A propensity score matching analysis of the relationship between forest resources and household welfare in Vietnam

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Abstract

Using secondary data from a socio-economic quantitative household survey in of the North Central region of Vietnam, the main aim of our study is to analyze the causal effect of forest resources on household income and poverty. Based on the observed characteristics of a forest-based livelihood and forest-related activities, we use a propensity score matching (PSM) method to control for potential bias arising from self-selection. The PSM results indicate that households with a forest livelihood had a higher level of income and lower level of poverty than did those without. Interestingly, our findings confirm that a forest-based livelihood offers much higher income than any other type of livelihood adopted by local households. Also, the poverty rate among households with a forest livelihood is lower than those earning non-labor income or engaged in wage/crop and crop livelihoods. Moreover, households whose livelihoods depend on timber forest products (TFPs) and animals (non-TFPs) also had higher income and lower levels of poverty than did those lacking these resources. Among households and provinces, we find differing opportunities deriving from forest resources, suggesting that there are potential barriers hindering local households from pursuing a forest livelihood or participating in some forest activities. Therefore, government policy and regulations on forest management should focus on improving the access of households to forest resources, at the same time enhancing the sustainability of these resources.

Keywords: forest resources; household income; livelihood; poverty; rural livelihood.

JEL codes: D13; D15; I 32, O12, J15

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1. Introduction

Forests are of great importance for the economic development of a country. They offer a variety of goods, namely raw materials for several industries, firewood as a main source of energy for rural households, and places for outdoor recreation. Forests provide countless goods and services to households residing in and around forests, which become the main source of livelihood for a major portion of poor populations in developing societies (Ali & Bahadur, 2018; Angelsen et al., 2014; Das, 2010; Kar & Jacobson, 2012). In developing areas, a large proportion of smallholder farmers still adopt livelihoods that partially or totally rely on forest resources (Angelsen et al., 2014). Empirical evidence confirms that forest resources make a significant contribution to reducing poverty and inequality in many developing countries (Adam & Eltayeb, 2016; Ali & Bahadur, 2018; Angelsen et al., 2014; Das, 2010; Shackleton, Shackleton, Buiten, & Bird, 2007; Walelign, Charlery, Smith-Hall, Chhetri, & Larsen, 2016).

Like many other developing societies, in Vietnam forest resources play an important role in the livelihood of rural households, especially for those living in mountainous and remote areas (Nguyen & Tran, 2018; Sunderlin & Huynh, 2005). Poor people in remote regions tend to rely on goods and environmental resources from forests for their living. Local people receive various benefits from converting forestland into arable land, and timber and other non-timber forest products into income and capital (Sunderlin & Huynh, 2005). Evidence shows that areas with a high poverty rate tend to overlap with areas of remaining natural forest. Specifically, areas with a high incidence of poverty are concentrated in the North Central region and the Central Highlands (Nguyen, Tran, & Vu, 2017; Sunderlin & Huynh, 2005). These regions are also home to many ethnic minorities who have much lower living standards than do the Kinh and Hoa population (Nguyen et al., 2017).

It is estimated that in rural Vietnam, around 25 million poor and ethnic minority people depend on forests for a subsistence livelihood, energy and a safety net when facing economic hardship (World Bank [WB], 2016). A number of studies confirm the contribution of forest resources to reducing poverty and inequality in mountainous and remote areas of Vietnam (McElwee, 2008; Nguyen & Tran, 2018; Sunderlin & Huynh, 2005). These studies

often focus on the contribution of forest resources to household income and poverty reduction, using descriptive statistics and regression analyses. However, to the best of our knowledge, no study accounts for possible selection bias when estimating the causal effects on household welfare of participating in forest-related activities. This gap inspired us to implement the current research.

Our study focuses on the poorest districts of the North Central region of Vietnam where the majority of the population are ethnic minorities with access to large forest areas. Our research objectives are *first,* to classify distinct livelihoods adopted by local households, with the help of cluster analysis. *Secondly*, we compare the differences in income and poverty between households with and without a forest-based livelihood, using propensity score matching (PSM) to address the effect of potential bias, such as self-selection, on observed characteristics into livelihood choices (Caliendo & Kopeinig, 2008; Dehejia & Wahba, 2002). A similar analysis is also applied to compare the outcome for households that engage in various forest activities and those that do not.

Cluster analysis identified six distinct livelihoods pursed by local households. About 57% of the household sample engaged in at least one forest-related activity, while about 25% of them pursued a forest-based livelihood (hereafter called "forest livelihood"). The results of PSM confirmed that a household pursuing a forest livelihood would, on average, achieve a much higher income level than one with some other livelihood. Also, the poverty rate is lower for those following a forest livelihood than for those with other livelihoods, such as crop, wage/crop and non-labor livelihoods. Households earning from timber forest products and forest animal (non-timber) products also have higher incomes and lower poverty levels than those without. Thus, the study provides the first evidence that forest resources play an important role in the livelihood of local households. This finding is inconsistent with that obtained in some developing countries, which found that forest-dependent households tend to be much poorer than others (McElwee, 2008).

The paper is structured as follows. The data and methods used are described in Section 2, while results and discussion are presented in Section 3, followed by policy implications and conclusion in Section 4.

2. Data and methods

2.1. Data and study areas

We utilize data from the Quantitative Socio-Economic Survey for the Emission Reduction-Program (ER-P) Provinces Areas [QSESERPA], conducted by the Mekong Development

Research Institute [MDRI] in 2016 (MDRI, 2016). The key purpose of the survey was to collect information on the socio-economic characteristics of the communities in the proposed ER-P program, including vulnerable groups and forest-based households and communities, particularly ethnic minorities. The survey was implemented in six provinces in the Northern Central Coastal Region, namely Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri and Hue, where the richest natural forests are located (MDRI, 2016). The survey region covers 50 districts and about 327 communes in the midlands and uplands. The region is the home of a relatively large ethnic minority population, including seven major and four to five minor groups. A large number of ethnic minorities live in Thanh Hoa and Nghe An, a smaller number in Ha Tinh and Quang Binh, and a medium number in Quang Tri and Thua Thien Hue.

A random, multi-stage sampling method was applied for the survey. First, 102 communes from the six previously mentioned provinces were selected, according to probability proportional to the population size of the provinces. Next, from each of the chosen communes, two villages were selected and 15 households in each village were chosen for the interview, providing a total sample size of 3,060 households (MDRI, 2016). The survey included a large number of households from many ethnicities, such as Thai, Muong, Bru-Van Kieu, H'Mong, Co Tu, Ta Oi-Pa Co, and other ethnic minorities. The survey encompasses rich information about households and individuals such as demographic characteristics, education and employment, housing, durable goods and income sources (MDRI, 2016).

2.2. Methods

2.2.1. Classification of household livelihoods

We use a cluster technique to partition households into *k* mutually exclusive clusters, so that households in each cluster are as similar as possible, and at the same time, as dissimilar as possible from households in other clusters (Mooi, Sarstedt, & Mooi-Reci, 2018; Scott & Knott, 1974). Following previous studies (Tran, Tran, Tran & Nguyen, 2018; Hoang, Tran, Nguyen, & Nguyen, 2019), we draw on income proportional to its source for input variables for clustering household livelihoods (Table 1). First, we employ a hierarchical method to identify the optimal number of clusters, using the Calinski stopping rule (Halpin, 2016). At this stage, the result indicates that the largest value of Calinski/Harabaz pseudo-F is 1463.07, corresponding to the optimal number of six clusters. Second, cluster analysis was

performed with six groups, using k-mean clustering. Finally, six livelihood groups were classified, and their corresponding household income structures are reported in Table 2.

Table 1: Income from various sources

Categories	Definitions
1. Crop income	Incomes from all crops, both annual and perennial.
2. Nonfarm income	Income from self-employment in non-farm activities (non-farm household businesses).
3. Wage income	Income from all wage-earning activities, including both formal and informal wage paying work (wage paying work with and without a labor contract).
4. Forest income	Income derived from both timber and non-timber products, as well as other forest-related resources.
5. Livestock income	Income earned from livestock production.
6. Non-labor income	Income received from remittances, interest, rentals, subsidies, scholarships, and other sources.

Note: All income sources are measured in both cash and kind.

2.2.2. Measuring the impact of forest resources on household welfare

We employ propensity score matching (PSM) to evaluate the impact on income of a household pursuing a forest-dependent livelihood and forest-related activity. PSM has become a popular method to study casual treatment effects. This approach allows researchers to obtain an unbiased treatment effect estimate adjusted for the influence of other confounders in non-randomized and observational studies (Abadie & Imbens, 2016; Caliendo & Kopeinig, 2008; D'Agostino Jr, 1998; Dehejia & Wahba, 2002). Thus, this method enables us to address potential bias, such as self-selection, influencing observed characteristics in livelihood choice (Caliendo & Kopeinig, 2008). Another major merit of this approach is that we can utilize existing data sources, which requires less time and is low in cost. Also, PSM is not conditioned on any functional forms linking the outcome to livelihood choice (Tran, 2015).

In the current study, the PSM method estimates the propensity score for each household with a forest livelihood (participant or treatment unit) and households with other livelihoods (non-participant, e.g., a crop livelihood) on the basis of observed characteristics, and then compares the mean per capita income of participants with that of matched (similar) non-participants. Specifically, the main task of PSM is to seek out comparable non-participating households among all such households to build a control group, and then compare the mean income of the treatment and control groups. As a result, control and treatment units with the same propensity score would have the same probability of being assigned to the treatment group as in random experimental research (Dehejia & Wahba, 2002).

Let FL be an indicator variable equal to 1 if a household pursues a forest livelihood and zero if that household adopts any other livelihood. In the PSM framework, FL is an indicator that receives the 'treatment'. The propensity score $P(T_1)$ is identified as the conditional probability of being assigned the treatment, given pre-treatment characteristics.

$$P(T_1) \equiv Prob(D_1=1/T_1) = E(D_1/T_1); P(T_1) = F(T_1) \quad (1)$$

Where T_1 represents the characteristic vector of a household *i, E* is the expectation outcome, and $F(T_1)$ shows normal or logistic cumulative distribution frequency. Assuming the conditional independence of the score result allows us to utilize the propensity scores for estimating the conditional treatment effect. The predicted propensity scores are used to estimate the treatment effect.

The average treatment effect on the treated (ATT) is the most important parameter in the impact evaluation literature (Dehejia & Wahba, 2002). Hence, our study employs the ATT to measure the influence of livelihood dependence on household outcome (e.g., income, poverty). The ATT is estimated via matching participants and non-participants that are closest in terms of propensity scores. In the current study, the treated group is identified as households pursuing a forest livelihood. The ATT is calculated as follows:

$$ATT = E(T/1=1) = E(Y/1)/D=1) - E(Y/0)/D=1) \quad (2)$$

Where E(Y/1)/D=1 denotes the expected outcome of households with a forest livelihood while E(Y/0) represents the counterfactual outcome of households with another livelihood. The counterfactual estimates show what the outcome of forest-dependent households would be, if they had not adopted a forest livelihood. We also use PSM analysis to examine the effect of forest participation on household welfare. Kernel matching was applied to match treatment and control observations in our study.

2.2.3. Investigating factors affecting the choice of forest livelihood and forest participation

To model factors affecting a household's livelihood choice, we use a logit model with the response variable being a binary variable that receives a value of one if a household pursued a forest livelihood and a value of zero otherwise. This model is also employed to estimate the determinants of a household's participation in various activities. The logit model takes form (Gujarati & Porter, 2009) as follows,

$$\Pr(\boldsymbol{Y} = 1|X) = \frac{Exp\left(\boldsymbol{\beta'}_s \boldsymbol{X'}_s\right)}{1 + Exp\left(\boldsymbol{\beta'}_s \boldsymbol{X'}_s\right)}$$

where the coefficients $\boldsymbol{\beta'_s}$ are the parameters that need to be estimated and X'_s are the explanatory variables. The model measures the probability that some event occurs, which in this case is the probability of a household choosing a forest livelihood or a specific forest activity ($\boldsymbol{Y}$=1). Because the maximum likelihood estimation (MLE) of a logit model is based on the distribution of $\boldsymbol{Y}$ given $\boldsymbol{X}$, the heteroscedasticity in $Var(\boldsymbol{Y}|X)$ is automatically addressed (Wooldridge, 2016).

Following previous research (Ali & Bahadur, 2018; Khundi, Jagger, Shively, & Sserunkuuma, 2011; Rahut, Behera, & Ali, 2016), various individual and household characteristics are included as explanatory variables in the models. These include household size, dependency ratio, the age, education, ethnicity and gender of the household head, the size of various types of land (annual and perennial croplands, forestland, and residential/garden land), assets (electricity generator, water pump, tractor, motorbike, and computer) and internet connection. We also control for omitted between-province variance through the province dummy variables. These variables account for fixed province effects.

3. Results and discussion

3.1. Background on household characteristics and livelihoods

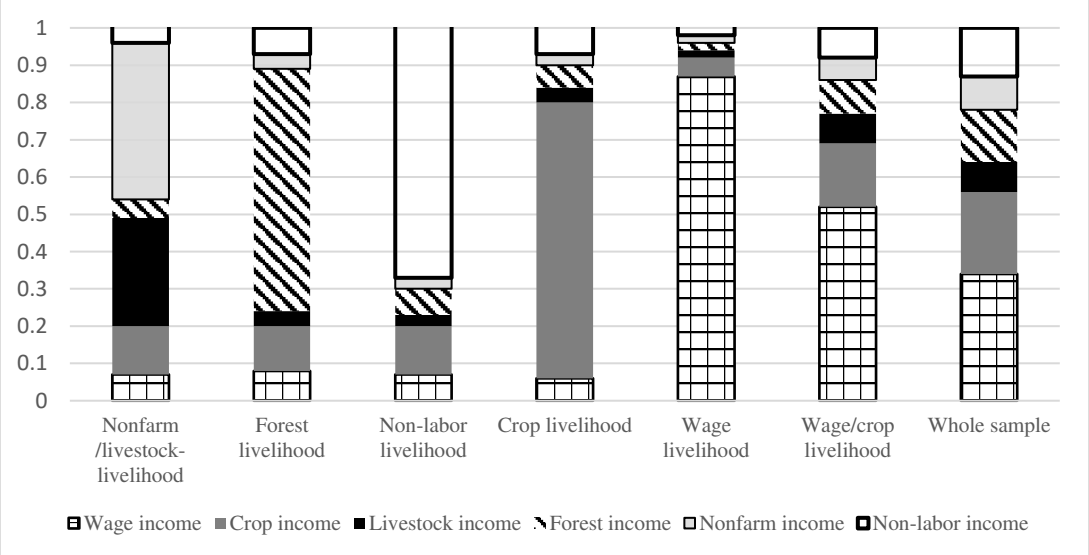

Figure 1: Household income structure by livelihood
Source: Authors' calculation from the QSESERPA

Figure 1 shows that for the whole sample, wage income on average accounts for about one third of total household income, followed by crop income (22%), forest income (14%), and other income (13%). Livestock and nonfarm self-employment income each contributed about 9% of total income. Income from nonfarm self-employment and livestock

contributed about 42% and 29%, respectively, of total household income for nonfarm and livestock livelihoods. The mean proportion of forest income constituted 65% of total household income among those with a forest livelihood, while the mean share of wage and crop income was 87% and 74%, respectively, for households engaged in wage and crop livelihoods. For those whose livelihoods are dependent on wage and crop income, 57% and 17%, respectively, of total income derived on average from wage work and crops. Finally, the proportion of crop and non-labor income made up about 68% and 13%, respectively, of total income among those with non-labor livelihoods.

Table 1 provides information about forest income by source for households that engaged in at least one forest-related activity. On average, around 60% of the total household sample received forest income from at least one source. Only 8% of the sample had income from forest timber products, with the annual mean income of timber forest products at about 44.52 million Vietnamese dong (VND) per household. Half of the sample earned income from non-timber forest products (NTFP) from plants. The mean value of this source is about 8.636 million VND per household. About 10% of the sample received income from NTFP from animals, and each household on average earned about 4.2 million VND per year. Only 5% of the sample had income from forest management services, with their mean value at about 3.18 million VND per household, while 12% of the sample earned income from other forest-related activities. These sources, on average, provided each household with about 9.08 million VND per year.

Table 1: Annual forest income by source

Forest income by source	Number of households	% participation	Mean forest income	Standard deviation
Timber forest products (TFP)	221	8%	44521	115748
Non-timber forest plant products (NTFP)	1455	50%	8636	24449
NTFP from animals	278	10%	4195	16440
Forest management services	131	5%	3182	5716
Other activities	336	12%	9079	33975
Total forest income	1695	59%	15951	57007

Source: Authors' calculation from the QSESERPA

Figure 2 shows that the level of household income per capita varies significantly across livelihoods. It is evident that households with a forest livelihood earned the highest income (about 16.6 million VND per person/year), while the lowest level is observed for those whose livelihood derived from crops (4.76 million VND per person/year). Figure 3

compares the level of household income per capita between households with and without forest derived income. Interestingly, descriptive statistics reveal that forest-related endeavors are positively correlated with income for some activities but negatively for others. For instance, households with timber forest product earnings achieved higher per capita income than did those without, while those obtaining non-timber forest products from plants and animals derived lower levels of per capita income than those without.

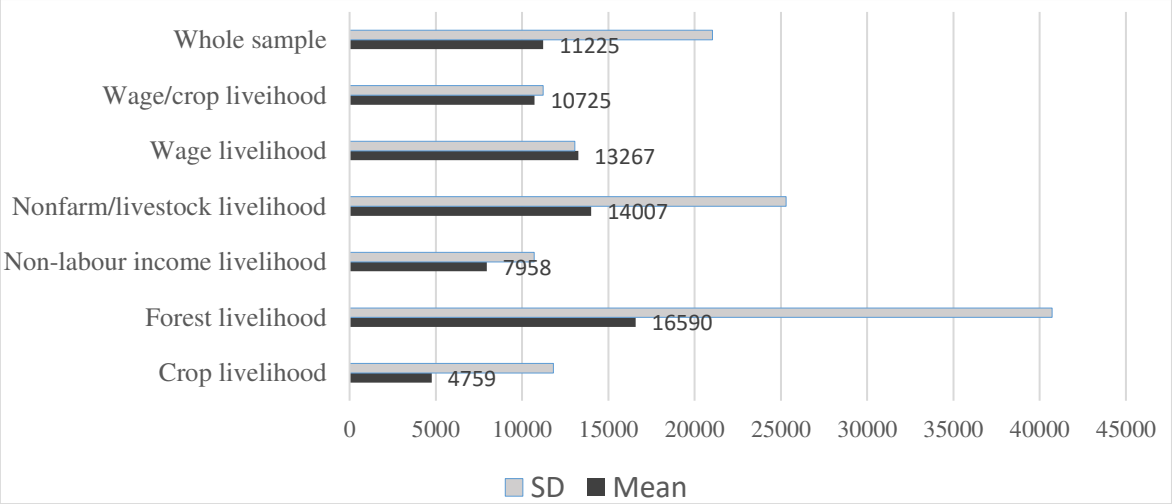

Figure 2: Annual household income per capita by livelihood
Source: Authors' calculation from the QSESERPA

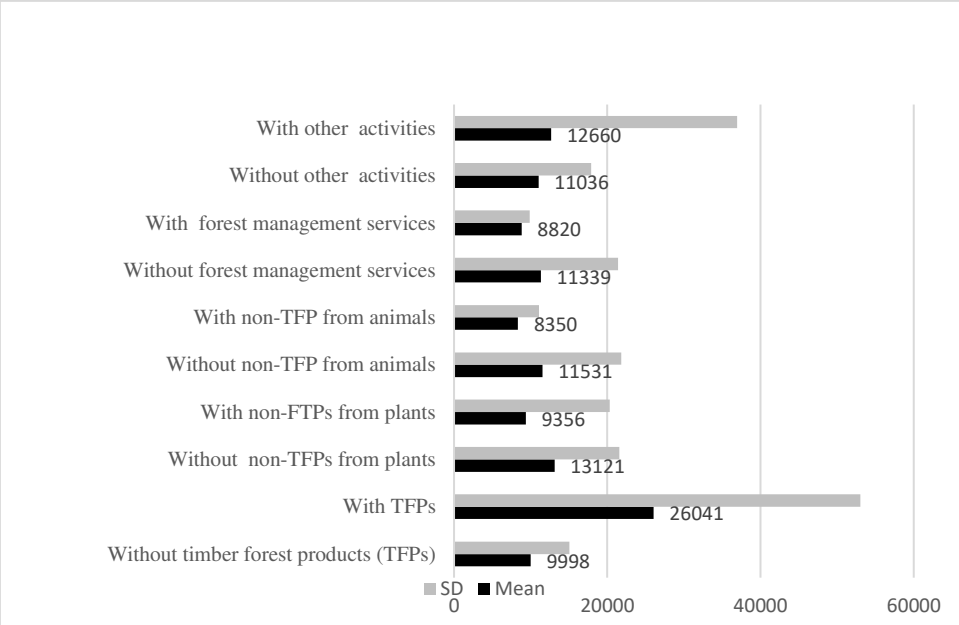

Figure 3: Annual household income per capita by forest activity
Source: Authors' calculation from the QSESERPA

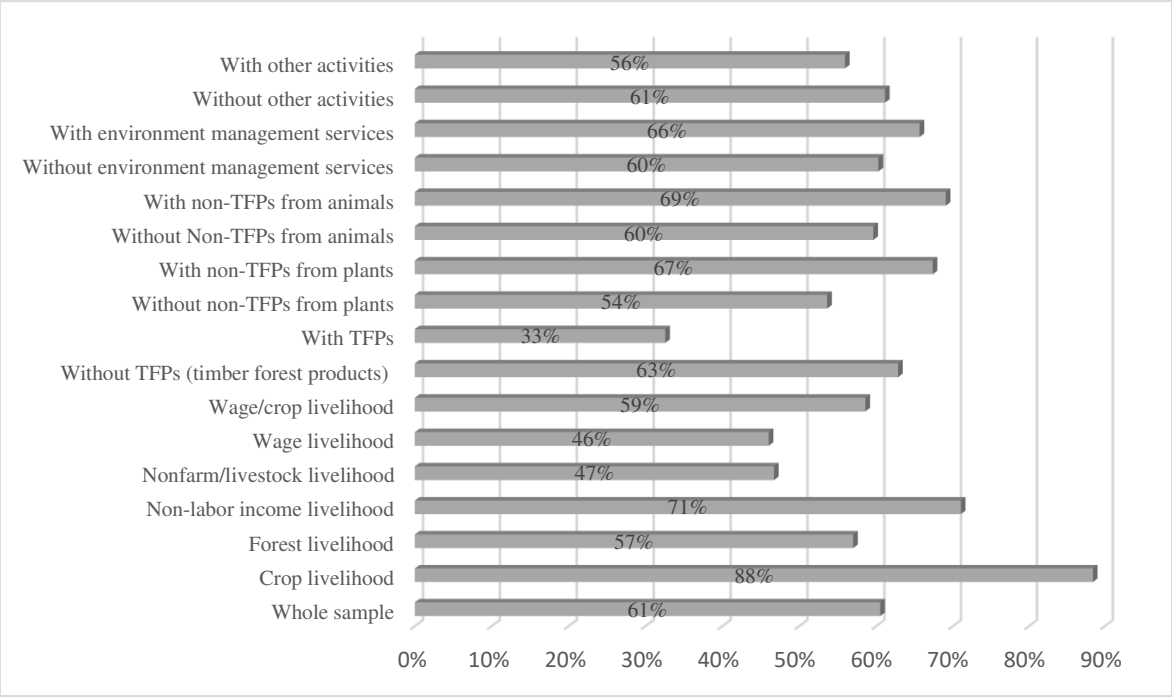

Figure 4: Poverty rate by forest livelihood and activity
Note: This poverty line is calculated using the poverty line for rural areas in 2014 (GSO, 2015) and adjusted for the CPI (consumer price index) in 2015.
Source: Authors' calculation from the QSESERPA

Household characteristics are given in Table 2. The majority of household heads are male and come from ethnic minorities. However, the proportion of household heads who are from an ethnic minority varies across livelihoods. The highest figure is observed for the crop and forest livelihood groups (83% and 85% respectively), while the corresponding figure is much lower for the nonfarm/livestock (58%) and wage-earning (64%) livelihood groups. The data reveal that about 40% of household heads in the crop, forest and non-labor income livelihood group lack formal education. The corresponding figure is only about 24% for those with a nonfarm/livestock livelihood. The proportion of household heads with more than upper secondary school education is 13% among wage-dependent households, while it is only 1% among crop-dependent households and 4% among forest-dependent households.

Figure 4 compares the poverty rate across various livelihoods and forest activities. The poverty rate for the whole sample is 61%. This figure varies significantly across livelihoods, however. The highest poverty rate is found for households with a crop livelihood, whilst the lowest one is observed among those with a wage or nonfarm/livestock livelihood. The poverty rate is 57% for those with a forest livelihood, which is lower than the average rate. The poverty rate for households earning from timber forest products (TFP) is only 33%, which is much lower than for those without such income (63%). However, the corresponding figure is higher for those obtaining non-timber forest products (NTFP) from

plants than for those without this source of income. Similarly, those dependent on NTFP from animals have a higher poverty rate than do those without such income. Descriptive statistics also indicate that the poverty rate is greater for those participating in environment management services than for those without such involvement.

Although household size is quite similar among livelihoods, the dependency ratio varies across livelihoods. The highest dependency ratio is found for households dependent on non-labor income (1.05) and the lowest figure is recorded for wage-dependent households (71%). For the whole sample, on average each household had 1360 m^2 of annual cropland, 7148 m^2 of forestland, 1450 m^2 of perennial cropland and 432 m^2 of residential/garden land. The size of annual cropland is smaller for the forest and wage livelihood groups than for other livelihoods. However, households with a forest livelihood and those with a nonfarm/livestock livelihood owned more forestland than did households with other livelihoods. Finally, households whose livelihood was based on wage or wage/crop income had owned less perennial cropland than did those with other livelihoods. The estimates in columns 6 and 7 reveal that households with a forest livelihood have lower levels of education than do those with a non-forest livelihood. Also, forest-dependent households have more perennial cropland and forestland but own less annual cropland than those not dependent on forest income.

Regarding productive and durable assets, Table 2 shows that, on average, 36% of the household sample owned water pumps, 79% had motorbikes, 6% had electricity generators, 7% had computers and only 3% had an internet connection. The figures vary significantly across livelihood groups, however. For example, the proportion of households owning a water pump was only 21% for crop-based households but 47% for wage-based households. The number of households with computers and an internet connection was also higher for those with livelihoods based on wages or wage and crop incomes. Table 3 compares household characteristics for households with and without forest-based income. On average, households with TFPs owned more forestland, and annual and perennial croplands, than did those without TFPs. Those with NTFPs from plants had less annual and perennial cropland but held more forestland than did those without NTFPs from plants. A higher proportion of heads of households with NTFPs lacked education than those without, while the number of households owning water pumps and motorbikes was larger for those without NTFPs than for those with. Finally, households that derived income from animal NTFPs had less forestland, and annual and perennial croplands, than did those that did not.

Table 2: Household characteristics by livelihood

Livelihood group/ Explanatory variables	All		Nonfarm/ livestock livelihood (1)		Wage/crop livelihood (2)		Non-labor income livelihood (3)		Crop livelihood (4)		Wage livelihood (5)		Forest livelihood (6)		Non-forest livelihood[a] (7)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gender	0.88	0.32	0.88	0.33	0.88	0.32	0.79	0.41	0.91	0.28	0.89	0.31	0.92	0.27	0.88	0.33
Ethnicity	0.29	0.45	0.42	0.49	0.31	0.46	0.29	0.45	0.15	0.36	0.36	0.48	0.17	0.38	0.31	0.46
Age	33.88	7.40	35.22	7.94	33.37	6.32	33.61	9.33	33.37	7.50	34.00	6.24	33.81	7.76	33.88	7.33
No education	0.32	0.47	0.24	0.43	0.25	0.44	0.43	0.50	0.41	0.49	0.24	0.43	0.40	0.49	0.30	0.46
Primary education	0.27	0.44	0.27	0.45	0.26	0.44	0.23	0.42	0.26	0.44	0.28	0.45	0.28	0.45	0.26	0.44
Lower secondary	0.28	0.45	0.35	0.48	0.33	0.47	0.24	0.43	0.26	0.44	0.29	0.45	0.22	0.42	0.30	0.46
Upper secondary	0.07	0.26	0.10	0.30	0.09	0.28	0.06	0.23	0.06	0.24	0.06	0.24	0.07	0.26	0.07	0.26
Above upper secondary	0.06	0.24	0.04	0.21	0.07	0.26	0.04	0.19	0.01	0.09	0.13	0.34	0.03	0.17	0.06	0.25
Household size	4.52	1.62	4.33	1.48	4.72	1.59	4.41	1.93	4.70	1.68	4.38	1.39	4.59	1.69	4.52	1.60
Dependency ratio[a]	0.82	0.70	0.75	0.71	0.80	0.65	1.05	0.81	0.84	0.72	0.71	0.60	0.89	0.76	0.81	0.69
Annual cropland	1373	3594	1659	4672	1450	3903	1469	3377	1454	3860	1160	2602	1028	2654	1414	3688
Perennial cropland	1442	5595	1516	5860	1197	4709	1625	5303	2276	6672	627	3114	1856	7771	1384	5169
Forestland	7109	18572	8219	20662	7626	16595	5470	12864	7128	19467	5578	13720	9240	26688	6805	16912
Residential/ garden land	432	1170	455	1006	470	977	461	848	374	984	441	1711	391	978	439	1202
Water pump	0.36	0.48	0.47	0.50	0.41	0.49	0.30	0.46	0.24	0.43	0.45	0.50	0.21	0.41	0.38	0.49
Electricity generator	0.06	0.24	0.08	0.28	0.04	0.20	0.05	0.22	0.11	0.31	0.03	0.16	0.07	0.26	0.06	0.24
Agri motor	0.03	0.17	0.05	0.22	0.02	0.15	0.03	0.17	0.04	0.19	0.02	0.14	0.04	0.19	0.03	0.17
Tractor	0.79	0.41	0.91	0.28	0.82	0.38	0.56	0.50	0.74	0.44	0.86	0.34	0.75	0.43	0.80	0.40
Computer	0.07	0.26	0.09	0.29	0.10	0.30	0.04	0.19	0.03	0.17	0.12	0.33	0.04	0.19	0.08	0.27
Internet	0.04	0.20	0.08	0.26	0.04	0.19	0.02	0.14	0.01	0.11	0.08	0.27	0.02	0.14	0.05	0.21
Observation	2905		426		570		335		510		641		407		2482	

Note:[a]: all households not adopting a forest-based livelihood, including livelihood groups in column 1, 2,3,4,5. [b]: This ratio is calculated by the number of members aged under 15 and over 59, divided by the number of members aged 15-59.

Source: Authors' calculation from the QSESERPA

Table 3: Household characteristics by forest activity

Livelihood group/ Explanatory variables	With timber forest products (TFP)		Without TFP		With plant (non-timber) forest products (NFTP)		Without plant NTFPs		With animal NFTPs		Without animal NFTPs	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gender	0.88	0.33	0.88	0.32	0.90	0.31	0.87	0.33	0.90	0.30	0.88	0.32
Ethnicity	0.33	0.47	0.28	0.45	0.09	0.29	0.49	0.50	0.13	0.34	0.30	0.46
Age	34.23	7.21	33.85	7.41	33.19	7.19	34.57	7.53	31.40	6.44	34.14	7.44
No education	0.31	0.46	0.32	0.47	0.39	0.49	0.24	0.43	0.44	0.50	0.31	0.46
Primary education	0.24	0.43	0.27	0.44	0.28	0.45	0.25	0.44	0.27	0.44	0.26	0.44
Lower secondary	0.31	0.46	0.28	0.45	0.23	0.42	0.34	0.47	0.22	0.41	0.29	0.45
Upper secondary	0.06	0.24	0.07	0.26	0.06	0.24	0.09	0.28	0.04	0.19	0.08	0.27
Above upper secondary	0.08	0.27	0.06	0.23	0.04	0.20	0.08	0.27	0.04	0.20	0.06	0.24
Household size	4.62	1.75	4.52	1.61	4.74	1.66	4.32	1.54	5.12	1.80	4.46	1.58
Dependency ratio	0.75	0.68	0.83	0.70	0.87	0.72	0.77	0.68	0.96	0.72	0.81	0.70
Annual cropland	1754	3715	1341	3583	1075	3008	1649	4029	1073	3123	1390	3605
Perennial cropland	4321	11106	1205	4799	1155	4826	1750	6293	1287	5879	1468	5581
Forestland	15729	35632	6400	16205	7658	17176	6631	19965	4986	11651	7379	19197
Residential/garden land	624	1157	416	1170	323	736	543	1483	301	915	446	1196
Water pump	0.42	0.49	0.35	0.48	0.22	0.41	0.50	0.50	0.17	0.37	0.38	0.49
Electricity generator	0.05	0.23	0.06	0.24	0.08	0.27	0.04	0.21	0.09	0.29	0.06	0.24
Tractor	0.03	0.18	0.03	0.17	0.04	0.20	0.02	0.15	0.02	0.13	0.03	0.18
Motorbike	0.80	0.40	0.79	0.41	0.72	0.45	0.86	0.35	0.59	0.49	0.81	0.39
Computer	0.10	0.29	0.07	0.26	0.04	0.20	0.11	0.31	0.04	0.19	0.08	0.27
Internet	0.06	0.24	0.04	0.20	0.02	0.13	0.07	0.25	0.00	0.06	0.05	0.21
Observations	221		2684		1445		1434		278		2611	

Source: Authors' calculation from the QSESERPA

3.2. The impact of forest resources on household welfare

As mentioned in Table 2, there is a significant difference in the observable characteristics of those with a forest livelihood and those with other livelihoods. This suggests that there is a potential for selection bias in the sample, which requires us to match households with the same characteristics across groups before estimating the treatment effect. In Table 3, a similar difference is also observed between those with and without forest-dependent income. A balancing property test was conducted and the results satisfied this requirement, which suggests that the matched samples show no difference in the distribution of conditioning characteristics between the treatment and comparison groups. This also confirms that there are no pre-treatment differences between the two groups. Thus, the result confirms that self-selection bias (due to observed characteristics) has been ruled out, complying with the matching requirements for estimating the treatment effect.

The average treatment effect on the treated (ATT) in our study is the difference in income or poverty status between households with and without a forest livelihood or between those with and without forest-dependent income. Thus, the treatment indicates the importance of forest resources to local people. As can be seen in Table 4, the ATT is positive and statistically highly significant. This confirms that households engaged in forest livelihoods would have a higher level of per capita income than those with other livelihoods. The results are robust, even after controlling for differences in observed characteristics that affect the probability of a household being forest dependent. For instance, the result of the average treatment effect shows that households with a forest livelihood would, on average, have about 7.76 million VND more per capita income than those adopting other livelihoods.

The results in Table 4 also indicate that the ATT is positive and statistically significant for other matched samples in any specific control groups. In particular, the ATT is about 10 million thousand VND for the crop livelihood matched sample and about 6.9 million VND for the wage livelihood sample. We also found that participation in some forest activities is positively associated with per capita income. The ATT is about 14879 million VND for households earning from forest timber products. A similar but smaller effect is also observed for households earning from plant and animal non-timber forest products, with the ATT about 1349 million VND and 1461 million VND, respectively. Our results are consistent with the finding for several developing countries, showing the positive effect of forest resources on household income in Bolivia (Uberhuaga, Smith-Hall, & Helles, 2012), rural Pakistan (Ali & Bahadur, 2018) and Uganda (Khundi et al., 2011).

Table 4: Treatment effects on household income

Matched samples	Income per person/year
Forest livelihood vs non-forest livelihood (all other livelihoods)	
Average outcome, treated (N=407)	16590
Average outcome, control (N=2482)	8830
Difference in average outcome, ATT	**7760*** **
	(1980)
Forest livelihood vs nonfarm/livestock livelihood	
Average outcome, treated (N=405)	16652
Average outcome, control (N=426)	10765
Difference in average outcome, ATT	**5887** **
	(2794)
Forest livelihood vs non-labor income	
Average outcome, treated (N=407)	16590
Average outcome, control (N=335)	6395
Difference in average outcome, ATT	**10195*** **
	(2059)
Forest livelihood vs crop livelihood	
Average outcome, treated (N=407)	16590
Average outcome, control (N=510)	5868
Difference in average outcome, ATT	**10722*** **
	(2312)
Forest livelihood vs wage livelihood	
Average outcome, treated (N=406)	16623
Average outcome, control (N=641)	9713
Difference in average outcome, ATT	**6910*** **
	(1781)
Forest livelihood vs wage/crop livelihood	
Average outcome, treated (N=405)	16650
Average outcome, control (N=571)	8937
Difference in average outcome, ATT	**7712*** **
	(2099)
With timber forest products (TFPs) vs without TFPs	
Average outcome, treated (N=221)	26041
Average outcome, control (N=2668)	11161
Difference in average outcome, ATT	**14879 *** **
	(3511)
With plant non-TFPs vs without plant non-TFPs	
Average outcome, treated (N=1434)	9356
Average outcome, control (N=1445)	8008
Difference in average outcome, ATT	**1349 ** **
	(648)
With animal non-TFPs vs without animal non-TFPs	
Average outcome, treated (N=405)	8350
Average outcome, control (N=571)	6933
Difference in average outcome, ATT	**1416*** **
	(924)
With environment management services (EMSs) vs without EMSs	
Average outcome, treated (N=405)	8820
Average outcome, control (N=571)	7554
Difference in average outcome, ATT	**1265**
	(1321)
With other forest activities (FRAs) vs without (FRAs)	
Average outcome, treated (N=405)	12660
Average outcome, control (N=571)	10133
Difference in average outcome, ATT	**2526**
	(2301)

Note: *** p<0.01, ** p<0.05, * p<0.1. 1 USD equated to about 21,000 VND in 2016. Estimates using the kernel matching method and bootstrapped standard errors are in parentheses, with 100 replications.

Table 5: Treatment effects on incidence of poverty

Matched samples	Poverty rate
Forest livelihood vs non-forest livelihood (all other livelihoods)	
Average outcome, treated (N=407)	0.57
Average outcome, control (N=2482)	0.68
Difference in average outcome, ATT	**-0.11*** **
	(0.04)
Forest livelihood vs nonfarm/livestock livelihood	
Average outcome, treated (N=407)	0.57
Average outcome, control (N=426)	0.63
Difference in average outcome, ATT	**-0.06**
	(0.04)
Forest livelihood vs non-labor income	
Average outcome, treated (N=407)	0.57
Average outcome, control (N=335)	0.79
Difference in average outcome, ATT	**-0.22*** **
	(0.04)
Forest livelihood vs crop livelihood	
Average outcome, treated (N=406)	0.57
Average outcome, control (N=510)	0.86
Difference in average outcome, ATT	**-0.29*** **
	(0.046)
Forest livelihood vs wage livelihood	
Average outcome, treated (N=405)	0.57
Average outcome, control (N=641)	0.56
Difference in average outcome, ATT	**0.01**
	(0.06)
Forest livelihood vs wage/crop livelihood	
Average outcome, treated (N=407)	0.57
Average outcome, control (N=570)	0.68
Difference in average outcome, ATT	**-0.11*** **
	(0.04)
With timber forest products (TFPs) vs without TFPs	
Average outcome, treated (N=221)	0.33
Average outcome, control (N=2668)	0.59
Difference in average outcome, ATT	**-0.26 *** **
	(0.05)
With plant non-TFPs vs without plant non-TFPs	
Average outcome, treated (N=1434)	0.67
Average outcome, control (N=1445)	0.70
Difference in average outcome, ATT	**-0.03**
	(0.03)
With animal non-TFPs vs without animal non-TFPs	
Average outcome, treated (N=278	0.69
Average outcome, control (N=2661)	0.76
Difference in average outcome, ATT	**-0.07*** **
	(0.04
With environment management services (EMSs) vs without EMSs	
Average outcome, treated (N=131)	0.67
Average outcome, control (N=2582)	0.74
Difference in average outcome, ATT	**-0.09**
	(0.06)
With other forest activities (FRAs) vs without (FRAs)	
Average outcome, treated (N=336)	0.56
Average outcome, control (N=2553)	0.63
Difference in average outcome, ATT	**-0.07**
	(0.05)

Note: *** p<0.01, ** p<0.05, * p<0.1. Poverty measures use the poverty line in 2016. Estimates use the kernel matching method and bootstrapped standard errors are in parentheses, with 100 replications.

The impact of forest-based livelihoods on the poverty head-count index was estimated in Table 5. The ATT result is negative and statistically highly significant, indicating that the poverty rate would be 11% lower if households were to pursue a forest livelihood. The ATT is also negative, statistically significant, and much larger for some matched samples using the other control groups. For instance, the poverty rate for households with a forest livelihood is 22% lower than for households with non-labor income, and 29% lower than for those with a crop livelihood. However, the ATT shows no difference in the poverty rate between households with a forest livelihood and those with a wage or nonfarm/livestock livelihood.

The effect of timber forest products (TFPs) on the poverty rate was also examined, with the ATT being -26%, signifying that households deriving income from TFPs have a much lower poverty level. The same effect is also observed for those with animal non-TFPs, with the corresponding ATT at -7%. This finding is similar to that from rural Pakistan (Ali & Bahadur, 2018) and Bhutan (Rahut et al., 2016). In conclusion, our research findings show clearly the important role of forest resources in income improvement and poverty reduction in the North Central region of Vietnam.

3.3. Factors associated with forest livelihood choice

Table 5 shows factors affecting the choice of a forest livelihood. The odds ratio of secondary education is smaller than one and statistically highly significant for all models, meaning that households whose head has completed secondary education are less likely to pursue a forest livelihood than those without such education. For instance, the odds ratio of secondary education in Model 1 is 0.44, which means that the odds of choosing a forest livelihood (vs all other livelihoods) for households whose head has a secondary education is 0.44 times that of those without such education. A similar trend is also found for households whose head has more than upper secondary education, except in Model 3. The finding suggests that better education tends to encourage households to adopt other livelihoods, rather than relying on a forest livelihood. Table 6 also confirms that households with better education are less likely to make their living from timber forest products and non-timber animal forest products. While our finding is similar to that in Uganda (Khundi et al., 2011) and Bhutan (Rahut et al., 2016), it is in not in line with that from rural Pakistan, which concluded that households with literate heads were more likely to obtain more forest resources (Ali & Bahadur, 2018).

Model 1 in Table 5 shows that the odds of a higher dependency ratio are smaller than one, meaning that households with a higher dependency ratio are more likely to adopt a forest livelihood. Similar results are also found for many models using a different reference or base group, except Models 3 and 6. This implies that a forest livelihood is a less labor intensive

strategy than some other livelihoods, except in Model 3. While households with ethnic majority heads are more likely than those with ethnic minority heads to choose a forest-dependent rather than a crop livelihood (Model 4), the former are less likely to pursue a forest livelihood than a nonfarm/livestock and wage livelihood (Models 2 and 5, respectively). To be precise, the odds that households whose heads are from the ethnic majority group will choose a forest livelihood over a crop livelihood is about 3.4 times greater than for those whose heads belong to ethnic minorities. Interestingly, male-led households are more likely than female-led households to adopt a forest livelihood. For example, the result in Model 1 shows that the odds of choosing a forest livelihood for male-led households are about 3 times greater than for their female counterparts.

Considering the role of land in choosing a livelihood, the odds ratio for annual cropland and residential/garden land is not statistically significant for all models in Table 5, which means that such types of land have no association with any specific type of livelihood. The odds ratio for perennial cropland is larger than one and statistically significant, which shows that it has a positive association with livelihood choice for all models, except for the choice of a non-labor livelihood. This suggests that households with more perennial cropland are more likely to pursue a forest livelihood rather than some other. The positive relationship between farmland and the extraction of forest resources is also found in rural Pakistan (Ali & Bahadur, 2018), which may suggest that owning more assets provides the means to acquire forest resources. The result in Model 1, Table 6, shows that households with more forestland are also more likely to pursue a forest-dependent livelihood rather than choosing any other livelihood. We find that while the ownership of forestland increases the odds of choosing a forest livelihood over a wage or wage/crop livelihood, it has no effect on the choice of a forest livelihood over a nonfarm/livestock, non-income labor and wage livelihood. Specifically, the results in Model 1 show that given a 10% increase in the size of forestland, the odds of choosing a forest livelihood over a non-forest livelihood (employing all other livelihoods as a reference group) would increase by about 11%. The corresponding odds of choosing a forest livelihood over a wage-earning livelihood (Model 4) and a wage-earning livelihood (Model 5) would increase by about 12% and 11%, respectively[2].

[2] Given a 10% increase in the size of forest land, the corresponding difference in the logarithm of the forestland is log (1.01)=0.9531, and the odds of choosing a forest livelihood rather than any other (Model 1) can be expressed in terms of the exponential functions as: exp (1.10*0.9531)= 1.110534≈1.11. The corresponding odds of choosing a forest livelihood over a wage and a wage/crop livelihood is about 1.12 and 1.11, respectively.

Table 5: Logit estimates with odds ratio for determinants of forest-based livelihood choice

Explanatory variables	Forest vs non-forest (1)	Forest vs nonfarm /livestock (2)	Forest vs non-labor income (3)	Forest vs crops (4)	Forest vs wages (5)	Forest vs wages/crops (6)
Primary education	0.97	0.98	2.30*	1.43	0.72	1.18
	(0.249)	(0.366)	(0.778)	(0.389)	(0.241)	(0.411)
Lower secondary	0.48**	0.45*	0.55+	0.45**	0.43**	0.40**
	(0.120)	(0.142)	(0.180)	(0.134)	(0.136)	(0.128)
Upper secondary	0.74	0.51	1.14	1.48	0.81	0.89
	(0.328)	(0.268)	(0.647)	(0.801)	(0.425)	(0.455)
Above upper secondary	0.19**	0.23*	0.55	8.59**	0.08**	0.17**
	(0.083)	(0.166)	(0.248)	(7.145)	(0.039)	(0.099)
Age	1.11	1.31+	1.45**	1.11	0.93	0.91
	(0.107)	(0.183)	(0.155)	(0.112)	(0.110)	(0.085)
Age squared	1.00	1.00+	1.00**	1.00	1.00	1.00
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Household size	0.94	0.90	1.02	0.92	0.90	0.90
	(0.060)	(0.093)	(0.091)	(0.082)	(0.079)	(0.074)
Dependency ratio	1.28*	1.37+	0.70*	1.57**	1.58*	1.24
	(0.155)	(0.234)	(0.117)	(0.268)	(0.290)	(0.213)
Ethnicity	0.74	0.44*	1.16	3.38**	0.46**	0.89
	(0.170)	(0.148)	(0.435)	(1.362)	(0.131)	(0.275)
Gender	3.09**	3.05**	4.36**	1.11	3.94**	3.36**
	(1.062)	(1.242)	(1.679)	(0.410)	(1.813)	(1.401)
Annual cropland	0.96	0.98	0.93	1.00	1.03	1.00
	(0.068)	(0.095)	(0.084)	(0.086)	(0.103)	(0.089)
Perennial cropland	1.17*	1.18+	1.07	1.14+	1.21+	1.28**
	(0.084)	(0.099)	(0.085)	(0.080)	(0.119)	(0.098)
Forestland	1.10*	1.07	1.09	1.06	1.18**	1.09+
	(0.042)	(0.053)	(0.058)	(0.059)	(0.058)	(0.054)
Residential/garden land	1.01	1.04	0.91	0.94	1.09	0.93
	(0.119)	(0.144)	(0.122)	(0.133)	(0.143)	(0.142)
Water pump	0.30**	0.36**	0.20**	0.18**	0.40**	0.27**
	(0.090)	(0.116)	(0.070)	(0.063)	(0.118)	(0.085)
Electricity generator	0.81	0.43+	0.70	0.58	2.36+	1.63
	(0.244)	(0.202)	(0.389)	(0.226)	(1.070)	(0.753)
Tractor	0.57	0.75	0.16**	0.24*	1.05	0.53
	(0.208)	(0.292)	(0.084)	(0.152)	(0.556)	(0.296)
Motorbike	1.28	0.46*	2.88**	1.07	1.17	1.29
	(0.237)	(0.154)	(0.788)	(0.255)	(0.289)	(0.323)
Computer	1.75	1.68	1.40	1.78	1.73	1.42
	(0.911)	(1.071)	(0.926)	(1.214)	(0.874)	(0.862)
Internet connection	0.28+	0.21+	0.25	0.95	0.25*	0.88
	(0.188)	(0.187)	(0.272)	(1.106)	(0.169)	(0.757)
Nghe An	0.57**	0.79	0.27**	0.32**	0.72	0.77
	(0.106)	(0.224)	(0.113)	(0.101)	(0.181)	(0.200)
Ha Tinh	0.91	1.14	0.25**	0.40+	1.02	0.79
	(0.344)	(0.553)	(0.134)	(0.219)	(0.444)	(0.362)
Quang Binh	1.08	1.51	0.23**	0.94	1.25	1.29
	(0.247)	(0.541)	(0.092)	(0.389)	(0.390)	(0.423)
Quang Tri	0.21**	0.38*	0.15**	0.05**	0.35**	0.27**
	(0.053)	(0.149)	(0.069)	(0.018)	(0.125)	(0.086)
Hue	0.32**	0.42*	0.17**	0.15**	0.48*	0.50*
	(0.081)	(0.159)	(0.070)	(0.055)	(0.158)	(0.160)
Constant	0.01*	0.01+	0.00**	0.53	0.87	1.57
	(0.024)	(0.029)	(0.002)	(0.964)	(1.942)	(2.743)
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Observations	2,889	833	742	917	1,048	977

Notes: *** p<0.01, ** p<0.05, * p<0.1. Estimates are given for sampling weights.

Table 6: Logit estimates with odds ratio for determinants of forest activities

Explanatory variables	With timber forest products (TFP) vs without	With plant non-TFPs vs without	With animal non-TFPs vs without
Primary education	0.98	0.88	1.23
	(0.392)	(0.199)	(0.318)
Lower secondary	0.53	0.58*	1.32
	(0.230)	(0.136)	(0.320)
Upper secondary	0.22*	0.92	1.32
	(0.134)	(0.352)	(0.778)
Above upper secondary	0.78	0.36**	0.67
	(0.440)	(0.110)	(0.338)
Age	1.15	1.03	0.87
	(0.136)	(0.067)	(0.079)
Age squared	1.00	1.00	1.00
	(0.002)	(0.001)	(0.001)
Household size	0.94	1.08	1.19**
	(0.070)	(0.050)	(0.078)
Dependency ratio	0.93	1.15	1.04
	(0.148)	(0.112)	(0.141)
Ethnicity	0.73	0.14**	0.17**
	(0.173)	(0.027)	(0.051)
Gender	1.50	1.15	1.59
	(0.552)	(0.295)	(0.605)
Annual cropland	1.00	0.86**	0.94
	(0.075)	(0.044)	(0.076)
Perennial cropland	1.28**	1.00	1.04
	(0.087)	(0.037)	(0.062)
Forestland	1.18**	1.05+	1.00
	(0.055)	(0.030)	(0.044)
Residential/garden land	1.42**	0.85*	0.88
	(0.163)	(0.069)	(0.108)
Water pump	0.72	0.85	1.14
	(0.238)	(0.149)	(0.261)
Electricity generator	0.87	1.01	1.09
	(0.366)	(0.226)	(0.369)
Tractor	0.66	0.80	0.21*
	(0.358)	(0.261)	(0.152)
Motorbike	1.44	0.82	0.64*
	(0.362)	(0.128)	(0.125)
Computer	1.04	0.89	1.47
	(0.703)	(0.281)	(0.911)
Internet connection	1.30	0.49+	0.12+
	(0.993)	(0.201)	(0.147)
Nghe An	2.05*	0.50**	10.40**
	(0.601)	(0.070)	(5.685)
Ha Tinh	2.27+	0.56+	21.21**
	(1.120)	(0.170)	(13.339)
Quang Binh	2.96**	1.20	75.42**
	(1.056)	(0.252)	(42.707)
Quang Tri	1.84+	0.33**	2.33
	(0.613)	(0.059)	(1.392)
Hue	1.67	0.73	10.66**
	(0.543)	(0.144)	(6.148)
Constant	0.00**	1.71	0.10
	(0.002)	(2.135)	(0.178)
Prob > chi2	0.000	0.000	0.000
Observations	2,889	2,889	2,889

Notes: *** p<0.01, ** p<0.05, * p<0.1. Estimates are given for sampling weights.

We also find that the odds of pursuing a forest livelihood over other types of livelihood are lower for households with water pumps than for those without. While owning an electricity generator is positively linked with the choice of a forest livelihood over a wage-earning livelihood, it is negatively associated with the choice of a forest livelihood rather than a nonfarm/livestock livelihood. Owning a tractor is negatively linked with the pursuit of a forest livelihood over a crop livelihood. Finally, owning a motorbike is also negatively related to the choice of a forest livelihood over a nonfarm/livestock livelihood but is positively linked with the pursuit of a forest livelihood over a livelihood deriving from non-labor income. Finally, it is evident that the odds ratio of province dummy variables is smaller than one and statistically highly significant in many models of Table 5. This suggests that the opportunity for choosing a forest livelihood over another is less in Nghe An, Ha Tinh, Quang Binh, Quang Tri and Hue than in Thanh Hoa.

Unsurprisingly, the odds ratio of some education variables is statistically highly significant and smaller than one in Table 6, meaning that better education lowers the odds of participating in some forest-related activities. For example, the odds of earning from timber forest products for households whose head has completed upper secondary education are 0.22 times greater than for those without education. Also, the odds of earning a living from non-timber forest products among those whose head has more than upper secondary education are 0.36 times greater than among those without education. We also find that households whose heads come from the major ethnicity groups are less likely to make a living from plant and animal non-timber forest products. Households with more forestland are also more likely to earn from timber forest products. The ownership of tractors, motorbikes and internet access are negatively linked with a livelihood based on animal non-timber forest products. We found great differences across provinces in opportunities for making a living from non-timber animal forest products. For instance, the odds of households in Quang Binh earning their living from these products are about 75.41 times those for households in Thanh Hoa. This suggests that opportunities for participating in some forest activities vary greatly across provinces.

4. Conclusion and policy implications

In this paper, we investigate the causal effect of forest resources on household welfare. We employed a propensity score matching (PSM) method to estimate the impact of forest resources on income and poverty. The main advantage of this approach is that it can correct for potential selection bias that might arise due to systematic differences between households pursuing a forest livelihood and those not doing so, as well as between those taking advantage (or not) of various forest resources. Controlling for factors associated with forest livelihood choice, the

gap of average income per person is about 7.760 million VND between the sub-samples of households choosing or not choosing a forest livelihood. Also, the difference in the poverty rate between these groups is about -11%.

Interestingly, we find that households with a forest livelihood earned higher income than those with any other livelihood. The former also have a poverty rate lower than that of households with wage/crop, crop livelihoods, or non-labor income. This finding suggests that pursuing a forest livelihood results in higher income and a lower poverty level for local households. We further investigate the impact of participation in some forest activities on income and poverty. On average, households with timber forest products have a much higher level of income and lower level of poverty than those without, with a difference in income and poverty level about 14.90 million VND and -26 percentage points, respectively. In addition, households with non-timber plant and animal forest products earned higher income than those without, while earning from non-forest timber animal products also helped reduce poverty levels.

Moreover, we find that the opportunity for acquiring forest resources is largely affected by certain household characteristics. The availability of more forestland and perennial cropland increases the likelihood of choosing a forest livelihood and related activities, such as timber production. Household heads with better education were found to be less likely to pursue a forest livelihood and engage in various forest activities. Households headed by individuals from ethnic majorities were more likely to choose a forest livelihood over a crop livelihood but were less likely to choose a forest livelihood over a nonfarm/livestock and wage-earning livelihood. Households whose heads were from ethnic majorities were also less likely to earn from non-timber forest products.

Notably, our study confirms that opportunities for acquiring forest resources vary greatly across provinces. For instance, opportunities for households to choose a forest livelihood are less in Nghe An, Ha Tinh, Quang Binh, Quang Tri and Thua Thien Hue, than in Thanh Hoa. However, the likelihood of earning a living from timber forest products is higher in Nghe An, Ha Tinh, Quang Binh and Quang Tri than in Thanh Hoa. Similarly, the probability of earning from non-timber forest products is much higher in Nghe Anh, Ha Tinh, Quang Binh and Hue than in Thanh Hoa. The varying opportunities for exploiting forest resources among households and provinces suggest that there are potential barriers hindering local households from pursuing a forest livelihood or benefiting from some forest activities. Accordingly, government policy and regulations on forest management should focus on improving the access of households to forest resources, at the same time enhancing the sustainability of forest

resources. This approach can help improve local livelihoods as well as maintain forest resources for later generations.

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