultural livelihoods	-0.165*** (0.062)	-0.127** (0.040)	-0.118** (0.054)	-0.135* (0.069)
Gender	-0.107 (0.137)	-0.083 (0.105)	0.119 (0.117)	-0.105 (0.153)
Marriage	-0.418** (0.106)	-0.338** (0.082)	-0.281*** (0.101)	-0.220 (0.169)
Internet usage	0.082 (0.140)	0.290** (0.116)	0.155 (0.152)	0.279 (0.263)
Smoking	-0.006 (0.148)	-0.034 (0.155)	-0.160 (0.156)	-0.033 (0.163)
Constant	8.651*** (0.442)	8.583*** (0.287)	9.295*** (0.272)	9.323*** (0.326)
Pseudo R^2	0.187	0.187	0.134	0.113
Observations	461	461	461	461

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively; the SEs are given in parentheses.

4.3. Mediation Effect Analysis

So far, given the complexity of the relationship between household income and production structure in the era of the ‘new normal’, it is crucial to examine how COVID-19 acts as a mediator, which potentially offsets the direct effects of conventional factors on household income. Hence, the probit model is used to estimate the correlation between the dummy of on-farm diversification and the covariates.

Table 6 clearly indicates a statistically significant

relationship between the adjusted COVID-19 infection (mediator) and mixed agriculture diversity (treatment). The positive correlation coefficient between the mediator and the treatment as in Column 2 implies that households with on-farm diversification were approximately 69% more likely to be exposed to the pandemic than the monocultural households in terms of household income. However, it failed to establish a significant association with the seriousness of COVID-19 due to weak statistical evidence. Nonetheless, there are mixed results

of the pandemic on households' strategies. Many farmers reported that they felt an incidence of unexpected situations and unpreparedness when the pandemic began, causing them to change their current practices for potential future disruptions^[5]. Whilst many farmers switch from mono-cropping to growing multiple crops

for maintaining food supply in case similar situations happen, others concern on income loss during and post-pandemic. Do^[24] added that households with higher risk-aversion tend to diversify their livelihoods, which helps them be more resilient to shocks and reduce the probability of falling back into poverty.

Table 6. Mediation analysis.

Variable	(a)		(b)	
	Adjusted COVID-19 Infection	Household Income	COVID-19 Seriousness	Household Income
Mixed agricultural livelihoods	0.686*** (0.175)	-0.257** (0.108)	0.223 (0.136)	-0.303*** (0.099)
Adjusted COVID-19 infection		-0.577*** (0.221)		
COVID-19 seriousness				-0.340*** (0.118)
Education of the household head	-0.038 (0.093)	0.126*** (0.045)	0.084 (0.070)	0.137*** (0.045)
Age of household head	0.004 (0.007)	-0.019*** (0.004)	0.020*** (0.005)	-0.017*** (0.004)
Arable land (m ²)	0.018 (0.100)	0.403*** (0.098)	-0.269* (0.148)	0.366*** (0.088)
Gender	0.233 (0.198)	0.039 (0.117)	0.182 (0.143)	0.042 (0.116)
Marriage	0.475** (0.233)	-0.269** (0.124)	0.175 (0.144)	-0.282** (0.122)
Internet usage	-0.035 (0.221)	0.186* (0.113)	-0.476*** (0.166)	0.134 (0.112)
Smoking	0.084 (0.205)	-0.043 (0.109)	0.183 (0.160)	-0.032 (0.109)
Constant	-2.209*** (0.655)	8.490*** (0.351)	-1.176*** (0.429)	8.539*** (0.342)
Adj- <i>R</i> ² /Pseudo <i>R</i> ²	0.087	0.201	0.095	0.198
Observations	461	461	461	461

Note: ***, and ** indicate statistical significance at 1% and 5% levels, respectively; (a) Mediating model with the adjusted COVID-19 infection variable; (b) Mediating model with the COVID-19 seriousness variable.

Specific information on the mechanism of mediation effect is presented in **Tables 7** and **8**. The total effect of the mixed agricultural livelihood on household income ranges from -0.307 to -0.264, indicating a reduction in income by 11.2–21.4% due to the adoption of on-farm diversification. This reverse impact can be disaggregated into two channels. First, the indirect effect constituted about one-fifth of the total effects of mixed farming on household income. As discussed earlier, on-farm diversification acted as a catalyst for the spread of COVID-19 infection, which in turn impedes household

income. On the other hand, household income was affected immediately due to the effect of the pandemic; hence, it affected farmers' decisions on agricultural budget allocation^[55]. As a result, it also influenced crop productivity, which was involved in the intensity of farming and input purchasing decisions^[6]. Second, the mixed agricultural livelihood itself is also detrimental to household income. Fragmented and small farmlands could be the reasons behind this effect; as far as they promoted on-farm diversification but simultaneously decreased household income^[3, 56].

Table 7. The average causal mediation effect (ACME) with adjusted COVID-19 infection.

Effect	Mean	95% Confidence Interval
ACME1	-0.056	[-0.140, 0.001]
ACME0	-0.071	[-0.165, -0.006]
Direct effect 1	-0.233	[-0.459, 0.013]

Table 7. Cont.

Effect	Mean	95% Confidence Interval
Direct effect 0	-0.248	[-0.471, -0.012]
Total effect	-0.307	[-0.494, -0.133]
% of total via ACME1	0.188	[0.113, 0.420]
% of total via ACME0	0.239	[0.143, 0.534]
Average mediation	-0.063	[-0.150, -0.003]
Average direct effect	-0.241	[-0.465, 0.002]
% of total effect mediated	0.214	[0.128, 0.477]

Table 8. The average causal mediation effect (ACME) of COVID-19 seriousness.

Effect	Mean	95% Confidence Interval
ACME1	-0.021	[-0.070, 0.006]
ACME0	-0.035	[-0.090, -0.001]
Direct effect 1	-0.228	[-0.446, 0.008]
Direct effect 0	-0.243	[-0.452, -0.014]
Total effect	-0.264	[-0.469, -0.053]
% of Total via ACME1	0.083	[0.045, 0.402]
% of Total via ACME0	0.140	[0.076, 0.676]
Average mediation	-0.028	[-0.770, 0.000]
Average direct effect	-0.235	[-0.449, -0.011]
% of total effect mediated	0.112	[0.160, 0.539]

Note: ACME1 and ACME0 are the average causal mediation effect (ACME) with and without mixed agricultural livelihoods respectively; Mediator: Adjusted COVID-19 infection.

Based on the results from the Appendices, the robustness tests revealed that ρ was equal to -0.3 (for adjusted COVID-19 infection) and -0.2 (for COVID-19 seriousness), indicating that the mediation effect models were not entirely free from concern about the existence of a potentially important omitted cofounder (**Appendix A Table A2**). Additionally, visualised results depicting the level of influence of an unobserved pre-treatment cofounder on either mediator or outcome, and therefore how sequential ignorability was fulfilled (**Appendix A Figures A1 and A2**). To sum up, the test results suggest a slight degree of sequential ignorability violation, albeit at a low probability. Thus, caution should be applied in interpreting the policy implications related to farmers' welfare.

5. Conclusion

Motivated by questions regarding the negative effects of COVID-19 pandemic on income in the rural areas of VMD, this study marks one of the initial attempts to build econometric models for facilitating the discussion on this topic. This study employs a quantitative research by conducting a household survey in three provinces, Can Tho, Vinh Long, and Dong Thap in the VMD of Viet-

nam. Facilitated by this dataset, we examined the influence of COVID-19 on farmers' income across various dimensions. First, all things being equal, families with infected members who had not been vaccinated experienced a significant income reduction. Second, COVID-19 not only directly reduced household income but also acted as a mediator, exacerbating the negative effects of the on-farm diversification. This finding implies impacts of the pandemic on household's welfare and financial stress on the society.

These findings are crucial for policymaking geared towards the economic recovery of rural communities as well as the preparation for future shocks. First, policy makers should take into account the unique characteristics of local conditions when designing the livelihood resilience policy. Second, more importantly, it is evident that the resilience of rural households remains weak even after the pandemic. The challenge may be attributed to the intricate consequences of negative influence in the rural economy. In addition to the adverse impacts of COVID-19, a conventional detrimental factor on farm diversification appears to pose complexity in post-Covid condition. Thus, a thorough understanding of the interconnection between COVID-19 pandemic on the

household economic conditions is essential to improve the efficiency of curbing the economic consequences of COVID-19 pandemic. Supportive macroeconomic policies need to be continued for safeguarding a resilient and inclusive recovery for preparation before any similar risk happens.

Because the level of education of the household head positively influenced an increase in income, farmers should be also better equipped with trainings for capacity building. In the context of post pandemic, those trainings should be developed in such a way that is closely to the expectation of increasing income. Additionally, this study showed that rural households with health insurance are less likely to be exposed to vulnerability and poverty resulting from shocks. Therefore, expanding access to healthcare services, reducing costs, and improving efficiency in healthcare would offer substantial benefits of reducing vulnerability for the poor.

In the potential pandemic crisis, the government should adopt a pro-agriculture policy stance, such as ensuring an uninterrupted supply chain of agricultural inputs to ensure food security, allowing the access to transport, infrastructure, and agricultural input shops, and providing a package loan for farmers at a low-interest rate, distribute subsidized fertilizers and seeds and promoting specific crop intensification and diversification, depending on available capacity of household and the local context.

Despite several contributions to literature and policy implications, this study has certain limitations. First, this research relied on a single cross-sectional dataset that barely recorded information on the household economic status before the pandemic. In this study, the authors only asked farmers to qualitatively compare their own status (better, the same, or worse than before COVID-19). This characteristic of the data prevented us from conducting a quantitative comparative analysis. Another limitation is that the accuracy of data is subject to the truthfulness of self-reports, which is commonly noted in most survey-based data. Finally, this study observed a low probability of a violation of the sequential ignorability assumption in the mediation effect models; consequently, we cannot say with certainty that there is

no concern about such a violation. Hence, when interpreting the results, future studies should incorporate appropriate cofounders in the mediation model.

Author Contributions

Conceptualization, L.B.-T. and V.-P.P.; methodology, L.B.-T. and T.D.N.H.; software, V.-P.P.; validation, L.B.-T., V.-P.P. and T.D.N.H.; formal analysis, L.B.-T. and V.-P.P.; investigation, L.B.-T.; resources, L.B.-T., V.-P.P. and T.D.N.H.; data curation, T.D.N.H.; writing—original draft preparation, L.B.-T.; writing—review and editing, V.-P.P. and T.D.N.H.; visualization, V.-P.P. and T.D.N.H.; supervision, T.D.N.H.; project administration, L.B.-T. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Data for this paper will be provided by the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no competing interests.

Appendix A

Table A1. The household income—mixed agriculture without the mediator.

Variable	Household Income
Mixed agricultural livelihoods	-0.330*** (0.104)
Education of the household head	0.127** (0.054)
Age of household head	-0.019*** (0.004)
Arable land (m ²)	0.403*** (0.069)
Gender	0.020 (0.112)
Marriage	-0.305** (0.113)
Internet usage	0.192 (0.130)
Smoking	-0.055 (0.129)
Constant	8.51*** (0.333)
Adj-R ²	0.163
Observations	461

Note: ***, and ** indicate statistical significance at 1% and 5% levels, respectively. This table reports the estimated results from Equation (5).

Table A2. Sensitivity analysis.

a) With Adjusted COVID-19 Infection		Value
ρ	at which ACME = 0	-0.3
$\rho^2 =$	$R_M^2 * R_Y^2$ at which ACME = 0	0.09
$\rho^2 =$	$\tilde{R}_M^2 * \tilde{R}_Y^2$	0.060
b) With COVID-19 Seriousness		Value
ρ	at which ACME = 0	-0.2
$\rho^2 =$	$R_M^2 * R_Y^2$ at which ACME = 0	0.04
$\rho^2 =$	$\tilde{R}_M^2 * \tilde{R}_Y^2$	0.026

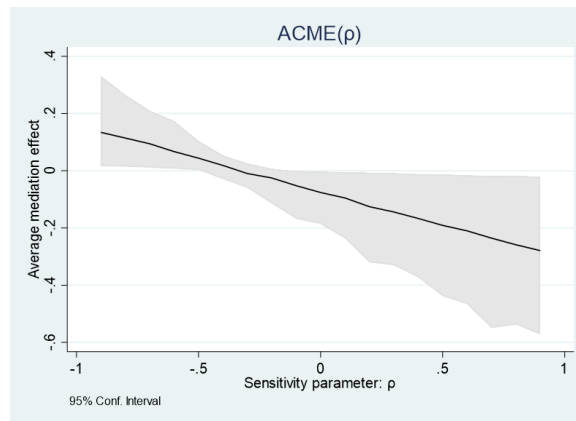


Figure A1. Graph of sensitivity analysis with adjusted COVID-19 infection.

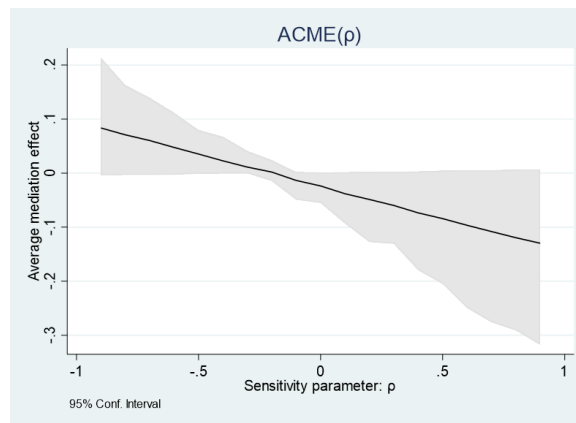


Figure A2. Graph of sensitivity analysis with COVID-19 seriousness.

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