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ORIGINAL PAPER

Indigenous pig production and welfare of ultra-poor ethnic minority households in the Northern mountains of Vietnam

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Abstract
Eliminating ultra-poverty has received particular attention of policymakers and scholars. The ultra-poor in mountainous regions often live on subsistence farming and natural resource extraction. One of the sustainable ways to support them is to find alternative livelihood options that reduce natural resource extraction and increase household income. During the last decades, Vietnam has reduced its poverty significantly. However, the ultra-poor still exist especially among ethnic minority groups in the northern mountains, increasing pressures on already degraded forest resources. This paper assessed the contribution of indigenous pig production to the welfare of ultra-poor ethnic minority households using the propensity score matching method and identified the factors affecting indigenous pig production using generalized Poisson, negative binomial and binary logistic regression models. The analysis was based on the data of 495 rural households surveyed in 2019. Results showed that (1) indigenous pig production had significant and positive effects on household income of and multidimensional poverty reduction among ultra-poor ethnic minority households and (2) the factors positively affecting indigenous pig production are access to credits, number of motorbikes, government support under the poverty reduction programs, road type at the villages, and irrigation systems, while the effects of distance from home to the nearest agricultural input shops and access to the national electricity are negative. We suggest the government to continue improving irrigation systems, road conditions and access to national electricity grids in this mountainous region.

Keywords Sustainable poverty reduction · Propensity score matching · Generalized Poisson regression · Negative binomial regression · Ultra-poor households

JEL Classification I32 · I38 · Q18 · O18

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1 Introduction

Livestock production at the small (household) scale is encouraged in mountainous regions of many developing countries because it promotes economical, social, and environmental sustainability (Ness et al., 2007). In mountainous regions, local people often rely on crop production that is insufficient for their livelihoods and on extraction of forest and other natural resources. However, forests have been degraded and crops have low productivity. Thus, livestock production could be a viable option to increase rural household welfare. In addition, small-scale livestock production does not pollute the environment as its wastes are used as manure for crop cultivation. In this regard, small-scale livestock production is complementary to cop production and reduces pressures on already degraded forest resources.

Within various types of livestock, small-scale pig production plays multiple roles in the livelihood improvement of rural households and the economy of densely populated developing countries like Vietnam where lands for crop production and for pastures are scarce (Delgado et al., 1999; Herrero et al. 2013; Baltenweck et al. 2018). Pig production provides animal protein to supplement consumers' meager diets (Murphy and Allen, 2003). It is also a source of income (Johannesen and Skonhoft, 2010; Do et al., 2019) through the sale of live pigs and other pig products, such as pork or sausages. Besides, pig wastes are also used as manure to improve soil fertility and thus contributing to greater crop production (Nguyen et al., 2016; Do et al., 2021). It also serves as an alternative source of savings and as an unconventional form of insurance, allowing rural households to sell their assets in times of need (Hoddinott, 2006; Kazianga and Udry, 2006; Mogues, 2011).

Vietnam has shown significant economic growth and poverty reduction through the recent years (Nguyen et al., 2021). Over the period from 2002 to 2011, its average annual gross domestic product (GDP) growth reached 7.2% (Berliner et al., 2013). Poverty reduction in Vietnam was evident as the poverty headcount rate declined from 57% in the early 1990s to 13.5% in 2014 (UNDP, 2018). The Government of Vietnam (GOV) has undertaken various poverty reduction programs such as Program 135 which aims to improve the living conditions of ethnic minorities. In November 2015, the GOV established a national multidimensional poverty measurement program for the period 2016–2020, marking an important step in Vietnam's transition from an income-based to a multidimensional poverty approach, which includes both income and non-income dimensions. The five dimensions of multidimensional poverty are: health care, education, housing, water and sanitation, and information access (Duc, 2019). Each dimension has two equally weighted indicators. A household is considered multidimensionally poor if it is deprived from at least three indicators (Duc, 2019). The multidimensional poverty rate in Vietnam was only 5.23% in 2018 (MOLISA, 2019). However, the achievements in poverty reduction are not homogeneous among regions and ethnic groups. The poverty rate among ethnic minorities decreased only by an average of 3–4% per year, but the areas resided by ethnic minorities such as the Northern mountains of Vietnam remain the core poor place of the country. By the end of 2018, ethnic minorities accounted for 12.51% of Vietnam's population. The results of poverty reduction were not sustainable, and the rate of re-poverty is still high (GOV 2019). In particular, the livelihoods of ethnic minorities are becoming more vulnerable as forest resources— one of their important livelihood sources—are degraded (Bierkamp et al., 2021). Thus, supporting ethnic minorities out of poverty is of critical importance.

Small-scale pig production has been very popular in Vietnam. Many Vietnamese pig breeds are indigenous such as Mong Cai, Muong Khuong, Soc, Meo and Co. These pig

breeds have unique characteristics, such as early sexual maturity, good adaptability to severe raising conditions and insensitivity to poor feeding practices (Dang-Nguyen et al., 2010). Indigenous pigs are more resistant to diseases and other shocks compared to other pig breeds (Huyen et al., 2019). Even though their productivity is low, their meat is preferred by consumers. Small-scale indigenous pig production also requires low investment. Thus, these breeds are normally chosen by poor households in the mountainous areas of Vietnam.

Although there have been several studies on poverty of ethnic minority households in Vietnam (Van de Walle and Gunewardena, 2001; Dong et al., 2005; Baulch et al., 2007; Baulch et al., 2011; Imai et al., 2011; Pham et al., 2011; Baulch et al., 2012; WB, 2012; Tuyen, 2014; Nguyen et al., 2017; Do et al., 2019), the relationship between production of indigenous pig breeds, which are locally available and well adapted, and poverty reduction have not yet been studied. Hence, this study aims to contribute addressing this gap. We focus on the poorest section of the ethnic minority poor (ultra-poor). The ultra-poor, defined as those individuals either eating less than 80% of their energy requirements despite spending at least 80% of their income on food (Lipton 1986) or earning less than US$1.25 per capita income per day (Marston and Grady 2014; Banerjee et al. 2015), are most vulnerable to seasonal fluctuations in food supply and wage employment and seasonally induced nutrition and health risks. Specifically, we look for the answers to the following research questions: (1) how does indigenous pig production contribute to improving the welfare of the ultra-poor? And (2) what are the factors affecting indigenous pig production by these poor households? The answers to these research questions would provide significant inputs in formulating policies and programs for supporting and improving the lives of the poorest in Vietnam.

1.1 Study area and data collection

The Northern mountains of Vietnam, considered the poorest region of the country (Nguyen et al. 2019), are home to many ethnic minorities including H'Mong, Tay, Dao, Thai, Muong. Some of these minorities have a population of less than 10,000 persons such as Ha Nhi, Mang, Cong, La Hu, Lo Lo, and La Ha. Of the three million households in the region, 1.7 million households belong to ethnic minority groups. The multidimensional poverty rate in the region is about 14.7%, around three times higher than the country's average. Moreover, around 85% of the ethnic minority households are poor (more details in Table 7). More importantly, they are very vulnerable to poverty due to the dependence on common pool forest resources which have been increasingly degraded. Therefore, finding a solution to support them to be permanently out of poverty is of critical importance.

The data used in this study are extracted from a survey conducted at the beginning of 2019 within the research project entitled "*Major solutions for sustainable poverty reduction in ethnic minority and mountainous regions of Vietnam by 2030*". The project was funded by the Committee of Ethnic Minority Affairs of Vietnam. The study areas are four provinces with high poverty incidences in the Northern mountains, namely Son La and Lai Chau (in the Northwest), and Cao Bang and Ha Giang (in the Northeast) (Fig. 1).

A three-stage procedure for data collection was used for this study. The first stage was to select sampled districts. Based on district profiles and consultation with local experts, we selected two districts in each province based on the following criteria: (i) representative in term of ethnic minority groups in the province and region, (ii) high poverty incidence of ethnic minorities, especially ultra-poor households, and (iii) high potential for indigenous

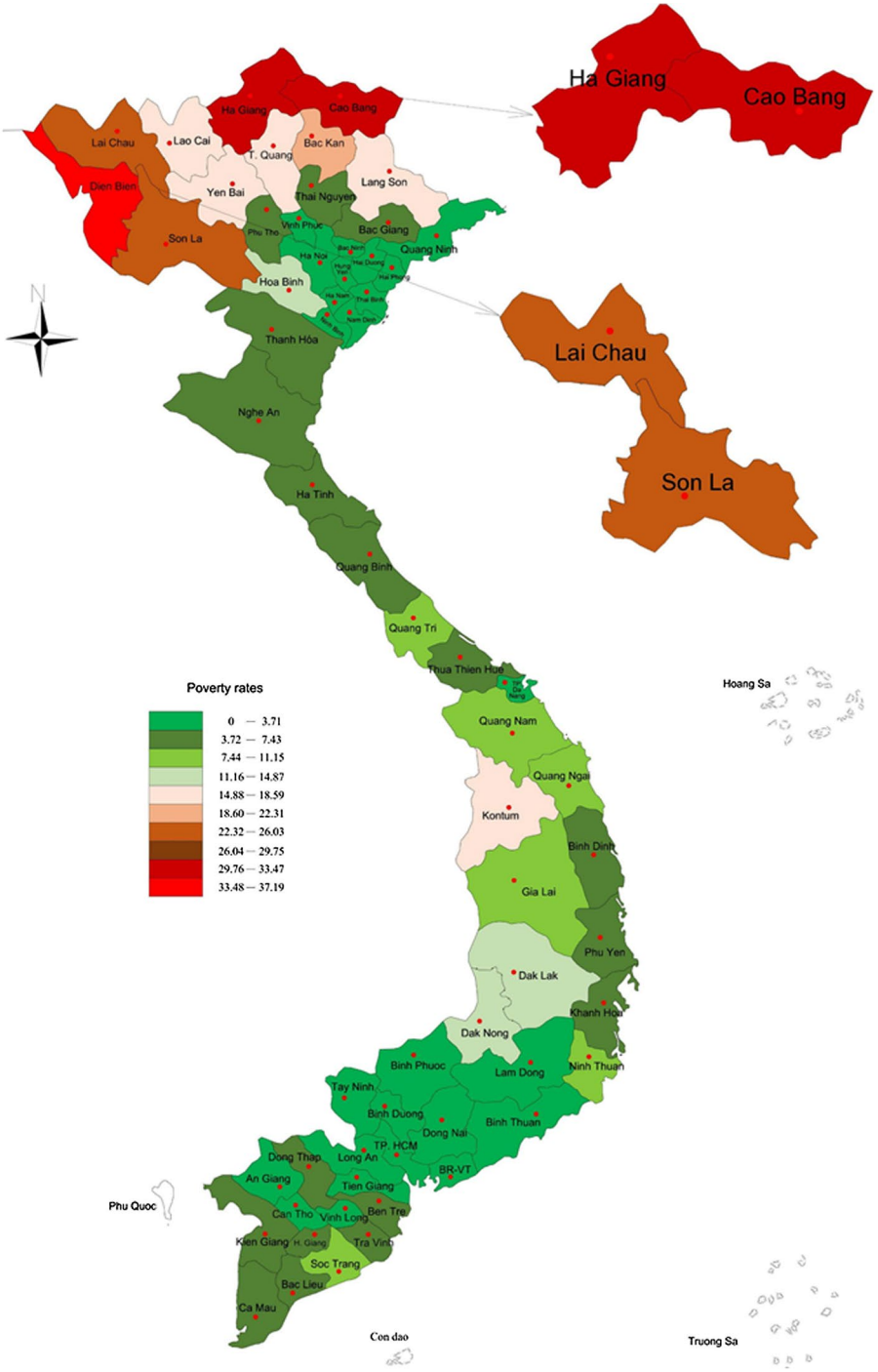

Fig. 1 Vietnam's poverty and the study sites of Son La, Lai Chau, Cao Bang and Ha Giang provinces. *Source*: Developed by the research team based on the household multidimensional poverty rate in 2018

pig production (based on pig density). The selected districts are Bac Yen and Quynh Nhai districts of Son La province, Bao Lam and Bao Lac districts of Cao Bang province, Quan Ba and Bac Me districts of Ha Giang province, and Nam Nhun and Muong Te districts of Lai Chau province. In the second stage, two villages in each selected district were selected following the similar criteria as described above. During the last stage, 20 to 30 households in each selected village were randomly chosen from a list of households provided by village leaders. This allows us to set up a cross-sectional data set of 530 households (167 households in Cao Bang province, 148 households in Son La province, 105 households in Ha Giang province and 110 households in Lai Chau province). After excluding the households with missing quantitative information, the final sample for the analysis includes 495 households.

Two questionnaires were used to gather data. The village questionnaire captures village-level data on population, infrastructure and other socioeconomic indicators of the village. The household questionnaire documents livelihood information at the household level, including livelihood assets (human, physical, social, natural and financial capital), livelihood activities (farming, non-farm self-employment, off-farm way employment and other income generating activities) and livelihood outcomes. The subsidies/support they have received from various governmental programs for the poor were also documented. The household questionnaire also includes a section on inputs and outputs of indigenous pig production and expenditures during the last 12 months of 2018. Besides, as shocks are considered one of the main factors pushing rural households to be poor in Vietnam (Nguyen et al., 2017; Do et al., 2019; Nguyen et al., 2020; Do et al., 2020), another section was designed for sampled households to report negative circumstances that the households faced during the last three years. These events are categorized into three groups, namely weather shocks, health shocks and other shocks (e.g., market shock). Weather shocks contain floods, droughts, landslides and storms. Health shocks consist of events as illness or death of household members. In addition, in each village, a group meeting was organized with villagers to discuss the advantages and disadvantages of indigenous pig production in each village.

2 Data analysis

2.1 Conceptual framework

We used the sustainable livelihoods framework (Carney, 1998; Ashley and Carney, 1999; Nguyen et al., 2018) as the conceptual framework to analyze the impact of indigenous pig production on household welfare such as income and poverty reduction and to examine the factors affecting indigenous pig production. The framework consists of three components: livelihood assets, livelihood strategies and livelihood outcomes (Fig. 2). Starting from the top of the figure, a rural household has five key livelihood assets, namely human, social, natural, physical and financial capital. The rural household chooses its livelihood strategies depending on its assets, the local infrastructure (e.g., physical accessibility) and the vulnerability context (such as income shocks) it faces. Once the selected livelihood strategies have been undertaken, the rural household gets a specific level of livelihood outcomes such as income (Nguyen et al., 2015).

In this framework, pig production is a livelihood activity. Therefore, it is theoretically affected by household assets and the conditions of the living environment,

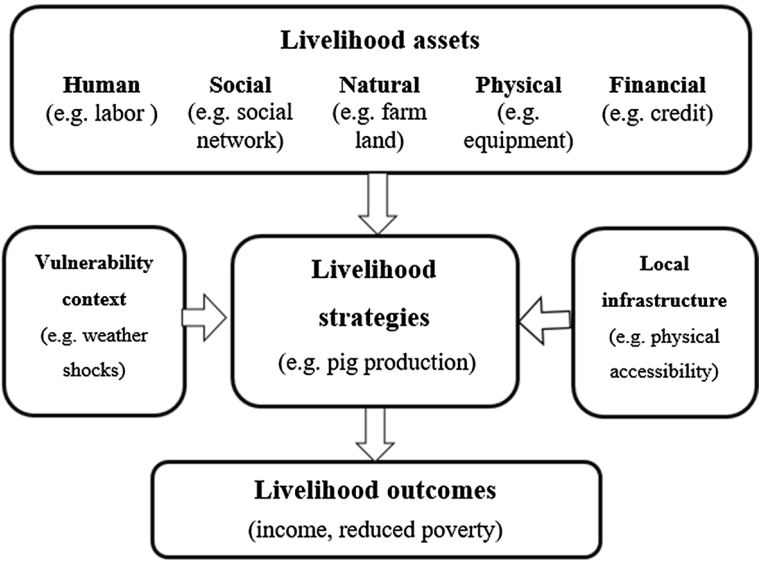

Fig. 2 The conceptual framework for the study

including supports from the national or local governments. It affects the welfare of households through three channels. First, it provides meat for home consumption. Second, it provides cash income from sales. Last, its wastes can be utilized as manure to improve soil fertility. Obviously, the factors affecting indigenous pig production and its impacts to welfare are closely related and require empirical analysis.

2.2 Evaluating the impact of pig production on household welfare

The Average Treatment Effect on the Treated (ATT) was used to assess the impact of indigenous pig production on household welfare. The outcome variables (daily income per capita, total household income and headcount poverty indices) between the treatment and control groups were compared. To measure the impact of pig production on the outcome variables, three cases were estimated using ATT, namely, the base case, Case 1 and Case 2. For the base case, the treatment group includes the households with at least one pig while the control group includes the households without pigs. For case 1, the treatment group includes the households with at least two pigs and the rest of sampled households belong to the control group. For case 2, the treatment group includes the households with at least three pigs and the rest of households belong to the control group.

The propensity score matching (PSM) method was used to match the households between the treatment and control groups for each case. This method allows us to correct biases from observed characteristics and to address the endogeneity problem on the estimated ATT via the following Probit model:

$$P(X) = \Pr\left(D_{ij} = 1 | X_{ij}, S_{ij}, VL_j, P_{fe}\right) \tag{1}$$

The dependent variable of Eq. 1 denotes the probability that household i in village j has at least one pig for the base case, has at least two pigs for case 1, and has at least three

pigs for case 2 (the treatment group). The dummy variable (D_{ij}) equals one if household i in village j is in the treatment group and zero otherwise. Observable household livelihood assets are represented by X_{ij}, whereas observable village characteristics are represented by VL_j and the number of income shocks that the household faced during the last three years is represented by S_{ij}. P_{fe} is a vector of factors that are unobservable but possibly influence the household decision at the provincial level.

The outcome variables were then estimated via three matching methods, nearest-neighbor matching (NNM), kernel-based matching (KBM) and radius matching (Radius). The NNM is based on the five nearest neighbor method with common support and replacement. The KBM estimator and the radius estimator are measured with common support and with bandwidth 0.06. For KBM and the radius, bootstraps were used for 1,000 replications to estimate standard errors for assessing the variability of propensity score matching estimators. For the NNM, as the standard bootstrap is not valid (Abadie & Imbens, 2008), the standard errors were not bootstrapped.

Different quality checks were performed upon testing the aforementioned matching methods. A considerable overlap in the common support was found. The histograms presented in Fig. 3 show the estimated propensity scores for the treatment and control groups and indicated that the common support condition was matched for all three cases. Table 11 presents the results of covariate balancing tests before and after matching. The standardized mean differences (Caliendo and Kopeinig 2008) for overall covariates (from 18.4 to 24.7%) before matching have been reduced (to 4.0 to 6.4%) after matching. Besides, the percentages of bias reductions are in the range of 65 to 84% through matching. Since the *p-values* of the likelihood ratio tests are greater than 0.1, the joint significance of covariates is consistently rejected after matching but not before matching. The pseudo-R^2 also decreased significantly from 21.7 to 23.2% before matching to 1.1 to 2.6% after matching. Thus, the proposed specification of the propensity scores was successful in terms of balancing the distribution of covariates between the treatment and control groups. Among the important findings were: (1) low mean standardized bias; (2) high percentage of bias reduction; (3) insignificance of the likelihood ratio test; and (4) low pseudo-R^2. Based on the propensity scores, the impact of indigenous pig production on household welfare is modeled as follows:

$$ATT = E\left(O^T|D = 1, P(X)\right) - E\left(O^C|D = 1, P(X)\right) \tag{2}$$

where C and T denote the treatment and control groups, respectively. O represents the outcome variable which includes daily income per capita, total household income, and headcount poverty indices.

2.3 Identifying the determinants of indigenous pig production

Regression models were used to assess the factors affecting pig production of rural ultra-poor households. First, the following poisson regression model (Gujarati, 2004) was used to examine the factors affecting the number of pigs raised by a household in 2018:

$$Y_i = E\left(Y_i\right) + u_i = E(Y_i|X_{ij}, S_{ij}, VL_j, P_{fe}) + u_i \tag{3}$$

where Y_i denotes the number of the pigs of household i. X_{ij}, S_{ij}, VL_j, and P_{fe} are as in Eq. 1, and $u_i$is the error term. As our likelihood ratio test results showed that the generalized Poisson regression and negative binomial regression models performed better than the Poisson

model; we used these models to examine the factors affecting the number of pigs of rural ultra-poor households. We also used the robust option to control for possible heteroscedasticity in these models.

In addition, as it was found out that having at least two pig contributes significantly to reducing poverty in the mountainous areas, we used a binary logit regression model to examine the factors affecting the decision of the household to have at least two pigs or not. The model used the following equation:

$$P_{ij}\left(Q_{ij}=1|X_{ij},S_{ij},VL_j,P_{fe}\right)=\frac{e^{\theta_0+X'_{ij}\theta_1+S'_{ij}\theta_2+VL'_j\theta_3+P'_{fe}\theta_4+\varepsilon_i}}{1+e^{\theta_0+X'_{ij}\theta_1+S'_{ij}\theta_2+VL'_j\theta_3+P'_{fe}\theta_4+\varepsilon_i}} \tag{4}$$

where Q_{ij} is a binary variable that is equal to 1 if the number of indigenous pigs of household i in village j is greater than one and equal to 0 for otherwise. X_{ij}, S_{ij}, VL_j, and P_{fe} are as in Eq. 1 and ε_i *is* an error term. The robust option was also used to control for possible heteroscedasticity in this model.

For the independent variables, we used different variables to represent human, financial, physical, social, and natural capital. Human capital was represented by ethnicity, age, gender, and education level of the household head, household size, and household labor. Financial capital was represented by the household's access to credit. The number of motorbikes of the household represents physical capital. Social capital was represented by the number of mobile phones used by household members, the number of socio-political groups that household members participate in and the support that the household receives from national and local government and non-government organizations. Natural capital was represented by the farmland size and perennial land size that the household owns. Income shocks were separated into three groups, namely weather, health and other shocks.

At the village level, four variables were included: a dummy variable of the physical accessibility of the village, the distance from the village to the nearest agricultural input shop, the share of farmland that the irrigation system can provide water for crop production and a dummy variable on household's access to the national electricity grids. The dependent and independent variables are summarized in Table 8. Even though the number of the explanatory variables is high, the variance inflation factor (VIF) values signal no serious multicollinearity issues (see Table 10).

3 Results and discussion

3.1 Description of household pig production groups

Table 1 captures the differences in household assets and village characteristics between the group of households who have at least one indigenous pig and the other group of households having no pigs. The Mann–Whitney and Chi-square tests showed that a number of household assets and village characteristics are statistically different between the two groups. The group with indigenous pig production is characterized by: (1) a higher share of male-headed households, (2) a higher share of household heads from a very minority group (e.g., Ha Nhi, Mang, Cong, La Hu, Lo Lo, La Ha), (3) higher numbers of laborers and household members, (4) higher numbers of motorbikes and phones, larger perennial land size, higher numbers of other shocks and (5) lower numbers of weather and health shocks as compared to the group without pig production. Regarding village characteristics,

Table 1 Basic household assets and village characteristics

Variable	Pig group (n = 229)		No-pig group (n = 266)		Statistic test
	Mean	SD	Mean	SD	
Human capital					
Ethnic	0.58	0.50	0.44	0.50	9.18^{**c}
Gender	0.91	0.28	0.84	0.37	5.59^{**c}
Age	40.76	11.54	39.73	12.07	1.13^{b}
Education	2.49	1.21	2.43	1.27	0.54^{a}
Labor	2.92	1.26	2.57	1.28	3.33^{***b}
Hhsize	5.02	1.57	4.58	1.72	2.82^{**b}
Natural capital					
farm_land_size	0.56	0.54	0.61	0.59	-0.71^{b}
perennial_land_size	0.07	0.24	0.04	0.17	1.77^{*b}
Social capital					
SPO ^{a}	23.58	42.54	29.70	45.78	2.34^{c}
policy	0.66	0.48	0.69	0.46	0.61^{c}
n_mobile	1.81	1.16	1.36	1.07	4.81^{***b}
Physical capital					
Motorbike	1.01	0.60	0.74	0.56	4.93^{***b}
Financial capital					
Access_credit	0.62	0.49	0.64	0.48	0.27^{c}
Shocks					
n_weather_shock	0.69	1.31	0.96	1.43	-3.05^{**b}
n_health_shock	0.31	0.57	0.43	0.69	-2.02^{**b}
n_other_shock	0.71	0.93	0.66	1.05	1.71^{*b}
Village variables					
Roadtype	0.45	0.50	0.58	0.49	8.15^{**c}
shop_dist	16.27	15.41	19.76	20.00	-1.37^{b}
Watersys	0.56	0.19	0.60	0.15	-2.35^{**b}
Electricity	0.72	0.46	0.91	0.29	29.82^{***c}

*Significant at 10%, **significant at 5%, ***significant at 1%; SD is standard deviation

[a]Ttest

[b]Nonparametric two-sample test: Mann–Whitney U test

[c]Chi-square test. Policy share means the share of the population that have received the supports from the government through poverty reduction programs

the former resides closer to the district/commune's shops where they can purchase agricultural inputs, experience worse road conditions and have poorer access to both irrigation and electricity compared to the latter.

Household income of the surveyed households is mainly from crop and livestock production. There is a significant share of income from pig production among ultra-poor ethnic minority households. Pig income is measured by total revenue minus total cost. The total revenue is equal to the value of the pigs' live weight raised in one year. Total costs consist of expenditures for food, breeds, veterinary treatments, depreciation and loan

interest. It is noted that forest income of the group without pig production is several times higher than that of the group with pig production (Table 2). Total income of the household group with pigs was found significantly higher than that of the household group without pigs. However, the income per capita is not significantly different between the two groups. As Nguyen (2012), Tran (2016) and Nguyen et al. (2017) showed ethnic minority households in the Northern mountains of Vietnam have fewer opportunities for incomes from wage and non-farm employment compared to other regions.

3.2 Pig production in the study areas and sampled households

The pig sector plays an important role in household livelihoods in all selected provinces and the whole region (see Table 9). Pig population and live weight of pigs increased throughout the 2014–2018 period, except for Cao Bang province. In the mountainous regions, farmers chose indigenous pigs for income generation and home consumption, especially indigenous black pig breeds like Muong Khuong, Meo, Lung Pu black pigs. The major feed source for indigenous pigs was crop residue feeds and household and agricultural by-products. So, the production cost is low.

Even though indigenous pig production plays an important role in generating income and nutrients for ethnic minority people in the Northern mountains of Vietnam, it is mainly reared by small farmers (more than 87% of surveyed households with less than 5 pigs per raising time) (Table 3). The results of the focus group discussion with pig farmers show that the major constraints include lack of technical knowledge on pig production, poor access to proper veterinary services, lack of quality piglets and high piglet prices, lack of availability of good breeding boars, the inbreeding and natural farrowing status in sows, and lack of market linkages. These constraints need to be solved to enhance economic performance in pig production of households in the region.

Table 4 shows that the variable costs of indigenous pig production are low because the pig's main feed sources are agricultural by-products such as vegetables, banana trees, corn and grazing. These feeding sources used by the poor for pigs are available on their farms. The results of cost–benefit analysis showed that there was a positive relationship between

Table 2 Annual household income by income source in 2018 (in USD)

Income source	Pig group (n = 229)		No-pig group (n = 266)		Statistic test
	Mean	SD	Mean	SD	
Crop income	456.93	379.75	378.38	428.06	4.07***[a]
Other livestock income	525.75	462.85	331.76	375.16	6.23***[a]
Pig income	177.65	163.93	0.00	0.00	15.84***[a]
Forest income	20.81	64.66	156.13	381.02	− 2.49**[a]
Government salary	40.79	335.48	33.12	278.67	0.31[a]
Labor rented income	326.00	622.90	328.37	597.05	− 0.28[a]
Other income	59.12	198.37	122.49	496.83	− 0.21[a]
Total income	1,607.05	1,085.10	1,350.25	957.39	2.90**[a]
Income per capita	340.32	235.29	334.49	271.57	1.39[a]

*Significant at 10%, **significant at 5%, ***significant at 1%; SD is standard deviation

[a]Nonparametric two-sample test: Mann–Whitney U test

Table 3 Indigenous pig production by minority ethnic households

Number of pigs	Number of households	Share (%)	Cumulative share (%)
1	74	32.31	32.31
2	66	28.82	61.14
3	41	17.9	79.04
4	20	8.73	87.77
5	17	7.42	95.2
6	2	0.87	96.07
7	4	1.75	97.82
8	2	0.87	98.69
9	2	0.87	99.56
10	1	0.44	100
Total	229	100	-

Table 4 Cost–benefit analysis of indigenous pig production

	Unit	One pig (n = 74)	from 2 up to 6 pigs (n = 146)	More than 6 pigs (n = 9)
Number of pigs per raising time	Heads	1	3	8
Price per kg of live weight	USD $/kg	3.23	3.32	3.44
Variable costs (VC)	USD $	187.93	520.48	1,288.28
Gross revenue (GR)	USD $	258.32	765.79	1,928.79
Household income	USD $	70.39	245.31	640.51
Net benefit–cost ratio (GR/VC)		1.37	1.47	1.50

the number of pigs (of up to 10 pigs) and the return from indigenous pig production. This can be explained that a higher number of pigs reduce input costs (economies of scale). Moreover, farmers with a large number of pigs might have better networks with local traders; then, he can sell their pigs with higher prices (Table 4).

3.3 Impact of indigenous pig production on the welfare of ultra-poor households

Table 5 shows the ATT of different numbers of pigs on multidimensional poverty rate, income poverty indices and total household income using the matching algorithms described above. The results indicated that having at least one pig improves total household income, but it does not necessarily improve the poverty status. This finding confirms the results from the field survey that the governmental support under the national program on sustainable poverty reduction for poor households which usually provided one sow pig per poor household is not sufficient for poverty reduction. Having at least two pigs (as in the last two columns of Table 5) leads to significant and positive effects on both poverty reduction and income improvement of households. As indigenous pig production continues to be an important economic activity in the Northern mountains, it is recommended that the national poverty reduction program for the poor considers setting a threshold of two indigenous pigs for poor households.

Table 5 PSM estimates of the impact of indigenous pig production on the welfare of ethnic minority households (ATT)

Outcome variable	Matching algorithm	ATT with pig treatment (Base case)	ATT with more than one pig treatment (Case 1)	ATT with more than two pigs' treatment (Case 2)
Multidimensional poverty rate	NNM[a]	−0.033	−0.178***	−0.207***
	KBM[b]	−0.068	−0.156**	−0.248***
	Radius[c]	−0.065	−0.155***	−0.239***
Headcount index with poverty line is 1.25$	NNM[a]	−0.074	−0.118**	−0.251***
	KBM[b]	−0.066	−0.095*	−0.238***
	Radius[c]	−0.065	−0.092*	−0.230***
Headcount index with poverty line is 1.90 US$	NNM[a]	−0.016	0.010	−0.063
	KBM[b]	−0.009	0.002	−0.060
	Radius[c]	−0.009	0.004	−0.053
Daily income per capita in US$	NNM[a]	0.124	0.206**	0.399***
	KBM[b]	0.093	0.173**	0.386***
	Radius[c]	0.091	0.170**	0.372***
Total household income in US$	NNM[a]	250.283**	435.422***	725.488***
	KBM[b]	216.813*	411.972***	736.934***
	Radius[c]	213.137*	410.072***	730.995***

*, **, ***Significant at 10%, 5%, and 1%, respectively, standard errors bootstrapped with 1,000 replications for kernel matching and radius matching,

[a]NNM = five nearest neighbor matching with common support and replacement,

[b]KBM = Kernel matching with common support and band width 0.06,

[c]Radius matching with common support and band width 0.06

These findings are in line with those of previous studies. For example, Deka et al. (2007) found that pig production in the Northeastern region of India contributed significantly to the livelihood of the majority of pig-rearing households. Similarly, Petrus et al. (2011) reported that pig production among communal farmers in Namibia has potential in improving their livelihood and thus helps to achieve the millennium development goals on poverty reduction. Katagame et al. (2017) also reported that pig production has positive effects on household income and poverty reduction of farmers in Papua.

3.4 Determinants of indigenous pig production of the ethnic minority households

Table 6 presents the effects of household, village and provincial characteristics on indigenous pig production. The results showed that households with better access to credit are more likely to have a higher number of pigs compared with other households. This is because a large pig farm size requires a higher level of the initial investment. However, access to credit variable is not significant in the binary logistic regression. This indicates that the existing credit policies to support the poor have insignificant effects on their decision of having at least two pigs. Further, the number of motorbikes has a positive effect on the indigenous pig production. This is because motorbikes are important transport means of the local people in the region. Governmental supports through the national program on sustainable poverty reduction to the poor households in terms of technical services and breeds tend to have significant effects on having at least two indigenous pigs, but it is not significant for increasing the number of pigs. There is a lack of support for the poor with a high number of pigs. At the village level, farmers with better road conditions in the villages and communes are more likely to have pigs since it is easier for farmers to buy inputs and sell outputs of pig production. The distance from home to the nearest agricultural input shop in the commune and district has negative effects on the number of pigs. It means that for farm households living closer to the nearest agricultural input shop producing pigs is more convenient because the inputs for their production is more accessible. In addition, agricultural input shops in the rural and mountainous areas in Vietnam are also the places where farm households not only purchase inputs and sell outputs of pig production but also to exchange information and technical knowledge between farmers and other stakeholders.

The results also showed that the availability of irrigation supports the development of indigenous pig production since pig farmers use crop by-products as feed for pig production. This is important as pig production and crop production are complementary and contribute to reducing production wastes and production costs. However, the share of households with access to national electricity has negative effects on the number of pigs. The households with better access to national electricity might have more opportunities to find an off-farm job. Our findings were consistent with most of the previous studies on livestock assets in general and on pig assets in particular (e.g., Andersson et al., 2011; Katagame et al., 2017; Do et al., 2019).

4 Conclusion

Analysis of the cross-sectional data gathered from the four provinces in the Northern mountains of Vietnam showed how indigenous pig production reduces poverty among ultra-poor ethnic minority households using the propensity score matching method and the factors influencing indigenous pig assets using generalized Poisson, negative

Table 6 Determinants of ethnic minority households' indigenous pig production

Variable	Generalized poisson regression		Negative binomial regression		Binary logistic regression	
	Coefficient	Robust standard error	Coefficient	Robust standard error	Coefficient	Robust standard error
Human capital						
ethnic	0.108	0.145	0.074	0.148	0.186	0.268
gender	0.142	0.216	0.188	0.222	−0.072	0.397
age	0.005	0.006	0.007	0.006	0.008	0.013
education	0.037	0.061	0.033	0.055	0.040	0.107
hh_labor	0.054	0.073	0.029	0.062	−0.112	0.141
hh_size	−0.008	0.049	−0.012	0.046	−0.060	0.094
Natural capital						
farm_land_size	0.020	0.166	0.161	0.157	0.272	0.273
perennial_land_size	0.318	0.239	0.545	0.345	0.345	0.630
Social capital						
SPO	0.145	0.155	0.217	0.157	0.190	0.296
Policy	0.054	0.126	−0.007	0.126	0.450*	0.264
mobile	0.055	0.070	0.041	0.064	0.128	0.133
Physical capital						
motorbike	0.451***	0.113	0.424***	0.110	0.887***	0.249
Financial capital						
access_credit	0.234*	0.135	0.282**	0.133	0.264	0.284
Shocks						
weather_shock	−0.020	0.063	−0.009	0.057	0.081	0.095
health_shock	0.008	0.111	−0.008	0.110	0.259	0.211
other_shock	−0.035	0.068	−0.040	0.068	−0.110	0.135
Village variables						
road_type	0.343**	0.159	0.321**	0.160	0.596*	0.350
distance_shop	−0.010**	0.004	−0.014***	0.005	−0.020**	0.009
watersys	0.017***	0.006	0.015***	0.005	0.024**	0.011
electricity	−0.845***	0.156	−0.745***	0.156	−1.388***	0.330
Province variables						
Son La	−1.430***	0.246	−1.618***	0.252	−2.508***	0.482
Lai Chau	−2.283***	0.301	−2.272***	0.307	−3.675***	0.570
Cao Bang	−0.530**	0.222	−0.739***	0.221	−1.206**	0.470
Constant	−0.732	0.599	−0.557	0.592	−1.056	1.230
Number of observations	495		495		495	
Wald $chi^2(23)$	227.64		180.97		95.66	
Prob > chi^2	0.000		0.000		0.000	
Pseudo R^2	0.131		0.112		0.219	

*, **, ***Significant at 10%, 5%, and 1%, respectively; robust standard errors clustered at the household level

binomial, and binary logistic regressions. The findings indicated that having indigenous pigs significantly improve household income. However, producing less than two pigs has only a significant effect on the total household income, but insignificant effect on poverty reduction. For significant effects on both income increase and poverty reduction, households need to have at least two indigenous pigs. Other factors positively affecting indigenous pig production include the number of motorbikes, access to credit, support from the governmental poverty reduction policy/programs, road conditions, and the availability of an irrigation system. However, the distance from home to the nearest agricultural input shops and the access to the national electricity at the village had negative effects on indigenous pig production.

Our findings lead to several important implications. First, ultra-poor ethnic minority households should be supported to have at least two indigenous pigs. The government should also support a package of services for technical know-how through practical extension and training for the poor to help them cope with pig production constraints. There are some tentative interventions proposed to improve the pig production efficiency of the ultra-poor such as the utilization of agricultural by-products for pig feeds, capacity building in health care services, adoption of scientific breeding, use of artificial insemination, proper use of pig by-products, establishment and expansion of the common interest groups in indigenous pig production for information and knowledge sharing, and coordination in the use of inputs and selling products, application of simple processing techniques to produce various pork products and development of indigenous pork value chain. Second, rural irrigation systems should be developed and the input supply shops should be established. These can bring indirect benefits through the effects on crop production as well as crop–pig production systems. The combined productivity growth in pig and crop production has been a strategy to improve the welfare of the ultra-poor ethnic minorities in many smallholder systems. Third, road infrastructure in the commune and village levels should be paid more attention to and improved in the future to help the poor have better access to the market and sell their agricultural products with higher value. Particularly, roads can connect not only within communes/villages but also among districts and provinces in the region. Finally, promoting ethnic minority households to access credit could help them to cope with shocks and provide opportunity to invest more in pig production which might lead to reducing poverty.

Appendix

See Tables 7, 8, 9, 10, 11; ; Fig. 3.

Table 7 Basic socioeconomic characteristics of the study areas in 2018

Indicators	Unit	Son La	Lai Chau	Cao Bang	Ha Giang	Others	Whole Region
Total land area	(1,000 ha)	1,412.4	906.9	670.1	792.9	5,738.0	9,520.3
Agricultural land area	(1,000 ha)	364.8	110.0	618.7	195.1	832.4	2,120.9
Human population	(1,000 perons)	1,242.7	456.3	540.5	846.5	9,206.7	12,292.7
Total number of households	(1,000 households)	282.4	96.9	126.5	179.9	5,738.0	3,074.3
Nummber of ethnic minority households	(1,000 households)	224.6	77.4	123.1	153.8	5,738.0	1,715.5
Multi-dimensional poverty rate	%	25.4	25.0	30.8	31.2	11.3	14.7
Percentage of the poor ethnic minority households[a]	%	97.7	99.0	99.1	99.4	75.3	84.2
GDP per capita	USD/year	1,732.2	1,439.3	1,177.0	1,046.8	-	-

Source: MOLISA (2019); GSO (2019); Government of Vietnam (2019). [a]Comparison of total number of the poor ethnic minority households over total poor households, GDP: gross domestic products

Table 8 Name and definition of the variables in the regression models

Variable	Definition	Scale
Dependent variables		
Q	1 if the household has pig production, 0 otherwise	Binomial
Y	No. of pigs of the household	Metric
Independent variables		
Household level		
Human capital		
Ethnic	Ethnicity of household head (1 = Very minority group; 0 = otherwise)	Binomial
Gender	Gender of household head (1 = male; 0 = otherwise)	Binomial
Age	Age of household head	Metric, in years
Education	No.of years in school of household head	Metric, in level
hh_labor	No. of household laborers	Metric
hh_size	Household size in persons	Metric
Natural capital		
farm_land_size	Farm land area of household in ha	Metric, in ha
perennial_land_size	Perennial land area of household in ha	Metric, in ha
Social capital		
SPO	No. of social/political groups	Metric
Policy	If the household received the supports from the governmental poverty reduction programs (1 = yes; 0 = otherwise)	Binomial
Mobile	No. of mobile phones of household	Metric
Physical capital		
Motorbike	No. of motorbikes of household	Metric
Financial capital		
access_credit	If households with access to credit (1 = yes; 0 = otherwise)	Binomial
Shocks		
weather_shock	No. of weather shocks during the last three years	Metric
health_shock	No. of health shocks during the last three years	Metric
other_shock	No. of other shocks during the last three years	Metric
Village level		
road_type	Accessible to the village all time (1 = yes; 0 = otherwise)	Binomial
distance_shop	Distance from home to the nearest agricultural input shops	Metric, in km
irri_system	Share of irrigated farmland area/total farmland area	Metric, in %
electricity	If households with access to electricity (1 = yes; 0 = otherwise)	Binomial
Province level		
Son La	If household in Son La province (1 = yes; 0 = otherwise)	Binomial
Lai Chau	If household in Lai Chau province (1 = yes; 0 = otherwise)	Binomial
Cao Bang	If household in Cao Bang province (1 = yes; 0 = otherwise)	Binomial

Table 9 Pig production in the Northern mountains of Vietnam, in period of 2014–2018

Study area	Indicators	Unit	2014	2015	2016	2017	2018	Average annual growth rate (%)
Cao Bang	Head count	1,000Heads	379.4	377.8	344.8	340.6	360.6	(1.26)
	Living weight	1,000Tonnes	23.9	27.1	29.7	26.8	28.0	4.02
Ha Giang	Head count	1,000Heads	460.2	485.4	490.7	485.4	548.7	4.50
	Living weight	1,000Tonnes	21.6	23.1	26.0	27.3	28.7	7.32
Son La	Head count	1,000Heads	514.4	530.3	559.0	553.5	582.5	3.16
	Living weight	1,0000Tonnes	33.3	35.1	38.9	45.6	47.5	9.34
Lai Chau	Head count	1,000Heads	179.4	185.1	199.4	194.7	209.4	3.94
	Living weight	1,000Tonnes	7.9	8.4	9.1	9.7	10.2	6.61
Whole region	Head count	1,000Heads	6,626.3	6,841.5	7,175.5	6,786.8	7,120.2	1.81

Source: GSO (2019)

Table 10 Multicollinearity test

Variable	VIF	1/VIF
Human capital		
Ethnic	1.31	0.76
Gender	1.20	0.83
Age	1.43	0.70
Education	1.34	0.75
hh_labor	2.17	0.46
hh_size	1.93	0.52
Natural capital		
farm_land_size	1.67	0.60
perennial_land_size	1.21	0.83
Social capital		
SPO	1.38	0.72
Policy	1.31	0.76
mobile	1.84	0.54
Physical capital		
Motorbike	1.39	0.72
Financial capital		
access_credit	1.35	0.74
Shocks		
weather_shock	1.38	0.72
health_shock	1.19	0.84
other_shock	1.24	0.81
Village variables		
road_type	3.2	0.31
distance_shop	2.8	0.36
irri_system	2.44	0.41
electricity	1.45	0.69
Province variables		
SonLa	3.58	0.28
LaiChau	3.17	0.32
CaoBang	3.73	0.27
Mean	1.90	

Table 11 Quality test for propensity score matching

Group and matching algorithm	Pseudo R^2 Before matching	Pseudo R^2 After matching	LR test (p-value) Before matching	LR test (p-value) After matching	Mean standardized bias before matching	Mean standardized bias after matching	Percent bias reduction
Basic case: Group of households with pig is Treatment, other group is Control							
NNM	0.232	0.024	0.000	0.919	24.682	5.662	77.059
KBM	0.232	0.017	0.000	0.992	24.682	4.021	83.709
Radius	0.232	0.016	0.000	0.994	24.682	4.061	83.545
Case 1: Group of households with more than one pig is Treatment, other group is Control							
NNM	0.217	0.026	0.000	0.980	18.359	6.354	65.392
KBM	0.217	0.012	0.000	1.000	18.359	5.059	72.446
Radius	0.217	0.011	0.000	1.000	18.359	4.595	74.971
Case 2: Group of households with more than two pigs is Treatment, other group is Control							
NNM	0.236	0.050	0.000	0.970	22.460	7.668	65.862
KBM	0.236	0.040	0.000	0.993	22.460	9.764	56.526
Radius	0.236	0.030	0.000	0.999	22.460	8.630	61.578

[a]NNM = five nearest neighbor matching with common support and replacement,

[b]KBM = Kernel matching with common support and band width 0.06,

[c]Radius matching with common support and band width 0.06

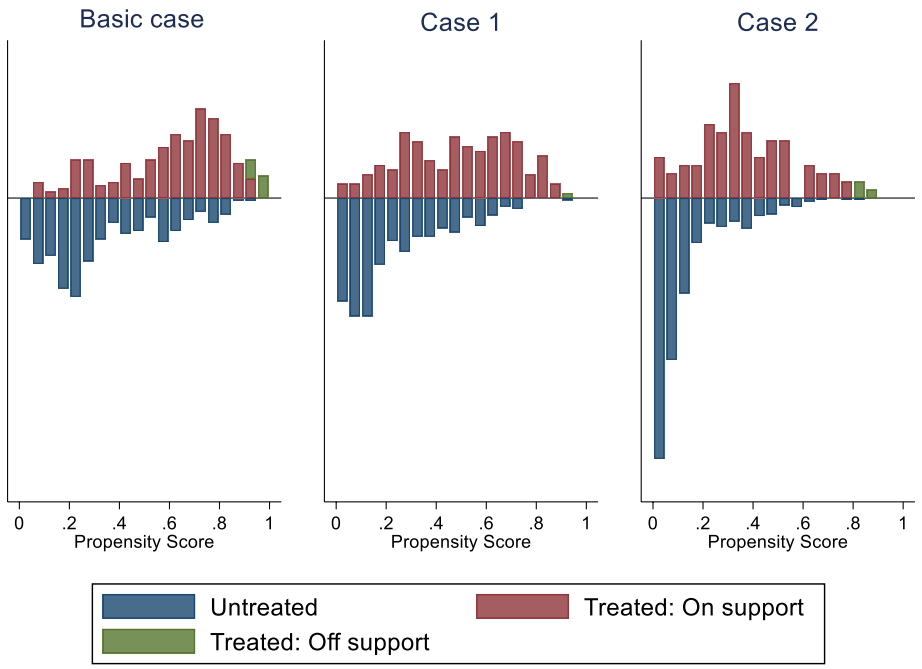

Fig. 3 Propensity score distribution and common support for propensity score estimation by groups. Note: "Treated: on support" presents the households with pig production that have a suitable match, while "Treated: off support" presents the households with pig production that do not have a suitable match, and "Untreated" presents the households without pig production. Basic case is that the group of households with pig production is treatment and the group of households with no pig production is control. Case 1 is that the group of households with more than one pig is treatment and the other households group is control. Case 2 is that the group of households with more than two pigs is treatment and the other households group is control

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Code availability Codes (do-files for STATA 15) could be provided upon request.

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