Livelihood Strategies and Welfare among Rural Households in South-East Asia

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Zusammenfassung

Obwohl die Länder in Südostasien, wie Vietnam, Kambodscha und Laos in den vergangen Jahren erhebliches Wirtschaftswachstum erfahren haben, sind Armut und Hunger weiterhin große Probleme in diesen Ländern. Zusätzlich resultiert das hohe Wirtschaftswachstum in steigende Einkommensungleichheit, da das Einkommen der höher verdienenden Gruppen relativ stärker wächst als das der niedrig verdienenden Einkommensgruppen. Diese Probleme treten insbesondere in den ländlichen Gegenden auf, wo die Haushalte einer Bandbreite an einkommensgenerierenden Aktivitäten nachgehen, wie beispielsweise Ackerbau, Viehzucht, Aktivitäten außerhalb der Landwirtschaft und Nutzung von natürlichen Ressourcen. Die vorliegende Dissertation, bestehend aus sechs Essays, zeigt, wie Strategien für den Lebensunterhalt der Haushalte in Vietnam, Kambodscha und Laos ihre Wohlfahrt in Form von Einkommen und Ernährungssicherung beeinflussen und wie die Haushalte diese Strategien erfolgreich verändern, um sich an die sich stetig verändernden Umweltbedingungen und sozioökonomischen Bedingungen anzupassen.

Kapitel zwei evaluiert den Beitrag tierischer Produktion zur Verminderung ländlicher Armut und untersucht die Einflussfaktoren von Nutztierhaltung mittels Paneldaten aus Vietnam. Die Ergebnisse zeigen, dass tierische Produktion der Armut entgegenwirkt und dass Nutztierhaltung durch die Anzahl an Schocks, die der Haushalt in den vorhergegangenen drei Jahren erfahren hat, sowie durch Zugang zu Krediten, Größe des verfügbaren Ackerlands, Bildung des Haushaltsvorstands, das Bewässerungssystem und dem Zugang zu Elektrizität beeinflusst werden. Wir empfehlen, ländliche Haushalte dabei zu unterstützen, besser mit Schocks umzugehen. Dies trägt dazu bei, die tierische Produktion weiterzuentwickeln und ländliche Armut zu vermindern.

Kapitel drei untersucht die Faktoren, die tierische Produktion beeinflussen mittels eines „Two-Part Fixed Effects“ Models und analysiert den Beitrag tierischer Produktion zur Verringerung von Einkommensungleichheit mittels der Gini-Dekompositions-Methode. Die Untersuchung basiert auf Paneldaten, die durch vier Haushaltsumfragen in den Jahren 2009, 2008, 2010 und 2013 in ländlichen Regionen in drei Provinzen Vietnams durchgeführt wurden. Die Ergebnisse zeigen, dass (i) tierische Produktion positives aber auch negatives Einkommen generieren kann; (ii) dass positives Einkommen durch tierische Produktion ungefähr 11% des jährlichen Gesamteinkommens der Haushalte ausmacht, allerdings nur 7% beträgt, wenn auch das negative Einkommen aus tierischer Produktion berücksichtigt wird; (iii) dass positives Einkommen aus tierischer Produktion die Ungleichheit in ländlichen Einkommen um circa 3.3% reduziert, allerdings nur um 1%, wenn negatives Einkommen ebenfalls einberechnet wird. Wir empfehlen, den Zugang zu Krediten zu erhöhen, die Bildung im ländlichen Raum zu fördern und die Straßen-Infrastruktur auszubauen sowie die ländlichen Haushalte zu

unterstützen, besser mit demographischen Schocks umzugehen, um auf diese Weise tierische Produktion zu fördern und dabei Einkommensungleichheit in ländlichen Regionen zu verringern. Gleichzeitig sollte die Entwicklung von großer tierischer Produktion priorisiert werden.

In Entwicklungsländern hat Beschäftigung außerhalb der Landwirtschaft die Ernährungssicherung ländlicher Haushalte zunehmend verbessert. Im vierten Kapitel legen wir (1) die Faktoren fest, die die Teilnahme an nicht-landwirtschaftlichen Beschäftigungen und nicht-landwirtschaftlichem Einkommen ländlicher Haushalte erklären, indem wir ein ökonometrisches Zwei-Komponenten-Zufallseffektmodell verwenden und (2) die Auswirkungen der nicht-landwirtschaftlichen Beschäftigung auf Indikatoren für die Ernährungssicherung in ländlichen Haushalten untersuchen, indem der Propensity-Score mit dem Differenz-in-Differenzen-Ansatz kombiniert wird. Wir verwenden einen Panel-Datensatz von 561 Haushalten in 30 Dörfern der Provinz Stung Treng in Kambodscha, die 2013 und 2014 gesammelt wurden. Wir teilen unsere Stichprobe in zwei Gruppen ein: Haushalte mit nicht-landwirtschaftlicher Beschäftigung und Haushalte ohne nicht-landwirtschaftliche Beschäftigung. Unsere Ergebnisse zeigen, dass (1) die nicht-landwirtschaftliche Beschäftigung im Durchschnitt etwa 32% zum gesamten jährlichen Haushaltseinkommen für die gesamte Stichprobe beiträgt und zu 57% für die Haushalte mit nicht-landwirtschaftlicher Beschäftigung; (2) die Beschäftigung außerhalb der Landwirtschaft und das Einkommen außerhalb der Landwirtschaft werden erheblich durch das Bildungsniveau der Haushaltsvorstände, die Anzahl der Motorräder und Mobiltelefone, die Straßenverhältnisse in den Dörfern, die Größe der landwirtschaftlichen Flächen, die Anzahl der Einkommensschocks und die Entfernung vom Wohnort zum nächsten Markt beeinflusst; (3) es besteht kein signifikanter Unterschied in Bezug auf die Verfügbarkeit von Nahrungsmitteln zwischen Haushalten mit und ohne nicht-landwirtschaftlicher Beschäftigung, aber erstere verbesserten den Zugang, die Verwertung und die Sicherung von Nahrungsmitteln. Wir schlagen vor, dass die Förderung der ländlichen Bildung, die Unterstützung landwirtschaftlicher Flächen, die Verbesserung der Straßenbedingungen und die Stärkung der ländlichen Haushalte zur Bewältigung von Einkommensschocks durch die Förderung ihres Zugangs zu Krediten zur Entwicklung der nichtlandwirtschaftlichen Beschäftigung beitragen und somit die Ernährungssicherung der ländlichen Haushalte verbessern würde.

Das Verständnis von Strategien für den Lebensunterhalt im ländlichen Raum und die Abhängigkeit von Umweltressourcen kann dazu beitragen, Existenzbelastungen, die durch Umweltzerstörung verursacht werden, zu reduzieren und zu verhindern. Im fünften Kapitel werden die Strategien zur Existenzsicherung von landwirtschaftlichen Haushalten im ländlichen Kambodscha beschrieben und ihre Determinanten mit dem Fokus auf der Abhängigkeit von Umweltfaktoren untersucht. Die Daten stammen aus einer Erhebung von 580 Haushalten in 30 Dörfern der Provinz Stung Treng in Kambodscha, die 2013 durchgeführt wurde. Eine aktivitätsbasierte zweistufige Clusteranalyse wird durchgeführt, um verschiedene Existenzcluster zu identifizieren. Zudem werden Regressionsmodelle durchgeführt, um die Hauptfaktoren zu bestimmen, welche die Wahl der Existenzstrategien und die Extraktion von Umweltressourcen beeinflussen. Die Ergebnisse zeigen, wie die Höhe der Ressourcenausstattung die Existenzsicherungsstrategien ländlicher Haushalte beeinflusst. Umweltressourcen tragen einen erheblichen Teil des Haushaltseinkommens (27%) bei und dienen als Mittel zur Verringerung der Einkommensungleichheit (7%) bei den Haushalten. Das absolute Umwelteinkommen korreliert positiv mit dem Gesamteinkommen, aber das relative Umwelteinkommen sinkt mit einem Anstieg des Gesamteinkommens. So scheint es, dass Haushalte mit niedrigem Einkommen nicht für Umweltzerstörung verantwortlich gemacht werden sollten, weil sie keine Aktivitäten mit hoher Rendite tätigen können. Die Ergebnisse dieser Studie deuten darauf hin, dass die Förderung von nicht-landwirtschaftlichen Arbeitsplätzen, Bildung und sozialen Netzwerken den Abbau von Umweltressourcen verringert.

Kapitel sechs zeigt die Verbindung zwischen der landwirtschaftlichen Produktion und der Entnahme von Rohstoffen aus den Wäldern. Beide Aktivitäten sind in vielen ländlichen Gebieten von Entwicklungsländern nach wie vor die wichtigsten Lebensgrundlagen der Menschen vor Ort. In diesem Kapitel wenden wir die stochastische Frontieranalyse an, um die Effizienz der landwirtschaftlichen Produktion zu bewerten. Um die Wechselbeziehung zwischen der landwirtschaftlichen Produktionseffizienz und der natürlichen Holzgewinnung zu schätzen, verwenden wir ein Simultan-Gleichungsmodell. Wir basieren unsere Analyse auf einen zweijährigen Panel-Datensatz von 430 ländlichen Haushalten in der Provinz Stung Treng in Kambodscha. Wir finden, dass die Entnahme von Rohstoffen aus den Wäldern bei steigender landwirtschaftlicher Produktionseffizienz abnimmt. Unsere Ergebnisse deuten darauf hin, dass die Verbesserung der Effizienz der landwirtschaftlichen Produktion durch die Förderung der ländlichen Bildung und die Privatisierung von Agrarflächen als integraler Bestandteil der Politikmaßnahmen zur Erhaltung natürlicher Wälder betrachtet werden sollte. Der Abbau natürlicher Ressourcen bedroht die nachhaltige Entwicklung in vielen Entwicklungsländern. Um hier ein Lösung anbieten zu können, müssen die Faktoren verstanden werden, die sich auf den Abbau und die Abhängigkeit von Ressourcen sowie auf den ländlichen Wohlstand auswirken.

In Kapitel 7 wird untersucht, welche Faktoren die Reduzierung und die Abhängigkeit von Wald- und Wasserressourcen bestimmen und wie sich diese auf das Wohlergehen ländlicher Haushalte in Laos auswirken. Wir bearbeiten diese Forschungsfragen mit einem ökonometrischen Modell, das die Extraktion und ihre Implikationen gleichzeitig modelliert. Wir verwenden die Daten von 430 ländlichen Haushalten aus einer 2013 durchgeführten Umfrage in 38 Dörfern der Provinz Savannakhet. Unsere Ergebnisse zeigen, dass die Gewinnung von Wald- und Wasserressourcen eine Strategie der ländlichen

Haushalte zur Bewältigung von Schocks darstellt, aber zur Verringerung der Haushaltseinkommensungleichheit beiträgt. Die Entnahme von Ressourcen führt zu höherem Haushaltseinkommen, Konsum und Ernährungssicherung für die Haushalte. Für nicht-extrahierende Haushalte würde die Teilnahme an der Extraktion von Ressourcen zwar die Ernährungssicherung erhöhen, aber ihr Einkommen und ihren Konsum verringern. Wir schließen daraus, dass die Förderung der ländlichen Bildung und außerbetrieblichen Beschäftigungsmöglichkeiten und die Erhöhung der Investitionen in physische Infrastrukturen die Extraktion und die Abhängigkeit von den Ressourcen der extrahierenden Haushalte reduzieren kann. Außerdem könnte so verhindert werden, dass bisher nicht-extrahierende Haushalte gezwungen werden, mit der Entnahme von Wald- und Wasserressourcen zu beginnen.

Stichworte: Lebensgrundlagen, Wohlfahrt, Südostasien.

Abstract

Even through some Southeast Asian countries such as Vietnam, Cambodia, and Laos have experienced remarkable economic growth rates in recent years, they still face high levels of poverty and food insecurity. In addition, the high economic growth rates lead to a higher level of income inequality since the income of the top income groups grows faster than that of the lower income groups. These problems are more serious in the rural areas where households pursue a wide range of livelihood activities such as livestock production, nonfarm employment, and environmental resources. Focusing on the household level, this dissertation shows how households' livelihood strategies impact on their welfare such as income and food security and how households successfully transform their livelihoods to adapt to the rapidly changing natural environment and socio-economic conditions in Vietnam, Cambodia, and Lao in six different essays.

Chapter two assesses the contribution of livestock to reducing rural poverty and examines the determinants of livestock assets with panel data from Vietnam. The findings show that livestock production contributes to reducing poverty and that livestock assets are influenced by the number of shocks that households faced during the last three years, access to credits, farmland size, education of household head, the irrigation system, and access to electricity. We suggest that empowering rural households to better cope with shocks contributes to developing livestock and consequently to reducing rural poverty.

Chapter three examines the factors affecting livestock production by using a two-part fixed effects model and assess the contribution of livestock production to reducing income inequality by using the Gini decomposition method. It uses panel household data obtained from four rural surveys in 2007, 2008, 2010, and 2013 in three provinces of Vietnam. The results show that (i) livestock production can result in both positive and negative income; (ii) positive livestock income contributes about 11% to annual household income, but this figure is only 7% if negative livestock income is included; (iii) positive livestock income reduces rural income inequality by about 3.3% but this figure becomes 1% if negative livestock income is included. We suggest that enhancing access to credits, promoting rural education and road conditions, and empowering rural households to better cope with demographic shocks contribute to developing livestock production and consequently improve income equality in rural areas. In addition, priorities should be given to the development of large livestock.

Nonfarm employment has been increasingly important of improving food security of rural households in the developing world. In chapter four, we (1) determine the factors explaining the participation in nonfarm employment and nonfarm income of rural households by employing a two-part random effects econometric model, and (2) examine the effects of nonfarm employment on rural household

food security indicators by combining the propensity score matching with the difference-in-differences approach. We use a panel dataset of 561 households in 30 villages of Stung Treng province in Cambodia collected in 2013 and 2014. We divide our sample into two groups, households with nonfarm employment, and households without nonfarm employment. Our findings show that (1) nonfarm employment contributes on average about 32% to total annual household income for the whole sample and 57% for the households with nonfarm employment; (2) nonfarm participation and nonfarm income are significantly influenced by the education level of household heads, number of motorbikes and mobile phones, conditions of roads to the villages, farmland size, number of income shocks, and the distance from home to the nearest market; (3) there is no significant difference in terms of food availability between households with and households without nonfarm employment but the former have improved food access, utilization, and stability. We suggest that promoting rural education, supporting farmland accumulation, improving road conditions, and empowering rural households to cope with income shocks via promoting their access to credit would contribute to developing nonfarm employment and consequently improve the food security of rural households.

Understanding about rural livelihood strategies and environmental resource dependence can help to reduce and prevent livelihood stresses induced by environmental resource degradation. Chapter five identifies livelihood strategies of farm households in rural Cambodia and explores their determinants with a focus on environmental resource dependence. The data are derived from a survey of 580 households in 30 villages of Stung Treng province in Cambodia undertaken in 2013. An activity-based two-step cluster analysis is conducted to identify different livelihood clusters and regression models are performed to determine the major factors affecting the choice of livelihood strategies and the extraction of environmental resources. The results demonstrate how different levels of livelihood assets influence livelihood strategies. Environmental resources contribute a significant portion of household income (27%) and act as a means to reduce income inequality (7%) among households. The absolute environmental income is positively correlated with the total income but the relative environmental income decreases with an increase in total income. Thus, it appears that low income households are not to be blamed for environmental degradation, because they are unable to undertake activities with high return. The findings of this study suggest that promoting off-farm employment, education and social networking reduces the extraction of environmental resources.

Chapter six shows the link between the farm production and natural forest extraction. The farm production and the natural forest extraction remain principal livelihood strategies of local people in many rural areas of the developing world. In this chapter, we apply stochastic frontier analysis to evaluate farm production efficiency and simultaneous equations modelling to estimate the interrelationship between farm production efficiency and natural forest extraction. We use a two-year

panel dataset of 430 rural households in Stung Treng province of Cambodia. We find that natural forest extraction is decreasing with higher farm production efficiency. Our results suggest that improving farm production efficiency via the promotion of rural education and privatization of farm land should be considered an integral component of natural forest conservation policy.

Degradation of natural resources is a threat to sustainable development in many developing countries. Solving this requires an understanding of the factors affecting the extraction of and the dependence on the resources as well as the impacts on rural welfare. In chapter seven, we identify these factors and their impacts of the extraction on rural household welfare in Laos. We address our research questions with an econometric framework that models the extraction and its implications simultaneously. We use the data of 430 rural households from a survey undertaken in 2013 in 38 villages of Savannakhet province. Our findings show that extracting forest and water resources is a shock-coping strategy of rural households but contributes to reducing household income inequality. For extracting households, the extraction increases household income, consumption and food security. However, for non-extracting households, although participating in the extraction would increase food security, it would reduce their income and consumption. We suggest that promoting rural education and off-farm employment opportunities and enhancing investments in physical infrastructures would reduce the extraction of and the dependence on the resources of extractors and prevent non-extractors from being forced to extract the resources.

Keywords: Livelihood stratergies, rural household welfare, Southeast Asian.

Table of Contents

List of Abbreviations

APE	Average Partial Effect
ATE	Average Treatment Effect
ATT	Average Treatment Effect on the Treated
ATU	Average Treatment Effect on the Untreated
CDRI	Cambodian Development Research Institute
CSG	Coping Strategy Group
CSI	Coping Strategies Index
DAPAE	Daily Value of Agricultural Production per Adult Equivalent
DEA	Data Envelopment Analysis
DFG	German Research Foundation
DID	Difference in Differences
DRCAE	Daily Rice, Corn and Bean Consumption per Adult Equivalent
Eq.	Equation
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FCG	Food Consumption Group
FGT	Foster-Greer-Thorbecke
GDP	Gross Domestic Product
HDDG	Household Dietary Diversity Groups
HDDS	Household Dietary Diversity Score
HFIAS	Household Food Insecurity Access Scale
HH	Household
KBM	Kernel Based Matching
Lao PDR	Lao People's Democratic Republic
LR	Likelihood Ratio
M-DID	Matching-difference-in-difference
MAHFP	Months of Adequate Household Food Provisioning
ML	Maximum Likelihood
NCDD	National Committee for Sub-National Democratic Development
NIS	National Institute of Statistics (Cambodia)
NNM	Nearest-Neighbour Matching
OLS	Ordinary Least Squares
PCA	Principal Component Analysis
PPP	Purchasing Power Parity
PSM	Propensity Score Matching
rCSI	reduced Coping Strategies Index
SFM	Stochastic Frontier Model
TLU	Tropical Livestock Units
TRE	True Random-Effects
UN	United Nations
VIF	Variance Inflation Factor
WCED	World Commission on Environment and Development
WFP	World Food Program

1 Introduction

1.1 Problem statement and research motivation

Many Southeast Asian countries have experienced remarkable economic growth rates in recent years. Over the last 10 years from 2007 to 2016 the average annual Gross Domestic Product (GDP) of Vietnam, Cambodia, and Laos grew by 6.0%, 6.6%, and 7.7%, respectively.[1] On the one hand, although the economic growth rates is at a relatively high level, the poverty rate and food insecurity are also still at a high level. The shares of population below the national poverty line are 7% for Vietnam in 2015, 14% for Cambodia in 2014, and 23.2% for Laos in 2012 (Asian Development Bank 2017). The proportions of undernourished people in the total population were about 15% for Cambodia and 17% for Laos in 2015 (World Bank 2017). On the other hand, the high economic growth rates lead to a higher level of income inequality since the income of the top income groups grows faster than that of the lower income groups (Rubin and Segal, 2015). A higher level of income inequality can threaten to stall future progress against poverty by attenuating growth prospects (Stiglitz, 2012) and result in social instability. These problems are more serious in the rural areas where households pursue a wide range of livelihood activities (Babulo et al., 2008). A detailed understanding of these different livelihood activities undertaken by rural households is pivotal to improve rural welfare such as income and food security. Thus, this dissertation focuses on analysing the relationship between the welfare and livelihood strategies (such as livestock production, nonfarm employment, and environmental resources) at the household level in rural areas to provide useful information for policy makers and practitioners to design effective programs for rural development and welfare improvement in Southeast Asia.

Agricultural production including crop production and livestock are considered the main and traditional livelihood strategies of the households in many rural parts of densely populated Southeast Asian countries such as Vietnam. While the scope for crop income increase is limited because of scarce arable land, livestock income still has potential to improve as the demand for livestock products is increasing due to rapid economic growth (Thornton, 2010). Livestock play an important role in improving the welfare and livelihoods of rural households in developing countries in multiple ways (Herrero et al., 2013; Delgado et al., 1999). They directly create income by providing live animals and livestock products, such as eggs or milk to sale and draft power for transport (McMichael et al., 2007; Powell et al., 1998). They contribute to generating crop income through providing draft power for

[1] Author's calculation bases on data at https://countryeconomy.com/gdp

farming and livestock waste for improving soil fertility (Nguyen et al., 2016). In addition, livestock waste is used as fuel for cooking and heating (Wilson et al., 2005). Moreover, livestock support rural households to deal with various types of shocks since shocks are often a pernicious phenomenon for people in agricultural economies (Mogues, 2011). In the absence or malfunctioning of credit and insurance markets, rural households are forced to undertake their own insurance mechanism by storing their wealth from good times for bad times (Ersado et al., 2003; Mogues, 2011). Livestock can be sold off to smooth income and consumption fluctuations due to shocks. Fafchamps, Udry, and Czukas (1998) make explicit, both theoretically and empirically, the link between the precautionary motive to save and asset accumulation behaviour in the face of realised shocks. Greater sales of livestock would be an indication that livestock is used as a precautionary form of wealth (Kazianga and Udry, 2006). Empirically, Rosenzweig and Wolpin (1993) find that, in India, bullocks are used as a buffer stock. That means they are sold off in bad times for consumption smoothing. Similarly, Ngigi and Birner (2013), and Mogues (2011) report that weather shocks reduce livestock assets and small livestock are the first to be sold off. However, Wainwright and Newman (2011) and Fafchamps et al. (1998) show that there is no evidence to suggest that livestock act as a buffer against overall income shocks and spatially covariant shocks. Therefore, it is important to further examine empirically the contribution of livestock to reducing rural poverty and income inequality and the determinants of livestock assets and livestock income for rural households, especially when rural households face shocks. This was the first motivation for the dissertation.

In addition to the traditional livelihood strategies such as crop production and livestock, rural households in Southeast Asian countries perform new livelihood strategies like working in factories, in services, including hotel and food service, etc. which are commonly referred to as nonfarm employment. Nonfarm employment including nonfarm self-employment and nonfarm wage-employment in rural areas is increasingly important to improve livelihoods and welfare of rural households in developing countries (see for example Mishra and Sandretto 2002; Chang and Mishra 2008; Owusu et al. 2011). Despite being labor intensive, the setting up of nonfarm employment of rural households requires relatively little capital and provides an important source of income (Reardon et al. 1998; Tsiboe et al. 2016). By easing capital constraints, nonfarm employment can enhance farm households' input purchasing capacity, thereby contributing to higher food production and farm income, thus improving household welfare (Ruben and van den Berg 2001; Babatunde and Qaim 2010). Rural households engaged in nonfarm employment tend to raise their household food consumption and income and have better food access (Owusu et al., 2011; Ersado 2006). There is also evidence that the importance of nonfarm employment has been increasing over the last few decades (de Janvry and Sadoulet 2001; Olugbire et al. 2011), especially in emerging Asian economies (Démurger et al. 2010).

Even though the effects of nonfarm employment on rural food security and the factors determining the participation of rural households in nonfarm employment have been fairly well documented (Abdulai and CroleRees 2001; van Leeuwen and Dekkers 2013; Tsiboe et al. 2016), there are still research gaps. First, previous studies mainly focused on the effects of nonfarm employment on food access of rural households without considering the effects on all four dimensions of rural household food security such as the availability, access, utilization, and stability of food. Second, these studies paid little attention to the factors affecting the intensity of the participation (e.g. nonfarm income). This was the second motivation for the dissertation.

The last motivation for the dissertation was to understand the role of environmental resources in the welfare and livelihoods of rural households in developing countries, especially of low income households who depend more on environmental resources. Environmental resources provide a variety of life-supporting ecosystem services to rural households such as timber, non-timber forest products and fish (Babulo et al., 2009; Bühler et al., 2015). The extraction of environmental resources in rural areas is often considered an important source of income and a means of livelihoods for low income rural households (Jansen et al., 2006; Schaafsma et al., 2014). Even though efforts to quantify the contribution of non-cultivated environments to rural income have been undertaken for decades (Beck, 1994; Beck and Nesmith, 2001; Thondhlana and Muchapondwa, 2014), some issues still need to be further examined in order to enrich our understanding. These are: (i) the underestimation or ignorance of environmental income. Environmental resources providing income are often communally owned or open access and thus are omitted in rural household surveys, which cover only conventional activities such as crop production and livestock rearing (Babulo et al., 2009; Morsello et al., 2014); (ii) the factors determining the dependence of rural households on environmental sources are often site-specific (Adhikari et al., 2004; Pouliot and Treue, 2013), which makes the generalization of the research findings difficult (Angelsen et al., 2014); (iii) the interrelationship between farming and extracting forest products through smallholders' input allocation decisions and through potential technical interdependencies is not clearly evidenced; and (iv) the environmental resources are exhausted and difficult to be accessed, and the relationship between natural resource extraction and rural household welfare such as food security, consumption, and income is unclear. Therefore, understanding rural livelihood strategies and environmental resource dependence can help to improve rural household welfare and livelihoods and to reduce and prevent livelihood stresses induced by the degradation of environmental resources during the development process, especially for low income households (de Sherbinin et al., 2008; Babigumira et al., 2014).

1.2 Research Objectives

The aim of this dissertation is to provide insights into which sources of income rural households in Southeast Asian countries depend on, how these affect their welfare such as income and food security, and how households successfully transform their livelihoods to adapt to the rapidly changing natural environment and socio-economic conditions in the region. Specifically, the following research questions are addressed:

1) What are the roles of livestock production in reducing rural poverty? What are the factors affecting livestock assets of rural households, with a specific focus on weather and demographic shocks perceived by rural households?

2) What are the factors affecting livestock income of rural households? What are the roles of livestock production in reducing income inequality?

3) How important is the nonfarm income to household income? What are the factors affecting the participation in and the intensity of nonfarm employment of rural households? What are the effects of nonfarm employment on different food security dimensions of rural households?

4) Focusing on environmental resource extraction, what are the livelihood strategies of rural households and how are they determined? How much is the environmental income and how is it distributed? What are the determinants of environmental resource extraction?

5) How to take into account the non-separability of farming efficiency and foraging activities in farm level modelling? What are the factors promoting or hindering farm production efficiency in forest peripheries? To what extent and how does an increase in farm production efficiency reduce natural forest extraction by smallholders?

6) What are the factors affecting forest and water resource extraction and dependence of rural households? What are the impacts of forest and water resource extraction on rural household welfare?

1.3 Structure and contribution of the dissertation

This dissertation in structured into seven chapters. The first chapter introduces the general introduction which includes problem statement, research motivation, research objectives, structure and contribution of the dissertation. Chapter two assesses the contribution of livestock production in reducing rural poverty and examines the determinants of livestock assets, with a specific focus on weather and demographic shocks faced by rural households. This chapter applies the propensity score matching approach combined with the difference in differences method and dynamic models. Panel data are obtained from four rural surveys in 2007, 2008, 2010, and 2013 in three provinces in Vietnam, namely Ha Tinh, Thua Thien Hue, and Dak Lak. To our understanding, this is pioneer work to empirically examine the impact of having and giving up livestock on rural poverty reduction at the household level. This chapter was published in *Journal of Development Studies* as Do et al., 2017.

Chapter three examines the factors affecting livestock production by using a two-part fixed effects model and assess the contribution of livestock production to reducing income inequality by using the Gini decomposition method. The chapter uses panel household data obtained from four rural surveys in 2007, 2008, 2010, and 2013 in three provinces of Vietnam, namely Ha Tinh, Thua Thien Hue, and Dak Lak. The chapter contributes to enriching the current literature in several important facets. First, this is the first effort taking into account both negative and positive livestock income in investigating the impact of livestock production on income inequality reduction. Second, as income inequality actually reflect the income gap between the poor and the non-poor, and the government and non-governmental organizations in Vietnam are supporting the poor to develop livestock production, we separate the contributions of small livestock and of large livestock to income inequality reduction with different livestock production scenarios. This chapter is submitted to *Journal of Development Economics*.

Chapter four determines the factors affecting nonfarm employment and examine the effects of nonfarm employment on household food security with panel data of 561 rural households collected in 2013 and 2014 in Cambodia. In this chapter, two-part random effects models and the matching difference in differences approach are employed to control for endogeneity biases and to eliminate the effects of unobserved (time-invariant) variables on food security indicators. This chapter contributes to the literature in two important ways. First, while previous studies mainly focused on the effects of nonfarm employment on food access of rural households, we measure the effects of nonfarm employment on household food security by using various indicators to cover all four dimensions of food security. Second, whereas previous studies paid little attention to the factors affecting the intensity of nonfarm employment, we determine the factors explaining both the participation in and the intensity of nonfarm employment. This chapter is under review in *Food Security*.

Chapter five identifies different livelihood strategies of rural households in Cambodia with a special focus on the role of environmental resource extraction. It provides the foundation for understanding which role extraction plays in different livelihood strategies and identifies the determinants of livelihood strategy choices and environmental resource dependence. In this chapter, principal component and cluster analysie are applied to data from Cambodia, resulting in three livelihood strategy segments: One cluster with low-skilled non-permanent wage employment and farming, another with environmental resource extraction and farming and a third one with high-skilled wage employment, businesses and farming. A multinomial logit regression provides insights to the question which factors determine which livelihood strategy a household chooses depending on the capitals (natural, human, physical, financial and social capital) it owns. Lastly, a Tobit type II model gives insight to the determinants of participation in extraction activities and to the factors explaining the amount of environmental income a household extracts. This chapter was published in *Ecological Economics* as Nguyen et al., 2015.

Chapter six examines the interrelationship between farm production efficiency and natural forest extraction by using a two year panel dataset of 430 rural households in Stung Treng province of Cambodia. This chapter shows that natural forest extraction is a decreasing function of farm production efficiency and thus suggests that improving farm production efficiency should be considered an integral component of natural forest conservation policy. To our understanding, this is pioneer work to empirically examine the interrelationship between farm production efficiency and natural resource extraction in a simultaneous econometric framework that takes into account the simultaneity and endogeneity biases. This chapter was published in *Land Use Policy* as Nguyen et al., 2018.

Chapter seven determines the factors affecting the extraction of and dependence on forest and water resources and examine the impacts of the extraction on rural household welfare in Laos. This chapter applies Heckman models and endogenous switching regressions with the data of 430 rural households from a survey undertaken in 2013 in 38 villages of Savannakhet province. One of our important contributions to the literature is that our study is the first effort to account for both observable and unobservable selection bias in determining the welfare impacts of natural resource extraction by addressing the research questions with an econometric framework that models the extraction and its implications simultaneously. This chapter has been under review in *Land Degradation and Development*.

Table 1 shows an overview of all the papers included in the dissertation. In addition, the author also contributed to a working paper which is also related to this dissertation but not presented herein.

Bühler, D., Grote, U., Hartje, R., Ker, B., **Lam, D. T.,** Nguyen, L. D., Nguyen, T. T. and Kimsun Tong (2015). *Rural livelihood strategies in Cambodia: Evidence from a household survey in*

Stung Treng. ZEF Working Paper Series, No. 137, Center for Development Research (ZEF), Bonn.

Table 1 List of papers included in the dissertation.

Chapter	Authors	Title	Published in / Submitted to / Presented at
2	**Do, T.L.,** Nguyen, T.T., and Grote, U. (2017)	Livestock Production, Rural Poverty, and Perceived Shocks: Evidence from Panel Data for Vietnam	Published in *Journal of Development Studies* (2017), 0, 1-21. https://doi.org/10.1080/00220388.2017.1408795
3	**Do, T.L.,** Nguyen, T.T., and Grote, U.	Livestock Production and Income Inequality in Rural Vietnam	Submitted to *Journal of Development Economics* Early version was presented at Tropentag 2016 held in Vienna, Austria, September 18 - 21, 2016.
4	**Do, T.L.,** Nguyen, T.T., and Grote, U.	Nonfarm Employment and Household Food Security: Evidence from Panel Data for Rural Cambodia	Submitted to Journal '*Food Security*'
5	Nguyen, T. T., **Do, T. L.,** Bühler, D., Hartje, R., and Grote, U. (2015)	Rural livelihoods and environmental resource dependence in Cambodia	Published in *Ecological Economics (2015)*, 120, 282-295
6	Nguyen, T. T., **Do, T. L.,** Parvathi, P., Wossink, A., and Grote, U. (2018)	Farm production efficiency and natural forest extraction: Evidence from Cambodia	Published in *Land Use Policy* (2018), 71, 480-493
7	Nguyen, T.T., **Do, T.L.,** and Grote, U.	Natural Resource Extraction and Household Welfare in Rural Laos	Resubmitted to Journal '*Land Degradation & Development'*

Note: Chapter two to seven are the result of co-authorships. Chapters two, three, and four are mainly developed, analyzed and written by the author with the contributions of Trung Thanh Nguyen and Ulrike Grote. For chapters five, six, and seven the author contributes to analyzing the data and writing the manuscripts.

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2 Livestock Production, Rural Poverty, and Perceived Shocks: Evidence from Panel Data for Vietnam

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3 Livestock Production and Income Inequality in Rural Vietnam

This chapter is submitted to *Journal of Development Economics.*

Abstract

We examine the factors affecting livestock production by using a Two-Part Fixed Effects model and assess the contribution of livestock production to reducing income inequality by using the Gini Decomposition method. We use panel household data obtained from four rural surveys in 2007, 2008, 2010, and 2013 in three provinces of Vietnam. Our results show that (i) livestock production can bring both positive and negative income; (ii) positive livestock income contributes about 11% to annual household income, but this figure is only 7% if negative livestock income is included; (iii) positive livestock income reduces rural income inequality by about 3.3% but this figure becomes 1% if negative livestock income is included. We suggest that enhancing access to credits, promoting rural education and road conditions, and empowering rural households to better cope with demographic shocks reduce negative livestock income and consequently improve income equality in rural areas. In addition, priorities should be given to the development of large livestock.

Keywords: Income inequality, Gini Decomposition, panel data, Two-Part Fixed Effects model, livestock income

JEL classification: D63, O13, O18

3.1 Introduction

Income inequality within developing countries stands at a high level and has been further slowly rising (Ravallion, 2014). In addition, a number of developing countries such as China and Vietnam have experienced relatively high economic growth rates during the last several years (Fosu, 2017). This leads to a higher level of income inequality (Rubin and Segal, 2015), which certainly is one of the main concerns of policy makers in these countries (Alvaredo and Gasparini, 2015). Income inequality can threaten to stall future progress against poverty by attenuating growth prospects (Stiglitz, 2012) and result in social instability. In explaining how the substantial economic growth in developing countries may have contributed to improving human development, it is crucial to understand the role of specific income sources in income inequality reduction (Bourguignon, 2003; Kalwij and Verschoor, 2007; World Bank, 2006).

Various studies have examined income inequality between countries and within a country such as between urban and rural areas (Benjamin et al., 2017). However, income inequality also exists among rural households in developing countries (Reardon et al., 2000). In many rural parts of densely populated Asia such as in Vietnam and China, crop and livestock production are major income generating activities. While the scope for crop income increase is limited because of scarce arable land, livestock income still has potential to improve as the demand for livestock products is increasing due to rapid economic growth (Thornton, 2010). Livestock create income for rural households in developing countries, both directly and indirectly. They directly generate income by providing live animals and livestock products, such as eggs or milk to sale and draft power for transport (McMichael et al., 2007; Powell et al., 1998). They contribute to generating crop income through providing draft power for farming and livestock waste for improving soil fertility (Nguyen et al., 2016). In addition, livestock waste is used as fuel for cooking and heating (Wilson et al., 2005). As livestock income is becoming more important, the question arises to what extent livestock income contributes to reducing rural income inequality.

Vietnam has experienced remarkable economic growth rates with the average annual Gross Domestic Product (GDP) growing at 7.2% during the 2002-2011 period (Berliner et al., 2013). At the same time, rising income inequality has been witnessed in Vietnam (World Bank, 2012), also in rural areas (VASS, 2011). Nearly 70% of the Vietnamese population live in rural areas, of which 65% depend on crop and livestock production for their livelihoods (GSO, 2014). Even though livestock plays an important role in generating rural income, it is mainly reared by small-scale rural households (about 70% of total livestock production). About 8.3 million rural households produce poultry and 7 million rural households produce pigs. The share of livestock production is about 27% of the agricultural GDP and

5.4% of the total GDP (Stanton et al., 2011). Due to high economic growth and poverty reduction, the demand for livestock products is rapidly increasing. Thus, the government is planning to promote livestock production. By 2020, it is expected that livestock production will contribute 42% to the agricultural GDP and that the annual growth will be 5-6% in the period 2015-2020. While the effect of livestock production on reducing poverty in Vietnam was investigated by Do et al. (2017), its effect on rural income inequality reduction remains unclear. Vietnam is thus a suitable setting for examining the role of livestock in reducing rural income inequality.

Against this background, this paper aims to address the following research questions: (i) what are the factors affecting livestock income of rural households? and (ii) what are the roles of livestock production in reducing income inequality? Answering these questions provides useful information on how to promote livestock production and consequently reduce income inequality. In addition, we consider different livestock production pathways and thus our findings are expected to contribute to formulating robust rural development policy advice that is not only relevant for Vietnam but also for other rapidly developing economies.

The rest of the paper is structured as follows. Section two presents the analytical framework of the study. Section three describes the study area, data collection, and data analysis. Section four presents the results and discusses the findings. Section five concludes with policy implications.

3.2 Analytical framework

3.2.1 Factors affecting livestock income

In a standard farm household model (Huffman, 1991; Weersink et al., 1998), total household income (I) includes farm income (I_f), nonfarm income (I_n), and non-labor income (R). Farm income includes crop income (I_c) and livestock income (I_l). Assuming the household faces perfectly competitive output and input markets, livestock income ($I_l = P_lQ_l - P_{Xl}X_l$) is equal to the price of livestock output (P_l) multiplied by the quantity produced (Q_l) minus variable costs of production $P_{Xl}X_l$, where P_{Xl} is the livestock input price vector, and X_l is the quantity of purchased livestock inputs. Similarly, crop income ($I_c = P_cQ_c - P_{Xc}X_c$) is equal to the price of crop output (P_c) multiplied by the quantity produced (Q_c) minus variable costs of production $P_{Xc}X_c$, where P_{Xc} is the crop input price vector, and X_c is the quantity of purchased crop inputs. Nonfarm income is defined as the product of nonfarm wage and nonfarm labor supply, $I_n = w_n L_n$. Nonfarm wage (w_n) depends on its respective human capital characteristics (Z_{hu}) and local labor market conditions (Z_m), $w_n = w_n(Z_{hu}, Z_m)$. The household maximizes its income subject to production functions and its assets such as labor, farmland, and finance. The maximization of household income can be presented as follows:

$$Max\ \Pi = P_cQ_c - P_{Xc}X_c + P_lQ_l - P_{Xl}X_l + w_n L_n + R \quad (1)$$

While nonfarm wage rates are assumed to be independent of the hours worked, marginal returns to farm labor (includes crop and livestock labors) are assumed to diminish with increases in hours of farm work. Crop and livestock productions are represented by the following functions:

$$Q_c = Q_c(L_c, X_c, Z) \quad (2)$$

$$Q_l = Q_l\ (L_l, X_l, Z) \quad (3)$$

where Q_c and Q_l are strictly concave crop and livestock production functions, respectively. Z is a vector consisting of household characteristics and location characteristics, which provides the quantity of owner inputs for both crop production and livestock raising. The household characteristics include human capital characteristics ($Z_{hu} \in Z$) and the location characteristics include local labor market conditions ($Z_m \in Z$).

We focus in the analysis on the total household labor (L) allocated to crop production (L_c), livestock raising (L_l), and nonfarm employment (L_n) as follows:

$$L_c + L_l + L_n \leq L \qquad L_c > 0 \text{ and } L_l\ ,\ L_n \geq 0 \quad (4)$$

The household maximizes its income (1) subject to crop productivity (2), livestock productivity (3), and its total labor (4) through the quantity of crop and livestock inputs purchased (X_c and X_l), and the work hours allocated to crop production, livestock raising, and nonfarm employment. Solving this utility-maximization problem, we have optimal labor and purchased input for crop production, livestock raising, and nonfarm work, which can then be derived as follows:

$$L_j^* = L_j^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z) \qquad j = c, l, n \quad (5)$$

$$X_k^* = X_k^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z) \qquad k = c, l \quad (6)$$

A farm household will participate in livestock raising if the marginal value of livestock labor is greater than the marginal value of crop labor. Both the marginal value of livestock labor and the marginal value of crop labor are not observable at the same time. What is observable is the household's decision to participate or not in livestock raising. Therefore, we can use an index function with an unobserved variable to specify this decision as follows:

$$\begin{cases} L_i^* = Z' \cdot \alpha + e_i \\ L_i = 1 \quad \text{if} \quad L_i^* > 0 \\ L_i = 0 \quad \text{if} \quad L_i^* \leq 0 \end{cases} \quad (7)$$

where e_i is a random error term; L_i denotes a dummy variable equaling one, if household *i* participates in livestock raising and zero otherwise. Eq. 7 shows that the participation in livestock raising is influenced by household characteristics and location characteristics (*Z*). A farm household will get income if it participates in livestock raising. To build a livestock production function, we substitute Eq. 5 and Eq. 6 into Eq. 3 as follows:

$$Q_l^* = Q_l^*\{L_l^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z), X_l^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z), Z\} \quad (8)$$

$$\rightarrow \; Q_l^* = Q_l^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z) \quad (9)$$

From Eq. 6 and Eq. 9, the livestock income function is further derived as follows:

$$I_l^* = P_l Q_l^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z) - P_{Xl} X_l^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z) \quad (10)$$

$$\rightarrow \; I_l^* = I_l^*(P_c, P_l, P_{Xc}, P_{Xl}, L, R, Z) \quad (11)$$

The input and output prices in Eq. 11 are the farm gate prices which depend on the market prices (as given) and the transportation cost from the market to the household (for input) or from the household to the market (for output). Since the household faces perfectly competitive input and output markets, the farm gate prices depend on transport conditions such as the distance from the household to the market, road condition, and the transport mean. These factors reflect household characteristics and location characteristics (Z). In addition, the total household labor (L) and the non-labor income (R) also belong to household characteristics (Z). Thus, the livestock income function of household *i* is reduced as follows:

$$I_i = Z' \cdot \beta + \varepsilon_i \quad (12)$$

Selection bias occurs if unobservable covariates affect both the error term (e_i) of Eq. 7 and the error term (ε_i) of Eq. 12. When selection bias occurs, the Ordinary Least Squares method is not consistent to estimate the determinants of household livestock income (Eq. 12). Therefore, in our analysis, we employ a Two-Part Fixed Effects model to determine the factors affecting the participation in livestock raising and livestock income of the rural household. The model not only considers the correlation of the error terms in Eq. (7) and Eq. (12) but also eliminates the effect of unobserved (time-invariant) variables on the livestock income. That implies that the method contributes to addressing the endogeneity problem that usually precludes the identification of the outcome effects of livestock production.

3.2.2 Livestock income and income inequality

A rural household in developing countries has several income sources such as farm income (crop income and livestock income), non-farm income (wage employment income and self-nonfarm employment income), and non-labor income (remittances). Therefore, any change in livestock income leads to a change in the total household income and income inequality among households. In the literature, there are different methods to measure the effect of a change in an income source on income inequality. These methods include the Generalized Entropy Measures, Atkinson's Inequality Measures, Inequality Comparisons, Measuring Pro-Poor Growth, Decomposition of Income Inequality, Income Distribution Dynamics (Haughton and Khandker, 2009; Nguyen et al., 2015a; Boyce et al., 2016), the Robin Hood Index, the Kakwani Progressivity Index (De Maio, 2007), and Gini Decomposition (Shorrocks, 1982; Lerman and Yitzhaki, 1985; López-Feldman, 2014; Benjamin et al., 2017). In our analysis, we employ the Gini Decomposition method to measure the impact of livestock income on income inequality due to the following reasons: (i) it is similar to other methods by determining how much an income source (livestock income in our case) contributes to overall income inequality; and (ii) it has the advantage – compared to other methods - that it measures the impact of a small change in livestock income on overall income inequality.

While the effects of a change in other income sources such as wage employment income or self- and nonfarm employment income or even non-labor income on income inequality have been intensively examined in the literature (Reardon et al., 2000; Woldehanna and Oskam, 2001; Nguyen et al, 2015a), the effect of livestock income on income inequality has been studied much less. We are aware of only three studies that examine the effect of livestock income on income inequality in developing countries and their results are inconclusive. Adams (1996) shows that livestock income makes a small contribution to overall income inequality in rural Pakistan because it has a small income share. Meanwhile, Woldehanna and Oskam (2001) point out that the effect of livestock income on income inequality is negative when income is calculated in per capita terms, but positive when it is stated at household level in Northern Ethiopia. Nguyen (2010) shows that there is no impact of livestock production on income inequality in Vietnam in the period 2002 - 2004. The studies consider only positive livestock income. However, it is well known that livestock production, especially at the household level, is subject to different factors that might make livestock income turn negative. A typical example for a rural household to have negative livestock income is due to livestock diseases. In addition, a demographic shock such as sickness or death of a household member requires urgent cash that leads to a distress sale of livestock.

Our study contributes to enriching the current literature in several important facets. First, our study is the first effort taking into account both negative and positive livestock income in investigating the impact of livestock production on income inequality reduction. Second, as income inequality actually reflects the income gap between the poor and the non-poor, and the government and non-governmental organizations in Vietnam are supporting the poor to develop livestock production, we separate the contributions of small livestock and large livestock to income inequality reduction by estimating different livestock production pathways. Small livestock include poultry, pigs, goats, and rabbits, while large livestock include buffalos, beefs, and horses. Our results would be instrumental in selecting which type of livestock should be supported for the poor so that the income gap between them and the non-poor is reduced.

3.3 Study design

3.3.1 Study area and data collection

The data for the current study is taken from a series of rural surveys undertaken by the research project "Impact of shocks on the vulnerability to poverty: ***Consequences for development of emerging Southeast Asian Economies***" (DFG FOR 756)[2]. Our study area includes three provinces in Vietnam, namely Ha Tinh, Thua Thien Hue, and Dak Lak (Figure 1).

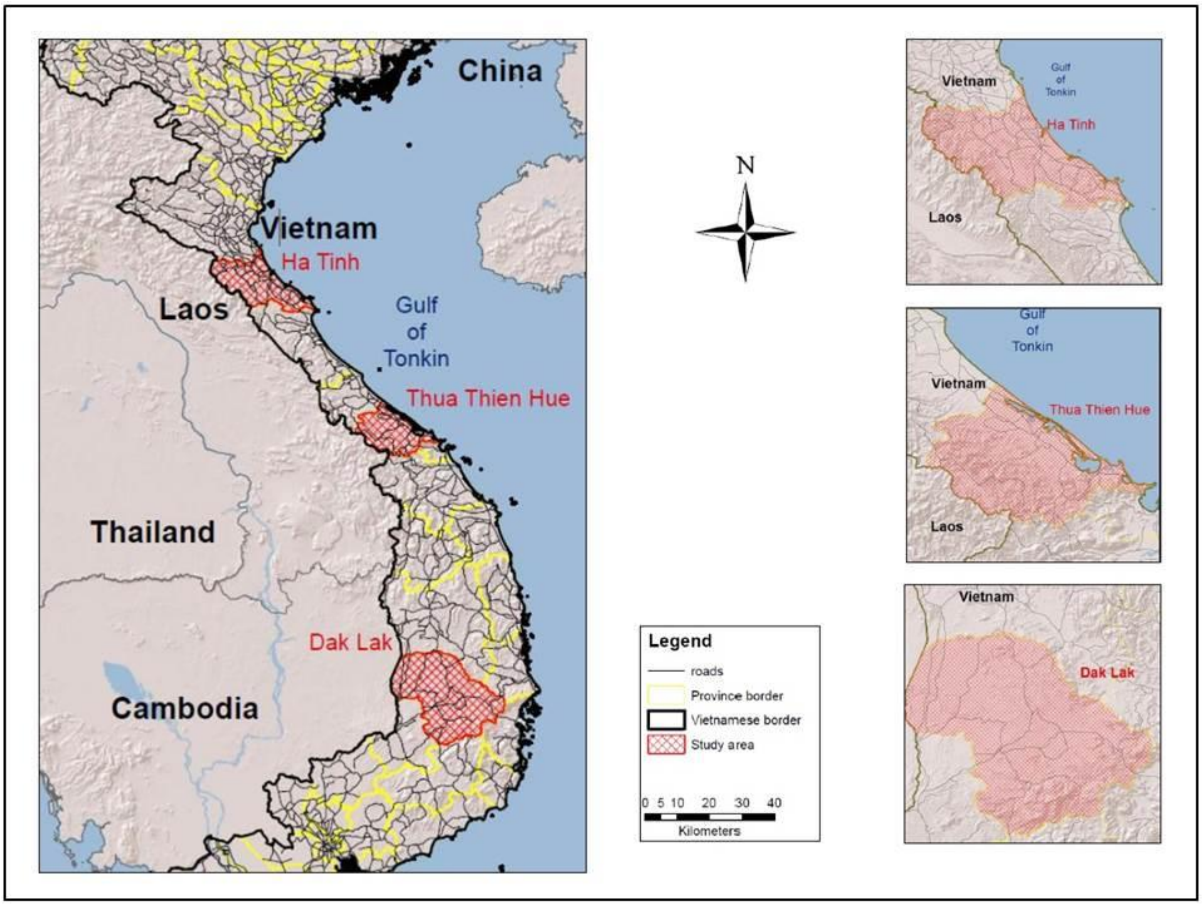
Our data collection was conducted in a two-stage procedure based on the guidelines of the UN Department of Economic and Social Affairs (UN, 2005) as described in Phung et al. (2015). The first stage is the selection of sampled villages in all districts in each province, with a probability proportional to the size of a village's population. In the second stage, a fixed sample size of ten farm households in each sampled village is randomly chosen from a list of households with equal probability selection. The surveys were undertaken in 2007, 2008, 2010, and 2013. This allows us to establish a panel dataset of about 2,200 households from 220 villages of these three provinces over four years.

Two survey questionnaires are used to collect data for the project. The village questionnaire captures village-level data on population, infrastructure, and the socio-economic structure of the village. The household questionnaire contains sections on the demographic, economic and social situation of households. This includes income-generating activities such as farming, livestock production, non-farm self-employment, off-farm wage employment, remittances and financial transfers. A separate section is designed for livestock production. For each type of livestock, information about its stock at the beginning and at the end of the period, stock change in the period, livestock products and expenditure is collected. Thus, livestock income is equal the total revenue minus the total cost. The total revenue includes the value of products such as eggs or meat that are sold or consumed and value of livestock

[2] See http://tvsep.de/; both village and household questionnaires can be downloaded from this webpage.

at the end of the period. The total cost contains cash expenditures for food, veterinary treatment, and hired labor, the value of livestock at the beginning of the period, the value of livestock household purchased or received during the period, depreciation, and interest.

Figure 1. Map of Vietnam and of the three provinces Ha Tinh, Thua Thien Hue, and Dak Lak (Do et al., 2017)



3.3.2 Data analysis

3.3.2.1 Two-Part Fixed Effects model for identifying the determinants of livestock income

The decision of a household to participate in and the intensity of livestock production can be represented first by a yes-no answer (for participating or not) and then by livestock income (for the intensity), respectively. The participation decision and livestock income are correlated (livestock income exists only when the decision is yes). Livestock income is zero for the households without livestock and non-zero for the households with livestock. Our sample includes 8,077 households in 4 years, of which 1,754 (22%) households are without livestock and 6,323 (78%) households are with livestock. Among the 6,323 (78%) households with livestock, 1,665 (21%) households have negative livestock income and the other 4,658 (58%) households have positive livestock income.

As livestock income variable has both zero and non-zero values, we follow Duan et al. (1983) and Manning et al. (1987) to apply a Two-Part Fixed Effects model with a panel dataset in 2007, 2008, 2010 and 2013 for estimating the factors affecting both livestock participation and livestock income. The first part is to model the decision to participate with a Fixed Effects Logit model (Eq. 13) (see Appendix 3 for the test to choose between the fixed effects logit and the random effects logit models). The second part is to model the livestock income with a Fixed Effects Ordinary Least Squares (OLS) model (Eq. 14) (see Appendix 4 for the test to choose between the fixed effects OLS and the random effects OLS models). Since livestock income is either negative or positive, we run another Fixed Effects Logit model to examine the factors affecting the probability that livestock income is positive or negative (Eq. 15). These are as follows:

The first part of the Two-Part Fixed Effects model is:

$$Pr(L_{ijt} = 1|X'_{ijt}, S'_{ijt}, V'_{jt}) = \frac{exp(\alpha_0+X'_{ijt}\alpha_1+S'_{ijt}\alpha_2+V'_{jt}\alpha_3+\epsilon_{ij}+e_{ijt})}{1+exp(\alpha_0+X'_{ijt}\alpha_1+S'_{ijt}\alpha_2+V'_{jt}\alpha_3+\epsilon_{ij}+e_{ijt})} \quad (13)$$

The second part of the Two-Part Fixed Effects model is:

$$Ln(LI_{ijt})_{|LI_{ijt}\lessgtr 0} = \beta_0 + X'_{ijt}\beta_1 + S'_{ijt}\beta_2 + V'_{jt}\beta_3 + \mu_{ij} + \omega_{ijt} \quad (14)$$

$$Pr(PLI_{ijt} = 1|X'_{ijt}, S'_{ijt}, V'_{jt})_{|LI_{ijt}\lessgtr 0} = \frac{exp(\theta_0+X'_{ijt}\theta_1+S'_{ijt}\theta_2+V'_{jt}\theta_3+u_{ij}+\varepsilon_{ijt})}{1+exp(\theta_0+X'_{ijt}\theta_1+S'_{ijt}\theta_2+V'_{jt}\theta_3+ u_{ij}+\varepsilon_{ijt})} \quad (15)$$

where L_{ijt} is a binary variable which is equal to 1 if the household has livestock and equal to zero if the household has no livestock. LI_{ijt} is livestock income of household *i* in village *j* at time *t*; PLI_{ijt} is a binary variable which is equal to 1 if the household has positive livestock income and equal to zero if the household has negative livestock income. X_{ijt}, S_{ijt}, and V_{ij} denote household characteristics, the number of income shocks that the household faced during the last three years, and observable village characteristics, respectively. ϵ_{ij}, μ_{ij}, and u_{ij} are time-invariant unobservable variables of Eq. (13), (14), and (15), respectively. e_{ijt}, ε_{ijt}, and ω_{ijt} time-variant unobservable variables of Eq. (13), (14), and (15), respectively. We use the robust option to control for possible heteroscedasticity in the Fixed Effects OLS model.

Household characteristics include human, financial, physical, social, and natural capital. Human capital is represented by the ethnicity, age, gender, and education level of the household head, household size, and household labor. Physical capital is represented by the number of tractors, motorbikes, and

Tropical Livestock Units[3] that the household owns. Social capital is represented by the number of phones (including mobile phones) used by household members and the number of socio-political groups that household members participate in. These variables reflect the contacts and the network a household has, as they allow the members to stay in contact with friends, relatives or business partners. Financial capital is represented by a dummy variable indicating if the household has access to credit. As this variable in the same survey year can be endogenous with other variables and might have a reverse causality with the decision to rear livestock and livestock income, we use the access to credit in the last 5 years before the survey year. Natural capital is represented by the farmland size of the household as it might be suggestive of wealth and status in rural areas of developing countries (Nguyen et al., 2015b). In addition, the number of weather shocks and demographic shocks reported by the household during the last three years is also included because weather shocks and demographic shocks might lead to losses of livestock or to the decision of selling livestock earlier than what is the ideal time. Weather shocks include droughts, floods, storms and landslides. Demographic shocks includes sicknesses, death, accidents and job loss of household members. At the village level, the following four variables are included: a dummy variable of whether the village is physically accessible during the whole year, the distance from home to the nearest town, the number of enterprises with more than nine employees, and the share of households with access to national electricity. These variables are summarized in Appendix 1. As the number of independent variables is high, the Variance Inflation Factor (VIF) test was used to detect potential multicollinearity and the results of the test reject the null hypothesis of the problem (see Appendix 2).

From the results of these models, we estimate the Average Partial Effect (APE) of each independent variable (e.g. the independent variable m^{th}) on the unconditional dependent variables *LI* and *PLI* for the whole sample (including both households with and without livestock) (Arouri et al., 2017) as follows:

$$\widehat{APE}_m = \hat{\alpha}_m \cdot \frac{1}{n_I} \cdot \sum_{ijt} LI_{ijt} \ (or \ \sum_{ijt} PLI_{ijt}) + \hat{\beta}_m (or \ \hat{\theta}_m) \cdot \frac{1}{n} \cdot \sum_{ijt} L_{ijt} \tag{16}$$

where $\hat{\alpha}_m$, $\hat{\beta}_m$, and $\hat{\theta}_m$ are estimates of the independent variable m^{th} in Eq. (13), (14), and (15), respectively. n_I is the number of observations with non-zero livestock income (*LI*), and n is the total number of observations in the sample.

[3] We follow Chilonda and Otte (2006) to convert different types of livestock into one standardized unit, namely Tropical Livestock Unit (TLU).

3.3.2.2 Gini Decomposition method for examining the impact of livestock on income inequality

The Gini Decomposition method developed by Shorrocks (1982) and Lerman and Yitzhaki (1985) is used to examine the impact of livestock production on household income inequality reduction. The Gini coefficient (*G*) is presented as follows:

$$G = \sum_{k=1}^{K} S_k G_k R_k \quad (17)$$

where S_k refers to the share of income source *k* in total household income, G_k represents the Gini coefficients of income source *k*, R_k is the Gini correlation of income source *k* with the distribution of total income ($R_k = Cov[y_k, F(y)]/Cov[y_k, F(y_k)]$, where *F(y)* and $F(y_k)$ are the cumulative distributions of total income (*y*) and of income source *k* (y_k)). Stark et al. (1986) show that the partial derivative of G with respect to a one percent change (*e)* in income source *k* is equal to:

$$\frac{\partial G}{\partial e} = S_k(G_k R_k - G) \quad (18)$$

Dividing both sides of Eq. (18) by *G*, we have a marginal percentage change of income source *k* in income inequality as follows:

$$\frac{\partial G/\partial e}{G} = \frac{S_k G_k R_k}{G} - S_k \quad (19)$$

We divide household income into two income sources: the livestock income and the other income. The latter includes income from crop production, self-employment, off-farm wage employment, remittances, financial transfers and capital income. This Gini Decomposition method is applied to the whole sample and to a sub-sample that includes only the households who have no livestock and households who have positive livestock income.

3.4 Results and discussion

3.4.1 Description of household livestock groups

Table 1 summarizes the differences in household assets and village characteristics among the three groups, namely households without livestock, households with negative livestock income, and households with positive livestock income. The statistic tests reveal that most household assets and village characteristics are statistically different among these groups. The households with positive livestock income mainly belong to the majority ethnic group, the Kinh; they are also characterized by an older and better-educated head, a higher number of laborers and tractors, a larger land size, and higher participation in social or political groups as compared to the other two groups. The negative livestock income group has a lower number of motorbikes but better access to credit and more shocks. With respect to the village characteristics, the positive livestock income group has better road conditions, is closer to town and has better electricity access. The households without livestock live in villages with a higher number of enterprises.

Table 1. Basic household assets and village characteristics

Variable	Whole sample (n = 8077)		Houshold without livestock (No livestock group) (n = 1754) (1)		Household with livestock: Negative livestock income group (n = 1665) (2)		Household with livestock: Positive livestock income group (n = 4658) (3)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Human capital								
ethnic share ^{b}	84.09	2.29	82.00^{2***}	3.39	80.55^{3***}	2.96	86.03^{1**}	2.11
age ^{a}	50.67	0.37	50.33^{2}	0.70	49.63^{3***}	0.50	51.14^{1***}	0.38
gender share ^{b}	17.56	0.81	21.63^{2**}	1.57	18.76^{3**}	1.26	15.67^{1***}	0.89
education ^{a}	6.78	0.14	6.30^{2}	0.24	6.35^{3***}	0.19	7.10^{1***}	0.14
hh_size ^{a}	4.17	0.05	4.02^{2***}	0.08	4.29^{3**}	0.06	4.18^{1***}	0.06
hh_labor ^{a}	2.12	0.03	2.04^{2***}	0.06	2.17^{3}	0.04	2.14^{1***}	0.03
Physical capital								
tractor ^{a}	0.36	0.02	0.20^{2***}	0.03	0.32^{3***}	0.02	0.43^{1***}	0.02
motorbike ^{a}	0.95	0.02	1.09^{2***}	0.06	0.82^{3***}	0.03	0.94^{1***}	0.02
Social capital								
n_phone ^{a}	1.20	0.04	1.36^{2***}	0.08	0.99^{3***}	0.06	1.22^{1}	0.03
SPO ^{a}	2.67	0.04	2.04^{2***}	0.07	2.61^{3***}	0.06	2.92^{1***}	0.05
Financial capital								
access_credit share ^{b}	40.97	0.92	32.03^{2***}	1.25	43.72^{3}	1.74	43.55^{1***}	1.11
Natural capital								
land_size ^{a}	0.30	0.02	0.14^{2***}	0.02	0.31^{3***}	0.03	0.36^{1***}	0.02
Shocks								
weather _shock ^{a}	0.50	0.02	0.38^{2***}	0.03	0.55^{3**}	0.02	0.54^{1***}	0.02
demo_shock ^{a}	0.44	0.01	0.39^{2*}	0.02	0.48^{3*}	0.02	0.44^{1**}	0.01
Village variables								
road_type share ^{b}	53.69	1.92	48.45^{2}	3.83	48.44^{3***}	2.56	57.35^{1***}	2.24
distance_town ^{b}	12.97	0.87	13.61^{2}	1.06	13.71^{3**}	1.15	12.49^{1**}	0.81
enterprise ^{a}	0.13	0.02	0.21^{2***}	0.05	0.12^{3}	0.02	0.11^{1***}	0.02
electricity ^{a}	95.24	0.91	94.05^{2**}	1.72	95.28^{3***}	1.03	95.66^{1**}	0.86

* Significant at 10%, ** significant at 5%, *** significant at 1%, SE is linearized standard error; ^{a} nonparametric two-sample test: Mann–Whitney U test, ^{b} Chi-square test; 1, 2, 3 compare with group (1), (2), (3), respectively; ^{b} unit of variables is %.

Table 2 presents the average changes in livestock assets within a survey year of the group of households with livestock and its subgroups (households with negative livestock income and households with positive livestock income). The changes are from births, losses, purchases, sales, and home consumption. In comparison to the livestock asset at the beginning of the period, the number of livestock that is newly born, purchased, or sold is about 96%, 42%, and 104%, respectively. The number of livestock that is lost is high, about 27%. Comparing between the two subgroups, the TLU of households with positive livestock income is on average higher and changes stronger than that of households with negative livestock income. The former sell more of their livestock and have more newly born livestock than the latter who have comparatively higher livestock losses.

Table 2. Changes in livestock assets by livestock groups

Livestock asset	Households with livestock (n = 6323)		Negative livestock income group (n = 1665)		Positive livestock income group (n = 4658)	
	(1)	(2)	(1)	(2)	(1)	(2)
At the beginning	1.31	100	1.22	100	1.34	100
Births	1.26	96	0.64	53	1.46	109
Purchases	0.55	42	0.47	38	0.58	43
Losses	0.36	27	0.50	41	0.31	23
Home consumption	0.15	11	0.09	7	0.17	13
Sales	1.36	104	0.74	61	1.56	117
At the end	1.25	96	1.00	82	1.33	100

(1) Number of TLU and (2) the percentage share compared with the number of TLU at the beginning of the period.

Table 3. Livestock income and its components for one TLU by household group

Component	Households have only large livestock (n = 321) (1)	Households have only small livestock (n = 3346) (2)	Households have both small and large livestock (n = 2656) (3)	Households have livestock (n = 6323) (1+2+3)
The value of stock at the beginning [a]	1046.1	330.4	745.3	605.3
Livestock purchases [a]	137.0	104.6	175.9	147.9
Livestock losses [a]	124.7	171.6	110.2	133.5
Livestock home consumption [a]	9.9	113.8	64.2	80.1
Livestock sales [a]	367.9	489.8	462.8	468.6
The value of stock at the end [a]	1115.6	367.7	835.4	675.0
Feed cost [a]	29.3	275.4	139.5	184.8
Veterinary treatment cost [a]	7.1	13.3	8.1	10.0
Hired labor cost [a]	8.8	0.5	0.1	0.6
Other cost [a]	38.5	21.5	15.9	18.9
Livestock income [a]	226.6	225.6	277.7	256.2
Coefficient of variation of livestock income	2.64	5.34	1.71	3.23

[a] unit of components is Purchasing Power Parity dollar in 2005.

Table 3 reports livestock income, its components and the coefficient of variation of livestock income for one TLU for (i) households who have only small livestock, (ii) households who have only large livestock, (iii) households who have both large and small livestock, and (iv) households with livestock in general. The table shows that households who have both small and large livestock gain the highest income and have the lowest livestock income risk, whereas households who have only small livestock have the highest livestock income risk since they have the highest coefficient of variation of livestock income. They also lose their livestock due to weather shocks, diseases and theft more than the others do. Households with only large livestock invest in livestock stables and in the initial livestock stock more than the others because the other cost (depreciation and interest) and the value of the large livestock are higher than for small livestock. Meanwhile, households with only small livestock spend more in feed than the others.

3.4.2 Determinants of household livestock income

Table 4 reports the estimates of the Two-Part Fixed Effects models. Column 2 presents the factors affecting the probability to raise livestock (yes-no). Column 3 presents the factors affecting livestock income of the households with livestock. Column 4 presents the APE on livestock income for the whole sample. Colum 5 displays the factors affecting the probability to have positive livestock income for the households with livestock. The last column presents the APE on the probability to have positive livestock income for the whole sample.

Regarding human capital, the results show that a higher education level of the household head is associated with a higher proportion of participating in livestock production and a higher probability to have positive livestock income. This is plausible because better-educated farmers are more innovative and entrepreneurial and thus, more likely to be active in generating income both from farming activities and from livestock production. In addition, with an older aged head the probability that the household would have positive livestock income increases. This is reasonable as an older head has more experiences in raising livestock. However, a large household size is associated with a smaller livestock income.

Physical capital and social capital of households have positive effects. The number of tractors facilitates livestock raising and increases livestock income. A higher number of motorbikes or phones are associated with higher livestock income and a higher probability to have positive livestock income. This might be because motorbikes are the main transportation means in rural Vietnam, and both phones and motorbikes facilitate rural marketing. This is also consistent with the positive effect of the membership in socio-political organizations. The scale of livestock production represented by the number of TLU is positively correlated with livestock income, indicating that the higher the scale of livestock production, the higher the livestock income. This finding is consistent with Mburu et al. (2017) who show that keeping livestock is still the main source of livelihood, especially among poor households in Northern Kenya.

Table 4. Determinants of livestock production

Variable	Having livestock (part 1)	Livestock income (part 2)		Having positive livestock income (part 2)	
	Fixed effects logit	Fixed effects OLS	APE	Fixed effects logit	APE
Human capital					
ethnic	1.308	-5.171	715.894	0.474	1.334
	(5.238)	(186.059)	(3448.12)	(2.248)	(5.888)
age	0.004	5.297	6.521	0.030**	0.027
	(0.013)	(7.682)	(10.643)	(0.012)	(0.020)
gender	-0.189	-199.499	-259.962	0.051	-0.099
	(0.306)	(130.239)	(272.944)	(0.302)	(0.478)
education	0.062**	7.045	39.811	0.047*	0.083*
	(0.029)	(15.498)	(28.181)	(0.028)	(0.044)
hh_size	0.105	-82.331**	-6.783	-0.087	0.009
	(0.070)	(40.177)	(62.842)	(0.055)	(0.094)
hh_labor	0.029	54.721	58.634	-0.020	0.005
	(0.088)	(54.547)	(84.489)	(0.072)	(0.130)
Physical capital					
tractor	0.298*	208.496***	327.469**	0.134	0.325
	(0.170)	(78.924)	(157.781)	(0.112)	(0.224)
motorbike	0.109	172.585***	195.341**	0.311***	0.324
	(0.106)	(53.853)	(98.631)	(0.086)	(0.150)
livestock_unit		76.689		0.116***	
		(51.842)		(0.042)	
Social capital					
n_phone	0.057	85.196**	98.033*	0.117**	0.134
	(0.062)	(37.098)	(55.303)	(0.059)	(0.096)
SPO	0.063*	-8.745	27.617	0.015	0.058
	(0.036)	(15.861)	(31.601)	(0.028)	(0.049)
Financial capital					
access_credit	0.408***	102.651**	305.178***	0.155**	0.422***
	(0.106)	(44.434)	(93.584)	(0.077)	(0.142)
Natural capital					
land_size (ln)	0.138***	32.850**	101.874***	0.068**	0.155***
	(0.036)	(16.053)	(33.424)	(0.033)	(0.053)
Shocks					
weather_shock	0.112	-31.809	36.635	0.061	0.130
	(0.080)	(48.996)	(81.739)	(0.057)	(0.107)
demo_shock	0.008	-84.112**	-61.605	-0.125**	-0.092
	(0.081)	(37.894)	(68.389)	(0.057)	(0.108)
Village variables					
road_type	-0.679***	251.726***	-176.614	0.356***	-0.222
	(0.181)	(92.792)	(162.988)	(0.110)	(0.231)
distance_town (ln)	0.042	-131.429**	-79.992	-0.169**	-0.101
	(0.119)	(51.702)	(99.984)	(0.084)	(0.166)
enterprise	-0.125	17.140	-55.292	-0.121	-0.186
	(0.104)	(60.663)	(98.702)	(0.091)	(0.166)
electricity	0.0005	0.624	0.749	0.0001	0.0004
	(0.003)	(1.115)	(2.751)	(0.003)	(0.005)
constant		211.952			
		(470.704)			
Number of observations	*2443*	*6323*		*3760*	
F/Wald chi²	*77.53*	*6.45*		*128.65*	
Probability > F/chi²	*0.000*	*0.000*		*0.000*	
R^2 overall		*0.081*			

* Significant at 10%, ** significant at 5%, *** significant at 1%, bootstrapped standard error with 500 replications for Fixed effects logit and for APE, robust standard error clustered at the village level for Fixed effects in parentheses.

Regarding financial and natural capital, access to credit supports livestock rearing, increases livestock income and the probability to have positive livestock income. A larger farmland size would also increase the proportion of households with livestock, livestock income, and the probability to have positive livestock income. This is plausible because rural Vietnam is mainly characterized by mixed farms, which include both crop and livestock production and these two components support each other (McMichael et al., 2007; Lemaire et al., 2014; Nguyen et al., 2016). For example, livestock's dung is used as manure for crop production whereas rice straw is used as feed for buffalo.

Regarding shocks and village characteristics, a higher number of demographic shocks are associated with lower livestock income and a lower probability to have positive livestock income. That indicates that households use livestock to cope with demographic shocks and to smooth their consumption. This finding is consistent with the development literature on the association between shocks and livestock production (Mogues, 2011; Turner et al., 2011). For example, Andersson et al. (2011) report that demographic shocks reduce livestock assets in Ethiopia. Kazianga and Udry (2006) demonstrate that livestock is used as an alternative asset for the poor to hedge against income fluctuations in Burkina Faso. Islam and Maitra (2012) present that rural households use livestock to deal with health shocks in Bangladesh. Better road conditions decrease the proportion of households participating in livestock rearing but increase the livestock income and the probability to have positive livestock income. This might indicate that better road conditions increase self- and waged-employment opportunities but at the same time increase access to livestock markets.

3.4.3 Impact of livestock on income equality

Table 5 presents the estimated impact of livestock production on income inequality for the whole sample (no-livestock households and both negative and positive livestock income households), and for a sub-sample (no-livestock households and positive livestock income households). For the whole sample, column 1 shows the share of each income source in total household income and the contribution (about 7% - 11%) of livestock income to total household income.

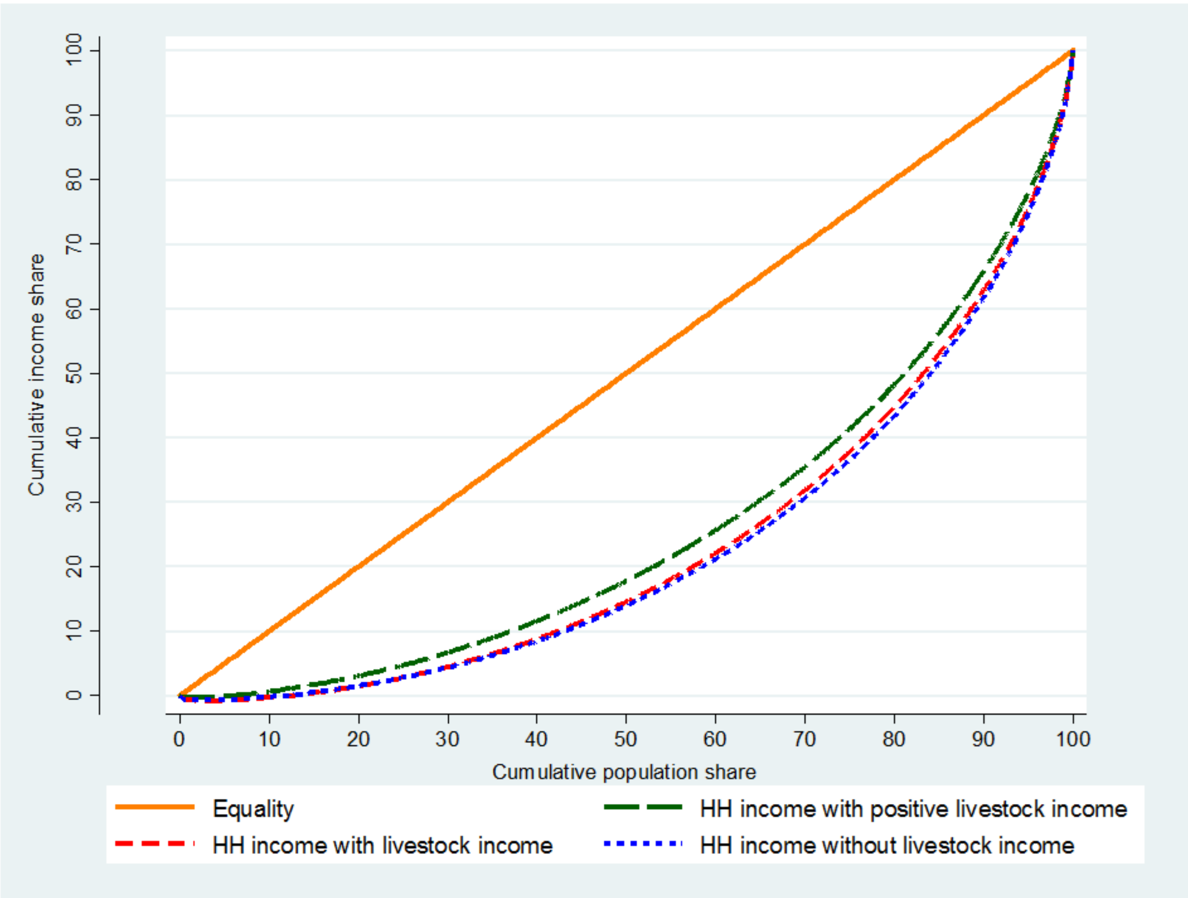
Column 2 presents the Gini coefficient of each income source. The Gini coefficient of livestock income in the first row (for the whole sample) is more than one (1.235) due to negative livestock income since it decreases to approximately 0.74 (the first row of the subsample) when we only account for no-livestock households and positive livestock income households. Column 2 for the whole sample shows that when negative livestock income is included, the overall Gini coefficient is slightly different between "with livestock income" and "without livestock income". However, column 2 for the subsample also shows that if we exclude negative livestock income, the overall Gini coefficient decreases significantly by about 3.3% (see Appendix 5 for the test of the impact of livestock on Gini coefficient). It means that positive livestock income reduces income inequality among rural households. This is illustrated in Figure 2.

Table 5. Gini Decomposition by income source (at the household level)

Income source	Share in total household income (1)	Gini coefficient for income source (2)	Gini correlation with total income rankings (3)	Share in Gini of total income (4)	Percentage change in Gini coefficient (5)
Whole sample (n = 8077)					
Livestock income	0.074	1.232	0.451	0.077	0.003 (0.0035)
Other income	0.926	0.543	0.975	0.923	-0.003 (0.0035)
Total income	1.000	0.532	1.000	1.000	
Subsample (households without livestock + households with positive livestock income, n = 6412)					
Livestock income	0.109	0.733	0.455	0.072	-0.037***(0.0035)
Other income	0.891	0.540	0.979	0.928	0.037***(0.0035)
Total income	1.000	0.507	1.000	1.000	

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard error bootstrapped with 1000 replications in parentheses.

Figure 2. Lorenz curves of household income with and without livestock income



Column 3 shows the Gini correlation between each income source and the total household income. The high correlations (0.45-0.46) reflect the important role of livestock income share in the overall Gini coefficient. The impact of a small change in livestock income and other income on the overall Gini coefficient is presented in column 5. An increase of 1%-point in livestock income, *ceteris paribus,* does not influence the overall Gini coefficient for the whole sample but decreases the overall Gini coefficient by 0.037% if our sample does not contain any negative livestock income households (the subsample). Therefore, if livestock production brings only positive income to the households, then it significantly contributes to reducing household income inequality. This is consistent with Woldehanna and Oskam (2001) who report that livestock contributes to the reduction of income inequality at the household level in Northern Ethiopia. However, if livestock production brings also negative income to a portion of the households, then it does not result in a significant effect on household income inequality reduction.

To further analyze the impact of livestock types on income inequality reduction, two livestock production pathways are considered and compared. We assume that the poor are provided with either one TLU of large livestock or one TLU of small livestock. Results in Table 6 show that livestock income increases total household income by 4% or 2% if the poor are provided with one TLU of large livestock or with one TLU of small livestock, respectively. The overall Gini coefficient is reduced by 5% or 4%, respectively (see Appendix 6). An increase of 1%-point in livestock income, *ceteris paribus,* decreases the overall Gini coefficient by 0.069% and 0.039%, respectively. Thus, large livestock should be prioritized in livestock production for reducing the rural income gap between the poor and the non-poor.

Table 6. Pathway analysis for Gini Decomposition by income source (at the household level)

Income source	Share in total household income (1)	Gini coefficient for income source (2)	Gini correlation with total income rankings (3)	Share in Gini of total income (4)	Percentage change in Gini coefficient (5)
Pathway 1: providing 1 large TLU for the poor					
Livestock income	0.109	0.817	0.223	0.041	-0.069***(0.0038)
Other income	0.891	0.543	0.974	0.960	0.069***(0.0038)
Total income	1.000	0.491	1.000	1.000	
Pathway 2: providing 1 small TLU for the poor					
Livestock income	0.095	0.935	0.319	0.056	-0.039***(0.0037)
Other income	0.905	0.543	0.975	0.944	0.039***(0.0037)
Total income	1.000	0.508	1.000	1.000	

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard error bootstrapped with 1000 replications in parentheses.

3.5 Conclusions and policy implications

We use panel household data collected in three provinces of Vietnam in four years, namely 2007, 2008, 2010 and 2013, to assess the factors affecting livestock income and the role of livestock production in reducing rural income inequality. Two-Part Fixed Effects models are used to estimate the effects of factors representing household livelihood assets and village characteristics on participating in livestock production and receiving livestock income. A Gini Decomposition method is used to identify the role of livestock production in reducing rural income inequality.

The findings show that livestock production significantly contributes to household income. Livestock production is positively influenced by human capital such as the education level of household head, physical capital such as the number of tractors and motorbikes, social capital such as the number of phones and memberships in socio-political organizations, financial capital such as access to credits, and natural capital such as farmland size. In addition, demographic shocks have a negative effect on livestock production, whereas the road conditions in the villages have a positive effect on the probability to have positive livestock income but a negative effect on the proportion of households having livestock. The effects of livestock production on income inequality depend on whether the livestock income is positive or negative. If there are households with negative livestock income, the effect is insignificant. If all households have positive livestock income, the effect is significant and positive on equal distribution of rural income. Having large livestock contributes more to reducing household income inequality.

Our findings lead to several important policy implications for income inequality reduction in Vietnam. First, we suggest that rural households should be supported to raise livestock for positive livestock income as this contributes significantly to reducing household income inequality. This can be done, for example, by promoting veterinary services. Second, priority should be given to large livestock such as cattle and buffaloes because their impact on income inequality reduction is higher than that of small livestock. This has an important implication for reducing the income gap between the poor and the non-poor: if the poor are provided with large livestock by aid programs from the government or non-governmental organizations, then income inequality can be reduced in a more sustainable manner. Third, we suggest that promoting access to credit and education as well as empowering rural households to cope with demographic shocks contribute to improving the welfare of rural households. Finally, better road conditions tend to improve the welfare of rural households.

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Appendix section

Appendix 1. Name and definition of the variables in the regression models

Variable	Definition	Scale
Dependent variable		
L	Household has livestock or not (1 = yes, 0 = otherwise)	Binomial
LI	Livestock income in PPP $ 2005	Metric
PLI	Household has positive or negative livestock income (1 = positive, 0 = negative)	Binomial
Independent variables		
Human capital		
ethnic	Ethnicity of household head (1 = Kinh; 0 = otherwise)	Binomial
age	Age of household head in years	Metric
gender	Gender of household head (1 = female; 0 = otherwise)	Binomial
education	Education of household head in years	Metric
hh_size	Household size in persons	Metric
hh_labor	Household laborers (are household members)	Metric
Physical capital		
tractor	No. of tractors of household	Metric
motorbike	No. of motorbikes of household	Metric
livestock_unit	No. of livestock of household in TLU	Metric
Social capital		
n_phone	No. of phones of household	Metric
SPO	No. of social or political groups the household participates in or is a member of	Metric
Financial capital		
access_credit	Households with access to credit in the last 5 years before the survey year (1 = yes; 0 = otherwise)	Binomial
Natural capital		
land_size	Agricultural land area of household in ha	Metric
Shocks		
weather_shock	No. of weather shocks during the last three years	Metric
demo_shock	No. of demographic shocks (e.g. sickness, death or birth of household member) during the last three years	Metric
Village variables		
road_type	Access to the village all year around (1 = yes; 0 = otherwise)	Binomial
distance_town	Distant from the household to the nearest town (in km)	Metric
enterprise	No. of enterprises with more than nine employees in the village	Metric
electricity	Share of households with access to electricity in %	Metric

Appendix 2. Multicollinearity test

Variable	VIF	1/VIF
Human capital		
ethnic	1.38	0.72
age	1.26	0.79
gender	1.17	0.85
education	1.34	0.75
hh_size	2.14	0.47
hh_labor	2.23	0.45
Physical capital		
tractor	1.11	0.90
motorbike	1.84	0.54
livestock_unit	1.06	0.94
Social capital		
n_phone	1.73	0.58
SPO	1.33	0.75
Financial capital		
access_credit	1.06	0.94
Natural capital		
land_size (ln)	1.21	0.83
Shock		
weather _shock	1.09	0.92
demo_shock	1.03	0.97
Village variables		
road_type	1.15	0.87
distance_town (ln)	1.02	0.98
enterprise	1.05	0.95
electricity	1.06	0.94
Mean	**1.33**	

Appendix 3. Hausman tests of Fixed Effects Logit and Random Effects Logit models

Variable	Fixed Effects Logit	Random Effects Logit	Difference	Standard errors of difference
Human capital				
ethnic	1.308	0.266	1.042	0.902
age	0.004	0.013	-0.009	0.010
gender	-0.189	-0.119	-0.070	0.237
education	0.062	0.059	0.003	0.023
hh_size	0.105	0.018	0.087	0.048
hh_labor	0.029	-0.002	0.031	0.056
Physical capital				
tractor	0.298	0.687	-0.388	0.100
motorbike	0.109	-0.222	0.332	0.061
Social capital				
n_phone	0.057	0.022	0.035	0.031
SPO	0.063	0.158	-0.095	0.017
Financial capital				
access_credit	0.408	0.400	0.008	0.049
Natural capital				
land_size (ln)	0.138	0.464	-0.325	0.024
Shock				
weather _shock	0.112	0.146	-0.034	0.032
demo_shock	0.008	0.056	-0.048	0.033
Village variables				
road_type	-0.679	-0.070	-0.608	0.131
distance_town (ln)	0.042	-0.014	0.055	0.092
enterprise	-0.125	-0.183	0.058	0.050
electricity	0.000	0.002	-0.002	0.001
$Chi^2(18)$		324.30		
Prob.>chi^2		0.0000		

Appendix 4. Hausman tests of Fixed Effects OLS regression and Random Effects OLS regression models

Variable	Fixed Effects OLS regression	Random Effects OLS regression	Difference	Standard errors of difference
Human capital				
ethnic	0.474	0.209	0.265	0.714
age	0.030	0.010	0.020	0.010
gender	0.051	-0.067	0.118	0.275
education	0.047	0.021	0.026	0.023
hh_size	-0.087	-0.012	-0.075	0.047
hh_labor	-0.020	-0.076	0.055	0.058
Physical capital				
tractor	0.134	0.292	-0.158	0.084
motorbike	0.311	0.117	0.194	0.063
livestock_unit	0.116	0.094	0.022	0.019
Social capital				
n_phone	0.117	0.106	0.011	0.027
SPO	0.015	0.004	0.011	0.020
Financial capital				
access_credit	0.155	0.025	0.130	0.052
Natural capital				
land_size (ln)	0.068	0.102	-0.034	0.027
Shock				
weather _shock	0.061	-0.021	0.082	0.036
demo_shock	-0.125	-0.093	-0.031	0.036
Village variables				
road_type	0.356	0.122	0.233	0.105
distance_town (ln)	-0.169	-0.040	-0.129	0.085
enterprise	-0.121	-0.081	-0.040	0.063
electricity	0.000	-0.001	0.001	0.002
$Chi^2(19)$		65.12		
$Prob.>chi^2$		0.0000		

Appendix 5. The impact of livestock on Gini coefficient (at the household level)

Sample	Gini coefficient with livestock income (1)	Gini coefficient without livestock income (2)	Impact (1) - (2)
Whole sample (n = 8077)			
	0.532***	0.543***	-0.012***
	(0.005)	(0.005)	(0.002)
Subsample (households without livestock + households with positive livestock income, n = 6412)			
	0.507***	0.540***	-0.033***
	(0.005)	(0.005)	(0.002)

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard error bootstrapped with 1000 replications in parentheses.

Appendix 6. The impact of livestock on Gini coefficient by pathway (at the household level)

Pathway	Gini coefficient with livestock income (1)	Gini coefficient without livestock income (2)	Impact (1) - (2)
Pathway 1: providing 1 large TLU for the poor			
	0.491***	0.543***	-0.052***
	(0.0047)	(0.0049)	(0.0019)
Pathway 2: providing 1 small TLU for the poor			
	0.508***	0.543***	-0.036***
	(0.0046)	(0.0049)	(0.0018)

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard error bootstrapped with 1000 replications in parentheses.

4 Nonfarm Employment and Household Food Security: Evidence from Panel Data for Rural Cambodia

This chapter is submitted to *Food Security.*

Abstract

Nonfarm employment has been increasingly important of improving food security of rural households in the developing world. In this paper, we (1) determine the factors explaining the participation in nonfarm employment and nonfarm income of rural households by employing a two-part random effects econometric model, and (2) examine the effects of nonfarm employment on rural household food security indicators by combining the propensity score matching with the difference-in-differences approach. We use a panel dataset of 561 households in 30 villages of Stung Treng province in Cambodia collected in 2013 and 2014. We divide our sample into two groups, households with nonfarm employment, and households without nonfarm employment. Our findings show that (1) nonfarm employment contributes on average about 32% to total annual household income for the whole sample and 57% for the households with nonfarm employment; (2) nonfarm participation and nonfarm income are significantly influenced by the education level of household heads, number of motorbikes and mobile phones, conditions of roads to the villages, farmland size, number of income shocks, and the distance from home to the nearest market; (3) there is no significant difference in terms of food availability between households with and households without nonfarm employment but the former has improved food access, utilization, and stability. We suggest that promoting rural education, supporting farmland accumulation, improving road conditions, and empowering rural households to cope with income shocks via promoting their access to credit would contribute to developing nonfarm employment and consequently improve the food security of rural households.

Keywords: impact assessment; propensity score matching; difference-in-differences; two-part random effects model; Cambodia

4.1 Introduction

Nonfarm employment such as self-employment or wage-employment in rural areas is important to improve livelihoods and welfare of rural households in developing countries (see for example Mishra and Sandretto 2002; Goodwin and Mishra 2004; de Janvry et al. 2005; Chang and Mishra 2008; Owusu et al. 2011). Despite being labor intensive, the setting up of nonfarm employment of rural households requires relatively little capital and provides an important source of income (Reardon et al. 1998; Tsiboe et al. 2016). By easing capital constraints, nonfarm employment can enhance farm households' input purchasing capacity, thereby contributing to higher food production and farm income, thus improving household welfare (Ruben and van den Berg 2001; Stark and Wang 2002; Taylor et al. 2003; Babatunde and Qaim 2010). Rural households engaged in nonfarm employment tend to raise their household food consumption and income and have better food access (Owusu et al., 2011; Babatunde and Qaim 2010; Ersado 2006; Ruben and van den Berg 2001). There is also evidence that the importance of nonfarm employment has been increasing over the last few decades (de Janvry and Sadoulet 2001; Olugbire et al. 2011), especially in emerging Asian economies (Démurger et al. 2010).

It is well known that food security is a complex and multidimensional concept that can be measured by different indicators. Typically, food security includes the availability, access, utilization, and stability of food (FAO et al. 2014). Even though the effects of nonfarm employment on rural food security and the factors determining the participation of rural households in nonfarm employment have been fairly well documented (see Abdulai and CroleRees 2001; Barrett et al. 2001; Fabusoro et al. 2010; Senadza 2012; van Leeuwen and Dekkers 2013; Tsiboe et al. 2016), there are still research gaps. First, previous studies mainly focused on the effects of nonfarm employment on food access of rural households without considering the effects on all four dimensions of rural household food security. Second, these studies paid little attention to the factors affecting the intensity of the participation (e.g. nonfarm income).

This study contributes to filling these research gaps in several important ways. First, we measure the effect of nonfarm employment on household food security by using various indicators to cover all four dimensions of food security. Second, we determine the factors explaining the participation in and the intensity of nonfarm employment. Our findings provide a more comprehensive understanding of the contribution of nonfarm employment to food insecurity reduction at the household level and of the factors affecting nonfarm employment of rural households. Methodologically, we employ the Matching-Difference-In-Differences approach (M-DID) (see Cerulli 2015), which is a combination of Propensity Score Matching with the Difference-In-Differences method, to correct for biases from observed characteristics and to eliminate the effects of unobserved (time-invariant) variables on the outcome variables (food security indicators) (Smith and Todd 2005). Previous studies did not address the effects of unobserved (time-invariant) variables on food security indicators at the household level. In addition, we use panel data which provide a more accurate inference of model parameters, less multicollinearity among variables, more sample variability, and more degrees of freedom than cross-sectional or time-series data, hence improving the efficiency of econometric estimates (Hsiao 2007; Baltagi 2013; Nguyen et al. 2017).

We use two-year panel data collected in 2013 and 2014 in Cambodia for our analysis. The country is among the least developed economies in the world and is characterized by a relatively low Gross Domestic Product (GDP) per capita, and high levels of both poverty and food insecurity (Seng 2015). The GDP per capita was about 1,270 US$ in 2016 (World Bank, 2017a) and the poverty rate was 14% in 2015 (Asian Development Bank 2017a). The proportion of undernourished people in the total population was about 14% in 2015 (World Bank 2017b). On the one hand, high poverty rates and limited social protection coverage lead to limited access to sufficient and nutritious food, especially for the rural poor. On the other hand, the country has experienced rapid economic growth of more than 7% over the last several years (Asian Development Bank 2017b). As a result, there is an increasing number of nonfarm employment opportunities for rural households in Cambodia. While the effects and determinants of nonfarm work are documented in other developing countries (Abdulai and CroleRees 2001; Barrett et al. 2001; Fabusoro et al. 2010; Senadza 2012; van Leeuwen and Dekkers 2013), these issues have not been investigated in Cambodia.

Against this background, we address the following research questions: (1) how important is the nonfarm income to household income, (2) what are the factors affecting the participation in and the intensity of nonfarm employment of rural households, and (3) what are the effects of nonfarm employment on different food security dimensions of rural households? Our findings are relevant not only to Cambodia but also to other emerging economies.

The remainder of the paper is structured as follows: Section 2 details the conceptual framework and econometric specifications of our study. Section 3 introduces our methods and data. Section 4 presents the results and discusses the findings. Finally, Section 5 concludes with policy implications.

4.2 Conceptual framework and econometric specifications

4.2.1 Conceptual framework

In a standard farm household model, the household maximizes its utility subject to its time, budget, and farm productivity constraints through its choice of consumption goods purchased, the quantity of farm inputs purchased, and the working hours allocated to farm and nonfarm employment (Huffman 1991; Weersink et al. 1998). The maximization of household utility (U) can be presented as follows:

$$Max\ U = U(G, L_s) \tag{1}$$

Subject to

$$\begin{cases} L = L_f + L_n + L_s, \quad L_s, L_f > 0 \text{ and } L_n \geq 0 & (2) \\ P_G G = P_Q Q - P_x X + W_n L_n + N & (3) \\ Q = f(L_f, X, Z) & (4) \end{cases}$$

where G denotes the household consumption of goods. L presents total household labor that is allocated to farm work (L_f), nonfarm work (L_n), and leisure (L_s). P_G and P_X are the goods price and the input price vectors, respectively. W_n denotes the nonfarm wage, N is household non-labor income such as remittances and capita income, Q is agricultural produce, X is the quantity of purchased farm inputs, and Z is a vector consisting of household and location characteristics.

Huffman (1991) and Weersink et al. (1998) present the results of this utility maximization problem for optimal allocation of labor between farm work, nonfarm work, and leisure. The optimal labor for farm and nonfarm work can then be derived as follows:

$$L_j^* = l_j^*(P_G, P_X, W_n, L, N, X, Z) \qquad j = f, n \tag{5}$$

If the potential market wage (w_{it}^m) is greater than the reservation wage (w_{it}^r)[4], household i will participate in nonfarm work at the time t (Huffman 1991). Thus, $L_{it} = 1$ if $w_{it}^m > w_{it}^r$ and $L_{it} = 0$ if $w_{it}^m \leq w_{it}^r$. The difference between these two wages is not observable because we could not observe these two wages at the same time. However, the household's decision to participate or not in nonfarm work is observable. Therefore, we can use an index function with an unobserved variable to specify this decision as follows:

$$\begin{cases} L_{it}^* = Z' \cdot \alpha + e_{it} \\ L_{it} = 1 \quad \text{if} \quad L_{it}^* > 0 \\ L_{it} = 0 \quad \text{if} \quad L_{it}^* \leq 0 \end{cases} \tag{6}$$

where e_{it} is a random error term; L_{it} denotes a dummy variable equaling one, if household i at time t participates in nonfarm work and zero otherwise. Equation 6 shows that the participation in nonfarm

[4] Assuming without nonfarm work and evaluated at the point of optimal allocation of time between farm work and leisure, the marginal value of farm labor is the reservation wage for nonfarm work.

work is influenced by household characteristics and location characteristics (Z). To further analyze the relationship between participation in nonfarm work and outcomes such as household nonfarm income and food security status, we start from the linear function as follows:

$$Y_{it} = \varphi + Z' \cdot \beta + \gamma \cdot L_{it} + \eta_{it} \quad (7)$$

where Y_{it} is nonfarm income or the food security status of household i at time t, and η_{it} is a random error term.

In Equation 7, L_{it} is an exogenous variable measuring the impacts of participation in nonfarm work on household nonfarm income or on household food security status. However, it is an endogenous variable in Equation 6. This implies that selection bias occurs if unobservable covariates affect both the error term (e_{it}) of Equation 6 and the error term (η_{it}) of Equation 7. When selection bias occurs, the pooled Ordinary Least Squares (OLS) method is not valid to estimate the impact of L_{it} on household nonfarm income or on household food security status (Equation 7).

There are several econometric techniques to address this selection bias such as the Endogenous Switching Regression model, the Heckman Two-Step model, the Instrumental Variable model, the Propensity Score Matching, the Matching-Difference-In-Differences (M-DID) method, the Fixed Effects model, and the Two-Part Random (Fixed) Effects model. The Endogenous Switching Regression model and the Heckman Two-Step model depend on the restrictive assumption for normally distributed errors but neither of them are employed in panel data analysis. The instrumental variable method is also restrictive as it is very difficult to find good instrumental variables. The Fixed Effects model with interaction between the time variable and the treatment variable not only requires to meet all assumptions of the OLS model but also requires no correlation between the difference in the interaction variable in period t and $t-1$, and the difference in the error term in period t and $t-1$ ($Cov(D_{it} - D_{it-1}; v_{it} - v_{it-1}) = 0$, D is the interaction variable and v is the error term) (Cerulli 2015). Therefore, in our analysis, we employ the Two-Part Random Effects model to determine the factors affecting the participation in nonfarm work and nonfarm income of the rural household and the M-DID method to measure the impact of nonfarm employment on food security of the rural household. The Two-Part Random Effects model includes two parts, namely the Random-Effects Logit model and the Random Effects OLS model. The former is used to determine the factors explaining the participation in nonfarm work, whereas the latter is used to determine the factors explaining the nonfarm income of the rural households who participate in nonfarm work. The Two-Part Random Effects model not only accounts for the correlation between the error terms of Equation 6 and Equation 7 (e_{it} and η_{it}) but is also applicable in panel data analysis. The M-DID method is a combination between the Propensity Score Matching (PSM) method with the Difference-In-Differences (DID) method. The M-DID method not only addresses the aforementioned selection bias but also eliminates the effect of unobserved (time-invariant) variables on the outcome variables (Smith and Todd 2005).

4.2.2 Two-part Random Effects model for identifying the determinants of participation in and intensity of nonfarm employment

The decision of a household to participate in and the intensity of nonfarm work can be represented first by a yes-no answer (for participating or not) and then by nonfarm income (for the intensity), respectively. As conceptualized in Section 2.1, the participation decision and nonfarm income are related (nonfarm income exists only when the decision is yes). Thus, nonfarm income is censored at zero (it is zero for the households without nonfarm employment and positive for the households with nonfarm employment). As nonfarm income variable has both positive and zero values, we follow Duan et al. (1983) and Manning et al. (1987) to apply a Two-Part Random Effects model with a panel dataset in 2013 and 2014 for estimating the factors affecting both nonfarm participation and nonfarm income.

The first part is to model the decision to participate with a Random Effects Logit model. The second part is to model the nonfarm income with a Random Effects OLS model. These are as follows:

$$Pr(D_{ijt} = 1|X'_{ijt}, S'_{ijt}, V'_{jt}) = \frac{exp(\theta_0 + X'_{ijt}\theta_1 + S'_{ijt}\theta_2 + V'_{jt}\theta_3 + R'\theta_4 + u_{ijt} + \varepsilon_{ijt})}{1 + exp(\theta_0 + X'_{ijt}\theta_1 + S'_{ijt}\theta_2 + V'_{jt}\theta_3 + R'\theta_4 + u_{ijt} + \varepsilon_{ijt})} \quad (8)$$

$$Ln(I_{ijt})_{|I_{ijt}>0} = \beta_0 + X'_{ijt}\beta_1 + S'_{ijt}\beta_2 + V'_{jt}\beta_3 + R'\beta_4 + \mu_{ijt} + \omega_{ijt} \quad (9)$$

where D_{ijt} is a binary variable which is equal to 1 for $I_{ijt} > 0$ and equal to 0 for $I_{ijt} = 0$. I_{ijt} is nonfarm income of household *i* in the village *j* at time *t*. X_{ijt}, S_{ijt}, and V_{ij} denote household characteristics, the number of income shocks that the household faced during the last three years, and observable village characteristics, respectively. *R* is the region fixed effects to capture the factors that are unobservable but might influence the decision of household to participate in nonfarm employment and the household nonfarm income at the regional level. u_{ijt} and μ_{ijt} are random effects of Equations (8) and (9), respectively. ε_{ijt} *and* ω_{ijt} are error terms of Equations (8) and (9), respectively. We use the robust option to control for possible heteroscedasticity in both models.

Household characteristics include human, financial, physical, social, and natural capital. Human capital is represented by the age, gender, and education level of the household head, household size, and household labor. Physical capital is represented by the numbers of tractors, motorbikes, and Tropical Livestock Units[5] that the household owns. Social capital is represented by the number of mobile

[5] We follow Chilonda and Otte (2006) to convert different types of livestock into one standardized unit, namely Tropical Livestock Unit (TLU).

phones used by household members and the number of socio-political groups that household members participate in. These variables reflect the contacts and the network a household has, as they allow the members to stay in contact with friends, relatives or business partners. Financial capital is represented by two dummy variables, one indicating if the household received remittances during the period and the other indicating if the household has access to credit. Having remittances or access to credit might influence household food security as it increases the available income for purchasing food. Natural capital is represented by the farmland size of the household as it might be suggestive of wealth and status in rural areas of developing countries (Nguyen et al. 2015). In addition, the number of income shocks perceived by the household during the last three years is also included because income shocks might lead to changes in labor allocated to nonfarm activities and nonfarm income. This consists of different types of shocks that lead to an income loss of the household. At the village level, the following two variables are included: a dummy variable of whether the village is physically accessible during the whole year, and the distance from home to the nearest market. Moreover, as our study site (Stung Treng province) consists of three regions, namely the Mekong, Mountain, and Lowland regions, we use two additional dummies (for the Mekong and Mountain regions) to take into account regional heterogeneities that are not included in these household and village variables. These variables are summarized in Table A1 in the Annex Section. As the number of independent variables is high, the Variance Inflation Factor (VIF) test is used to detect potential multi-collinearity. The result of the test rejects the null hypothesis of the problem (see Table A2 in the Annex Section). The results of the propensity score estimation are reported in Table A3.

From the results of these two models, we estimate the Average Partial Effect (APE) of each independent variable (e.g. the independent variable m^{th}) on the unconditional dependent variable *ln(I)* for the whole sample (including both households with and households without nonfarm employment) (Arouri et al. 2017) as follows:

$$\widehat{APE}_m = \hat{\theta}_m \cdot \frac{1}{n_I} \cdot \sum_{ijt} \ln(I_{ijt}) + \hat{\beta}_m \cdot \frac{1}{n} \cdot \sum_{ijt} D_{ijt} \tag{10}$$

where $\hat{\theta}_m$ and $\hat{\beta}_m$ are estimates of the independent variable m^{th} in equations (8) and (9), n_I is the number of observations with positive nonfarm income (*ln(I)*), and n is the total number of observations in the sample.

4.2.3 M-DID method for examining the impact of nonfarm employment

We use the M-DID method for a panel dataset in 2013 and 2014 to estimate the Average Treatment Effect on the Treated (ATT) for examining the impact of nonfarm employment on household food security. We compare the outcome variables (household food security indicators) between the group of households with nonfarm employment (Treatment Group, T) and the group of households without nonfarm employment (Control Group, C). This procedure consists of the following steps:

First, we use a Probit model to estimate the propensity scores based on household characteristics, income shocks, and village characteristics in 2013 to match the households between the Treatment and Control groups. The model is defined as follows:

$$P(X) = \quad Pr(D_{ij,2014} = 1 | \; X_{ij,2013}, \; S_{ij,2013}, V_{j,2013}, \; R) \tag{11}$$

The dependent variable in Eq. 11 represents the probability that household *i* in village *j* has nonfarm activities in the year 2014. The dummy variable ($D_{ij,2014}$) equals one if household *i* in village *j* has nonfarm activities in 2014 and zero otherwise. That probability is a function of observable household characteristics ($X_{ij,2013}$), the number of income shocks that the household faced during the last three years ($S_{ij,2013}$), and observable village characteristics ($V_{j,2013}$) in 2013. *R* is as in Eq. (8).

Second, based on the propensity scores, three matching methods, namely the Nearest-Neighbor Matching (NNM), the Kernel Based Matching (KBM), and the Radius Matching (RM) are used to match the control and the treatment groups. The NNM is the five nearest neighbor method with common support and replacement, whereas the KBM estimator and the RM estimator are with common support and with bandwidth 0.06. The standard errors are bootstrapped for 1,000 replications to assess the variability of propensity score matching estimators with the KBM and the RM methods.

We perform different quality checks for these matching methods. We find that there is a considerable overlap in the common support. Figure A1 in the Annex Section presents the histogram of the estimated propensity scores for the Treatment and Control groups. The density distributions of the estimated propensity scores indicate that the common support condition is matched. The results of covariate balancing tests before and after matching are presented in Table A4. They indicate that the standardized mean differences (Caliendo and Kopeinig 2008) for overall covariates used in the propensity scores before matching (from 24.5%) are sharply reduced after matching (to 4.0% - 4.4%). In addition, the percentages of bias reductions are in the range of 82% - 84% through matching. The likelihood ratio tests (*p-value*) show that the joint significance of covariates is always rejected after matching while it is never rejected before matching. The pseudo-R^2 also decreases significantly from 20.9% before matching to 0.8% - 1.4% after matching. The low mean standardized bias, high percentages of bias reduction, the insignificance of the likelihood ratio test, and low pseudo-R^2 after matching suggest that the proposed specification of the propensity scores is successful in terms of balancing the distribution of covariates between the Treatment and Control groups. Therefore, the ATT for examining the impact of nonfarm employment on household food security is modeled as follows:

$$ATT = E\left(Y_{2014}^{T} - Y_{2013}^{T} | D = 1, P(X)\right) - E\left(Y_{2014}^{C} - Y_{2013}^{C} | D = 1, P(X)\right) \quad (12)$$

where *C* and *T* denote the Treatment and Control groups, respectively. The outcome variables include a set of household food security indicators, which is presented in the next section.

The drawbacks of M-DID are the Conditional Independence Assumption (CIA) for PSM method and the Parallel Trend Assumption (PTA) for DID method (Cerulli 2015). CIA means that for a given set of covariates, participation in nonfarm work is independent of households' potential outcomes and PTA means that the trend of potential outcomes is similar between the households with nonfarm employment and the households without nonfarm employment when the former does not participate in nonfarm work. Therefore, we also use the Fixed Effects model with interaction between time variable and treatment variable to check for the robustness of the results of the M-DID method. The results show that the sign and statistical significance of the impact of nonfarm employment on household food security indicators from the fixed effects models and the M-DID models are in agreement, proving that our results are robust (see Tables A5-A6 in the Annex Section).

4.3 Data and descriptive statistics

4.3.1 Data collection

The panel data employed in this study come from a survey conducted in 2013 and 2014 in the province of Stung Treng in the northeastern part of Cambodia (Figure 1). This province was selected because of its relatively high incidence of poverty and food insecurity (Nguyen et al. 2015). Due to rapid economic growth, nonfarm employment opportunities have been increasing in emerging sectors such as tourism, trade, transport, and communication. The province includes five districts comprising 129 villages.

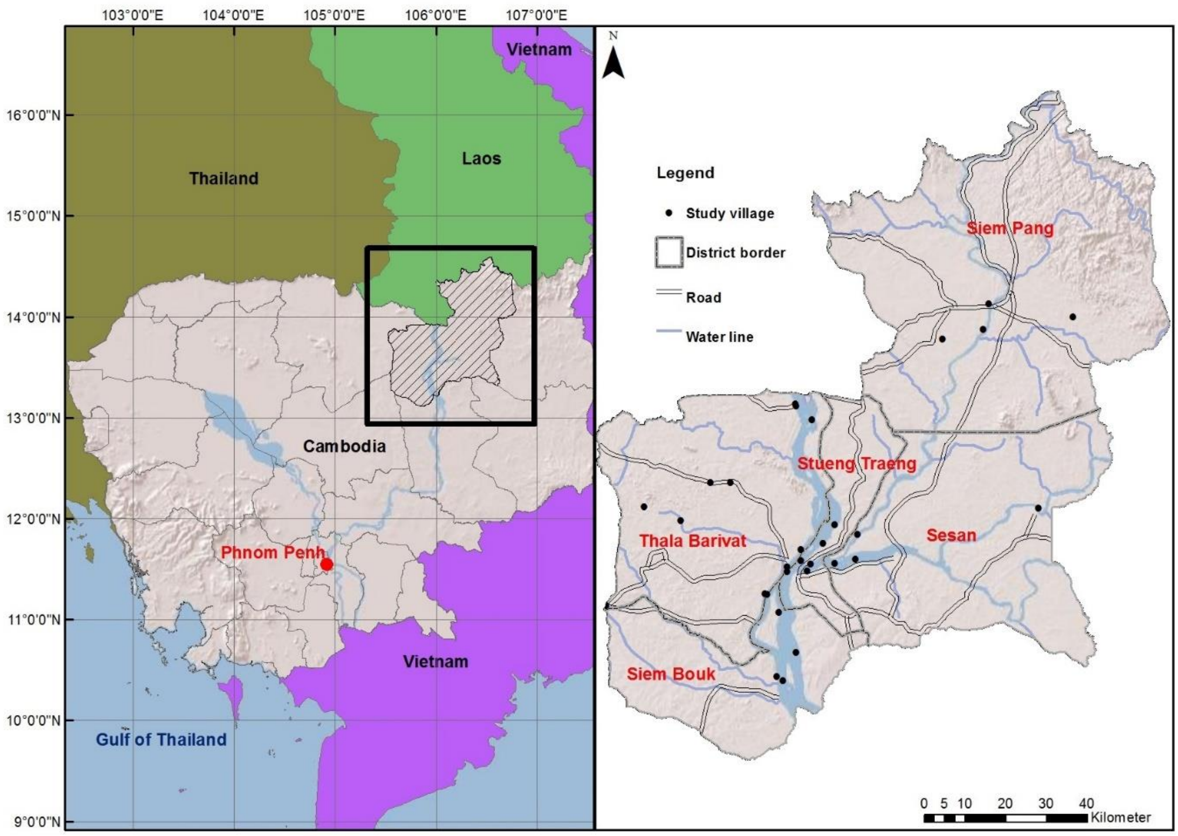
Our data collection is based on the guidelines of the United Nations Department of Economic and Social Affairs (United Nations 2005) and includes two steps. In the first step, 30 of these 129 villages were randomly chosen based on sampling proportional to a village's size (measured as the number of households in the village). In the second step, 20 households were randomly selected in each chosen village. The surveys were undertaken from April to May in 2013 and 2014. This allows us to establish a panel dataset of 600 households from 30 villages in the province over two years. However, we can use only 561 households for the analysis as the rest of the sample has either missing values or outliers in important variables.

We use two survey questionnaires with structured interviews[6] to collect data, one for the households

[6] Both village and household questionnaires are available and can be provided upon request.

and the other for the villages. The household questionnaire contains sections on the demographic, economic and social situation of households. This includes livelihood activities such as farming, nonfarm self-employment, off-farm wage-employment, and remittances. One separate section is designed for food security that includes: (1) information about quantity and monetary value of different foods that the household consumes during the last normal week; (2) information about different foods that the household consumed in each month of the last 12 months; (3) and information about food consumption when the household faced shocks (e.g. floods, droughts or job loss). The village questionnaire captures village-level data on population, infrastructure, and other socio-economic indicators of the village.

Figure 1. Map of Cambodia (left) and of the Stung Treng province (right) (Nguyen et al. 2015)



4.3.2 Descriptive statistics

The descriptive statistics of household and village characteristics from our collected data are summarized in Table 1, which also shows the differences between the two groups, the households with nonfarm employment, and the households without nonfarm employment. For the whole sample, the majority of rural households are male-headed and the average age of household heads is 45 years. The education level of household heads is low, about 3.5 years. About 28% of households have loans and 38% of households have remittances. About 90% of the villages are not accessible at all times throughout the year due to weather conditions in the rainy season. On average, each household has about 1.5 hectares of farmland, five people, and three laborers. The average distance from home to the nearest market is about 24 km. Each household experienced 1.5 income shocks during the last three years. Regarding the differences between the two groups, most household and village characteristics are statistically different. An older and better educated head, higher numbers of laborers, tractors, motorbikes, and mobile phones but a smaller farmland size characterize the households with nonfarm employment as compared to the households without nonfarm employment. With respect to the village characteristics, the households with nonfarm employment live closer to the market than the other households.

Table 1. Basic household and village characteristics

Variable	Whole sample (n = 1121)		Households with nonfarm employment (n = 451)		Households without nonfarm employment (n = 670)		Test statistics
	Mean	SD	Mean	SD	Mean	SD	
Household level							
land_size	1.44	1.79	1.38	1.97	1.49	1.66	-3.49***b
age	44.88	13.81	46.34	12.62	43.90	14.48	3.59***b
gender	87.69	32.87	87.80	32.76	87.61	32.97	0.01c
education	3.46	3.27	4.77	3.56	2.58	2.73	10.39***b
hh_size	5.20	1.95	5.29	2.02	5.13	1.91	1.07b
hh_labor	2.95	1.44	3.21	1.58	2.78	1.31	4.22***b
tractor	0.27	0.46	0.30	0.48	0.25	0.44	1.77*a
motorbike	0.80	0.75	1.10	0.83	0.60	0.61	10.83***b
livestock_unit	2.28	3.62	2.81	4.64	1.93	2.67	0.31b
remittance	38.36	48.65	37.69	48.52	38.81	48.77	0.14c
access_credit	27.92	44.88	29.27	45.55	27.01	44.44	0.68c
SPO	59.95	49.02	60.98	48.83	59.25	49.17	0.33c
mobile	1.35	1.38	1.94	1.54	0.95	1.09	12.94***b
shock	1.44	1.34	1.38	1.35	1.48	1.32	-1.64b
Village level							
road_type	10.08	30.12	11.75	32.24	8.96	28.58	2.33c
distance_market	24.45	24.20	18.89	22.04	28.20	24.88	-8.05***b

* Significant at 10%, ** significant at 5%, *** significant at 1%, SD is standard deviations; [a] t-Ttest, [b] nonparametric two-sample test: Mann-Whitney U test, [c] Chi square test.

4.3.3 Measuring food security

Food security is defined as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO et al. 2014). Similar to the national level, food security at the household level also has four dimensions, food availability, food access, food utilization, and food stability. Household food availability depends on home production and/or food purchases. Food access refers to household's ability to have adequate resources or entitlements for obtaining food. Food utilization depends on adequate diets and nutritious values of food. Food stability ensures that food can be accessed at all times. Each dimension can be reflected by different indicators (see FAO et al. 2014 for a review of different indicators). Our study uses the following indicators (summarized in Table 2).

Table 2. Household food security indicators

Dimension	***Indicator***	***Reference***
Food availability	Daily Value of Agricultural Production per Adult Equivalent (DAPAE) (PPP $)	FAO (2013); Di Falco et al. (2011); Lema et al. (2014).
	Daily Rice, Corn and Bean Consumption per Adult Equivalent (DRCAE) (PPP $)	Pangaribowo et al. (2013)
Food access	Household Dietary Diversity Score (HDDS)	Swindale and Bilinsky (2006); Coates (2013)
	Months of Adequate Household Food Provisioning (MAHFP)	Coates (2013); Bilinsky and Swindale 2010; Brüssow et al. (2017)
	Household Food Insecurity and Access Scale (HFIAS)	Coates, Swindale, and Bilinsky (2007); Mekonnen and Gerber (2017)
	Household Dietary Diversity Group (HDDG)	
Food utilization	Food Consumption Score (FCS)	World Food Programme (2008); Wenban-Smith et al. (2016); Dibba et al. (2017)
	Food Consumption Group (FCG)	
Food stability	Coping Strategy Index (CSI)	Leroy et al. (2015); Coates (2013)
	Reduced Coping Strategy Index (rCSI)	Leroy et al. (2015); Maxwell and Caldwell (2008)
	Coping Strategy Group (CSG)	

Two indicators represent food availability of a household: (1) Daily value (in PPP $ in 2013) of Agricultural Production per Adult Equivalent[7] (DAPAE); and (2) Daily Rice, Corn, and Bean Consumption (in PPP $ in 2013) per Adult Equivalent (DRCAE). The higher the values of DAPAE and DRCAE are, the higher the food availability of the household.

Three indicators measure food access: (1) Household Dietary Diversity Score (HDDS); (2) Months of Adequate Household Food Provisioning (MAHFP); and (3) Household Food Insecurity and Access Scale (HFIAS). To calculate the HDDS, we divide food that was consumed by the household in the last normal week into 12 distinct food groups. The value of HDDS ranges from 0 to 12. A high HDDS score means high food access of a household. MAHFP is measured as the number of months over the previous 12

[7] We follow Claro et al. (2010) to build adult equivalent scales for children and older people.

months that a household had adequate access to food (through self-production, purchase, or aid) for consumption (Bilinsky and Swindale 2010). HFIAS is measured at the household level based on a set of nine questions (Coates et al. 2007). A low HFIAS score also means high food access of the household. However, as not all these three indicators show the proportion of the households who are insecure in food access, we follow Vhurumuku (2014) to create the Household Dietary Diversity Groups (HDDG) that is based on HDDS to classify the households into two groups. The first HDDG includes the households who have HDDS of more than six (security in food access, the HDDG equal to zero). The second HDDG includes the households who have HDDS of less than or equal to six (insecurity in food access, the HDDG equal to one). Thus, the HDDG represents the proportion of the households who are insecure in food access.

A single proxy of household-level dietary diversity, namely the Food Consumption Score (FCS), measures food utilization. FCS is calculated based on the dietary diversity, food frequency, and weighted nutritional importance of eight different food groups consumed during the last normal week (World Food Programme 2008). Eight food groups are constructed, namely staples, pluses, fruits, vegetables, meat and fish, eggs and milk, oil, and sugar. A high FCS means high food utilization. However, as FCS does not show the proportion of household food utilization insecurity, we follow Leroy et al. (2015) to create the Food Consumption Groups (FCG) that are based on the FCS to categorize the households into two groups. The first FCG includes the households who have FCS of more than 35 (security in food utilization, the FCG equal to zero). The second FCG includes the households who have FSC of less than or equal to 35 (insecurity in food utilization, the FCG equal to one).

Two indicators, namely the (1) Coping Strategy Index (CSI) and the (2) Reduced Coping Strategy Index (rCSI) represent the food stability dimension. We follow Maxwell and Caldwell (2008) to calculate the CSI based on the 12 coping strategies used by the household when it does not have adequate food and does not have money to buy food. For the rCSI, we use a standard set of five individual coping behaviors that can be employed by any household anywhere with a universal set of severity weightings to calculate the rCSI. The five standard coping strategies and their severity weightings are: eating less-preferred foods (weight = 1); borrowing food/money from friends and relatives (weight = 2); limiting portions at mealtime (weight = 1); limiting adult intake (weight = 3); and reducing the number of meals per day (weight =1). A low CSI or a low rCSI means high food stability. However, both indicators cannot represent the proportion of household who are food insecure. Therefore, we create the Coping Strategy Group (CSG) based on the CSI to categorize the households into two groups. A household is insecure in food stability if it has CSI score greater than 12 (insecurity in food stability) and vice versa (security in food stability).

4.4 Result and discussion

4.4.1 Household nonfarm employment and food security

Nonfarm employment includes off-farm wage-employment and nonfarm self-employment. Off-farm wage-employment includes three activity categories: (1) working in factories such as in food processing, textile, wood industry, metal products and machinery, brickyard, or construction; (2) working in services such as in security, house care, transportation, shops, bars/restaurants; and (3) working in the public sector such as in hospital, public security, school, and military force. Nonfarm self-employment includes five activity categories: (1) agricultural services and livestock trading; (2) home production such as rice milling, silk spinning/weaving, mat making, basket making, brickyard, and pottery; (3) trade, transport and communication such as retail shops, petty trade, wholesale, taxi and transport, and internet-shops; (4) hotel and food services such as hotel/guesthouse, restaurant/bar, food stall operator, butchery, and other small-scale food processing; and (5) crafts and other services such as hair salon/barber, repair shops, car-washing, shoe-cleaner, handicrafts, construction, and funeral and wedding services. Table 3 reports the number of households that participate in nonfarm work, mean income of each nonfarm activity category, and its share in total annual income of the households with nonfarm employment.

Table 3. Nonfarm activities and annual nonfarm income of the households with nonfarm employment in 2013-2014

Activity	No. of households	Mean income (PPP$)	Share in total income of households with nonfarm employment (%)
Off- farm wage-employment	***299***	***2737***	***24.18***
	[66]	***(2294)***	***(30.22)***
working in factories	96	2469	7.01
	[21]	(2622)	(19.52)
working in services	17	1978	1.00
	[4]	(1491)	(7.30)
working in the public sector	201	2725	16.17
	[45]	(1979)	(26.35)
Nonfarm self-employment	***260***	***4300***	***33.03***
	[58]	(***4397***)	***(34.01)***
agriculture service and livestock trade	19	4694	2.64
	[4]	(5687)	(12.94)
home production	23	910	0.62
	[5]	(1687)	(5.44)
trade, transport and communication	170	4007	20.09
	[38]	(3599)	(29.68)
hotel and food service	40	4321	5.12
	[9]	(5499)	(17.60)
crafts and other services	39	3944	4.56
	[9]	(4843)	(17.81)
Total	**451**	**4294**	**57.21**
	[100]	**(4330)**	**(33.11)**

Standard deviation in parentheses, share of households with nonfarm employment in square brackets

As shown in Table 3, about 66% and 58% of households with nonfarm employment have off-farm wage-employment and nonfarm self-employment, respectively. However, the off-farm wage-employment income share is about 24%, which is lower than that of the nonfarm self-employment income (about 33% of the total income of the households with nonfarm employment). "Working in the public sector" and "trade, transport, and communication" are the categories with the highest number of household participation, whereas "agriculture service and livestock trade" and "working in services" are the categories with the lowest number of household participation.

Table 4. Annual household income by groups in 2013 - 2014

	Whole sample	Households with nonfarm employment	Households without nonfarm employment	Test statistics
Total annual household income (PPP$)	5326	7447	3898	13.87***b
	(4584)	(5555)	(3057)	
Income share (%)				
Farm income	62.92	38.57	94.09	-25.04***b
	(38.31)	(33.10)	(14.61)	
Farm self-employment	55.76	36.41	80.54	-19.01***b
	(39.05)	(32.69)	(31.88)	
Farm wage-employment	7.15	2.16	13.55	-9.69***b
	(21.12)	(8.76)	(29.10)	
Nonfarm income	32.12	57.21	0.00	19.86***a
	(37.70)	(33.11)	(0.00)	
Nonfarm self-employment	18.54	33.03	0.00	10.55***a
	(30.29)	(34.01)	(0.00)	
Nonfarm wage-employment	13.58	24.18	0.00	12.36***a
	(25.62)	(30.22)	(0.00)	
Remittances	3.64	3.09	4.34	-0.53b
	(11.81)	(9.86)	(13.88)	
Other income	1.32	1.13	1.57	-2.27**b
	(3.00)	(2.03)	(3.89)	

* Significant at 10%, ** significant at 5%, *** significant at 1%, standard deviation in parenthesis; a t-Ttest, b nonparametric two-sample test: Mann-Whitney U test

Table 4 presents data on total annual household income and income shares of different income sources. The total annual income of the households with nonfarm employment is significantly higher than that of the households without nonfarm employment. The former is most dependent on nonfarm income (about 57%), whereas the latter is most dependent on farm income (about 94%). For the former, the income from nonfarm self-employment is higher than that from nonfarm wage-employment. The remittances are not different between the two groups while the other income (capital income) of the households with nonfarm employment is slightly lower than that of the households without nonfarm employment. For the whole sample, nonfarm employment contributes on average 32% to the total annual household income.

Table 5. Households' food security by household groups

Dimension	Food security indicator	Whole sample (n = 1121)		Households with nonfarm employment (n = 451)		Households without nonfarm employment (n = 670)		Test statistics
		Mean	SD	Mean	SD	Mean	SD	
Food availability	DAPAE	0.95	0.89	0.75	0.88	1.08	0.86	-8.94***b
	DRCAE	0.43	0.63	0.33	0.63	0.49	0.61	-9.40***b
Food access	HDDS	8.18	1.42	8.56	1.34	7.91	1.41	7.60***b
	MAHFP	11.48	1.69	11.56	1.66	11.42	1.70	2.60**b
	HFIAS	4.35	4.94	3.99	4.62	4.59	5.13	-1.47b
	HDDG	3.39	18.10	1.55	12.38	4.63	21.02	7.78**c
Food utilization	FCS	53.62	17.58	57.76	18.64	50.84	16.26	5.86***b
	FCG	16.77	37.38	10.64	30.87	20.90	40.69	20.30***c
Food stability	CSI	6.74	8.86	6.05	8.50	7.21	9.07	-1.86*b
	rCSI	2.21	3.25	1.97	3.19	2.37	3.28	-1.84*b
	CSG	19.89	39.94	15.30	36.04	22.99	42.11	9.99**c

[*] Significant at 10%, [**] significant at 5%, [***] significant at 1%, SD is standard deviations; [a] t-Ttest, [b] nonparametric two-sample test: Mann-Whitney U test, [c] Chi square test

Table 5 reports the values of food security indicators for both households with and households without nonfarm employment as well as for the whole sample. Regarding food availability, the households without nonfarm employment have higher values of DAPAE and DRCAE because they have larger land farm areas. However, the households with nonfarm employment have higher income and thus they purchase more high-value food such as meat, eggs, milk, and fish. Thus, food access, food utilization, and food stability of the households with nonfarm employment are better than those of the households without nonfarm employment. For food access, the HDDS shows that rural households have good dietary diversity (about 8 points). The MAHFP and the HFIAS also point out that rural households are good in food access. However, there are about 3.4% of rural households with poor food access. For food utilization, on average the food utilization of rural households is at the acceptable level because the FCS is about 54, which is greater than the threshold value of 35 (the acceptable line of the FCS). However, there are still about 16.8% of rural households with poor food utilization. Regarding food stability, on average rural households are food secure as the CSI is about 6.7, which is less than 12 (the threshold value of the CSI). However, about 20% of the rural households are food insecure in terms of food stability.

4.4.2 Determinants of household nonfarm activities and nonfarm income

Table 6 reports the estimates of the determinants of the participation in nonfarm work (part 1), of nonfarm income (part 2), and the Average Partial Effect (APE) on the nonfarm income. The results show that a larger farmland size would reduce the proportion of the participants in nonfarm work and nonfarm income. This result is consistent with Seng (2015) who reports that farm households owning smaller land areas are more likely to prefer nonfarm work in Cambodia. A higher level of household head education is associated with a higher proportion of farm households participating in nonfarm work and with higher nonfarm income. This is plausible because in general, better educated farmers are more innovative and entrepreneurial (Rao and Qaim 2011) and thus, more likely to be active in generating income not only from farming activities but also from nonfarm activities (Seng 2015). This result is consistent with Lanjouw and Shariff (2004); Babatunde and Qaim (2010); Owusu et al. (2011); Senadza (2012); and Akaakohol and Aye (2014).

Table 6 also reports that a larger number of laborers lead to a higher probability to participate in nonfarm employment and, thus higher nonfarm income. Households with motorbikes or mobile phones find more easily nonfarm jobs than the others since they have better social networks and mobility. Access to credit facilitates households to find nonfarm jobs because they could use loans to invest in their nonfarm self-employment or invest in finding nonfarm wave-employment jobs. This is in line with Owusu et al. (2011) who point out that households have a higher opportunity to participate in nonfarm work if they can access credit. Other factors that have statistical and negative effects on nonfarm income of the households with nonfarm employment are the gender of household heads and the number of income shocks. Female household heads have higher nonfarm income than male heads since in our study site there are many nonfarm jobs for women such as working in garment sector, hotel and food service, and trade (retail shop, petty trader, and wholesale). The households with nonfarm employment who face more income shocks have less nonfarm income than the other households with nonfarm employment who do not have income shocks.

Regarding the village variables, better road conditions and a closer distance to markets increase the proportion of households participating in nonfarm work and increase nonfarm incomes. This result is consistent with Senadza (2012) and Babatunde and Qaim (2010) who report that a longer distance to market impacts negatively on a number of nonfarm activities and nonfarm income in rural Ghana and in Nigeria, respectively.

Table 6. Determinants of household nonfarm participation and nonfarm income

Variable	Participation in nonfarm work (yes = 1, no=0) (part 1)		Log of nonfarm income (part 2)		APE on Log of nonfarm income	
	Coefficient	RSE	Coefficient	RSE	Coefficient	RSE
Household level						
land_size	-0.196*	0.103	-0.086***	0.028	-1.582*	0.821
age	0.016	0.015	-0.003	0.004	0.126	0.120
gender	-0.462	0.586	-0.580***	0.164	-3.878	4.688
education	0.488***	0.090	0.060***	0.016	3.871***	0.713
hh_size	-0.161	0.152	-0.026	0.041	-1.283	1.217
hh_labor	0.365*	0.215	0.045	0.052	2.900*	1.714
tractor	-0.100	0.458	0.048	0.126	-0.768	3.665
motorbike	1.446***	0.338	0.116	0.080	11.452***	2.695
livestock_unit	0.066	0.053	0.010	0.012	0.525	0.425
remittance	-0.343	0.348	-0.127	0.087	-2.756	2.783
access_credit	0.813**	0.403	0.007	0.114	6.412**	3.222
SPO	-0.356	0.389	0.084	0.098	-2.771	3.105
mobile	0.530***	0.193	0.150***	0.041	4.239***	1.540
shock	0.070	0.132	-0.061*	0.034	0.525	1.055
Village level						
road_type	0.043	0.432	0.202*	0.121	0.421	3.458
distance_market	-0.019**	0.009	-0.009***	0.003	-0.152**	0.070
Regional level						
Mekong	-1.004**	0.508	0.099	0.119	-7.882*	4.054
Mountain	-0.668	0.731	-0.199	0.216	-5.352	5.855
constant	-3.903***	1.284	8.057***	0.327		
Observations	1121		451			
Wald $chi^2(18)$	65.60		138.80			
Prob. > chi^2	0.000		0.000			
R^2: within			0.101			
between			0.287			
overall			0.272			

* Significant at 10%; ** significant at 5%; *** significant at 1%. RSE is robust standard error clustered at the household level.

4.4.3 Impact of nonfarm employment on household food security

Table 7 presents the impact of nonfarm employment on food security indicators. Regarding food availability, the differences in DAPAE and DRCAE between the two groups are not statistically significant. This is because even though the households with nonfarm employment have a small farmland size, its area of low-value crops (e.g. cassava, corn) decreased by about 22% - 51% from 2013 to 2014, whereas the area of low-value crops of households without nonfarm employment increased by about 40% - 76% during this period. This result is consistent with Babatunde and Qaim (2010) who report that nonfarm employment does not affect household food availability in Nigeria.

For food access, the values of HDDS, MAHFP, and HFIAS differ significantly between the two groups. The HDDS of the households with nonfarm employment is about 0.5 higher than that of the households without nonfarm employment. This is because the households with nonfarm employment with higher income consumes more oils, milk, meat, fruits and eggs, which make up the additional diversity of higher diet scores. Thus, the HDDG shows that nonfarm employment reduces the proportion of the households who are food insecure in terms of access by about 3% - 5%. The MAHFP of the households with nonfarm employment is about 0.5 months higher than that of the households without nonfarm employment. September and October are the hunger months in Cambodia, and the households with nonfarm employment with higher income has fewer hunger months than the other does. The HFIAS of the households with nonfarm employment is about 1.1 - 1.2 lower than that of the other households, which implies that the households without nonfarm employment have more experiences of hunger than the households with nonfarm employment have. Overall, all three indicators of food access show that nonfarm employment increases food access. Our findings are consistent with previous studies in other countries. For example, Tsiboe et al. (2016) report that nonfarm work has a positive and significant effect on the HDDS of rural households in Northern Ghana. Owusu et al. (2011) find that in Northern Ghana nonfarm work appears to be crucial in raising household income and improving their food access. Babatunde and Qaim (2010) show that nonfarm income has a positive effect on household food access in Nigeria. Participation in nonfarm activities is associated with better food access. Mishra et al. (2015) point out that the impacts of nonfarm employment are uniformly positive across the unconditional quantile regression and significantly increase food consumption expenditures for all quantiles, except for the 25th quantile in rural Bangladesh. Zereyesus et al. (2017) also points out that by engaging in nonfarm activities, farm households gain in per capita food expenditure in Northern Ghana.

For food utilization, the FCS is significantly different between the two groups. The FCS of the households with nonfarm employment is about 4 - 5 points higher than that of the households without nonfarm employment, which implies that the households with nonfarm employment are more secure in food utilization than the households without nonfarm employment. Nonfarm employment reduces the proportion of the households who are food insecure with respect to food utilization by about 12%

- 13%. This is because the households with nonfarm employment have higher income and consume more fish, meat, milk, and eggs, which result in higher FCS.

Table 7. M-DID estimates of the impact of nonfarm employment on food security

Dimension	Indicator	Matching algorithm	ATT	Standard error	Critical value of Γ (hidden bias)
Food availability	DAPAE	N_5[a]	0.063	0.121	1.05-1.10
		K_6[b]	0.026	0.116	1.15-1.20
		R_6[c]	0.011	0.117	1.20-1.25
	DRCAE	N_5[a]	-0.009	0.096	1.20-1.25
		K_6[b]	-0.013	0.093	1.10-1.15
		R_6[c]	-0.029	0.096	1.10-1.15
Food access	HDDS	N_5[a]	0.473**	0.190	1.25-1.30
		K_6[b]	0.476***	0.183	1.35-1.40
		R_6[c]	0.475***	0.183	1.40-1.45
	MAHFP	N_5[a]	0.386	0.244	1.00-1.05
		K_6[b]	0.471**	0.188	1.75-1.80
		R_6[c]	0.482**	0.191	2.20-2.25
	HFIAS	N_5[a]	-1.164**	0.545	1.20-1.25
		K_6[b]	-1.145**	0.530	1.30-1.35
		R_6[c]	-1.108**	0.536	1.25-1.30
	HDDG	N_5[a]	-4.556*	2.673	5.30-5.35
		K_6[b]	-3.212**	1.532	13.25-13.30
		R_6[c]	-3.283**	1.560	13.25-13.30
Food utilization	FCS	N_5[a]	4.442**	1.813	1.20-1.25
		K_6[b]	4.646**	1.873	1.25-1.30
		R_6[c]	4.649***	1.742	1.25-1.30
	FCG	N_5[a]	-12.333**	5.381	1.60-1.65
		K_6[b]	-12.900***	4.687	1.40-1.45
		R_6[c]	-13.343***	4.832	1.40-1.45
Food stability	CSI	N_5[a]	-2.989**	1.161	1.60-1.65
		K_6[b]	-2.658**	1.169	1.60-1.65
		R_6[c]	-2.644**	1.175	1.60-1.65
	rCSI	N_5[a]	-0.900**	0.399	1.50-1.55
		K_6[b]	-0.788**	0.396	1.50-1.55
		R_6[c]	-0.779*	0.404	1.50-1.55
	CSG	N_5[a]	-13.778**	5.924	1.35-1.40
		K_6[b]	-12.558**	6.176	1.20-1.25
		R_6[c]	-12.243**	5.684	1.20-1.25

* Significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors bootstrapped 1,000 replications only for Kernel matching and Radius matching, [a] N_5 = five nearest neighbor matching with common support and replacement, [b] K_6 = Kernel based matching with common support and band width 0.06, [c] R_6 = Radius matching with common support and band width 0.06.

Regarding food stability, the CSI and the rCSI differ significantly between the households with nonfarm employment and the households without nonfarm employment. Both the CSI and the rCSI of the former are about 2.6 - 3.0 and 0.8 - 0.9 points lower than those of the latter, respectively. That implies that nonfarm employment improves food stability. The CSG shows that nonfarm employment reduces the proportion of households who are food insecure in terms of stability by about 12% - 14%. This is because the households with nonfarm employment having higher income and better food access have less limited adult intakes in order to feed children, less borrowed food from friends or relatives, and less consumed seed stock held for next season than the others do.

4.5 Conclusion

We use panel data of 561 rural households collected in Stung Treng province of Cambodia in two years (2013 and 2014) to investigate the factors affecting the participation in nonfarm work and nonfarm income and to assess the role of nonfarm employment in reducing food insecurity. The two-part Random Effects model, which includes a Random Effects logit model and a Random Effects OLS model, is used to examine the determinants of the participation in nonfarm work and nonfarm income. The Average Treatment Effect on the Treated, that measures the impact of nonfarm employment on different food security indicators, is determined by combining the difference-in-differences method with the propensity score matching (M-DID method).

The findings show that (i) nonfarm employment contributes 32% to total annual household income for the whole sample and 57% for the households with nonfarm employment; (ii) nonfarm participation and nonfarm income is positively impacted by the education level of household heads, the number of motorbikes and mobile phones, and the conditions of roads to the villages. They are negatively impacted by farmland size, the gender of household heads, the number of income shocks, and the distance from home to markets; (iii) there is no significant difference in terms of food availability between households with nonfarm employment and households without nonfarm employment. However, the households with nonfarm employment have better food access, better food utilization, and better food stability. Nonfarm employment reduces the proportion of households who are insecure in food access, food utilization, and food stability by about 3%-5%, 12%-13%, and 12%-14%, respectively.

Our findings lead to several important policy implications for developing the nonfarm sector and food security in Cambodia. First, we find that farmland accumulation should be supported to increase rural welfare such as income and food security. This is because households with nonfarm employment having smaller land farm sizes will transfer their human, financial, physical and natural resources as well as their social assets to developing nonfarm employment. Second, the market systems should be developed and the road conditions should be improved for better access to markets. This is because the households who stay closer to the markets or have better road conditions have a higher proportion of participation in nonfarm work and higher nonfarm income. Finally, empowering rural households to cope with income shocks via promoting their access to credit and their education would contribute to enhancing nonfarm employment and consequently improving the food security of rural households.

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Annex section

Table A1. Name and definition of the variables in the regression models

Variable	Definition	Scale
Dependent variables		
Non_farm	1 if household has nonfarm activity, 0 otherwise	Binomial
Non_farm_income	Household nonfarm income	Metric, in PPP $ 2013
Independent variables		
Household level		
land_size	Farm land area of household in ha	Metric, in ha
age	Age of household head	Metric, in years
gender	Gender of household head (1 = male; 0 = otherwise)	Binomial
education	Years in school of household head	Metric, in years
hh_size	Household size in persons	Metric
hh_labor	Household laborers	Metric
tractor	No. of tractors of household	Metric
motorbike	No. of motorbikes of household	Metric
livestock_unit	No. of livestock of household	Metric, in TLU
remittance	If household receipt remittance (1 = yes; 0 = otherwise)	Binomial
access_credit	If households with access to credit (1 = yes; 0 = otherwise)	Binomial
SPO	No. of social/political groups	Metric
mobile	No. of mobile phones of household	Metric
shock	No. of income shocks during the last three years	Metric
Village level		
road_type	Accessible to the village all time (1 = yes; 0 = otherwise)	Binomial
distance_market	Distance from home to the nearest market	Metric, in km
Regional level		
Mekong	If household in Mekong region (1 = yes; 0 = otherwise)	Binomial
Mountain	If household in Mountain region (1 = yes; 0 = otherwise)	Binomial
Lowland	If household in Lowland region (1 = yes; 0 = otherwise)	Binomial

Table A2. Multicollinearity test

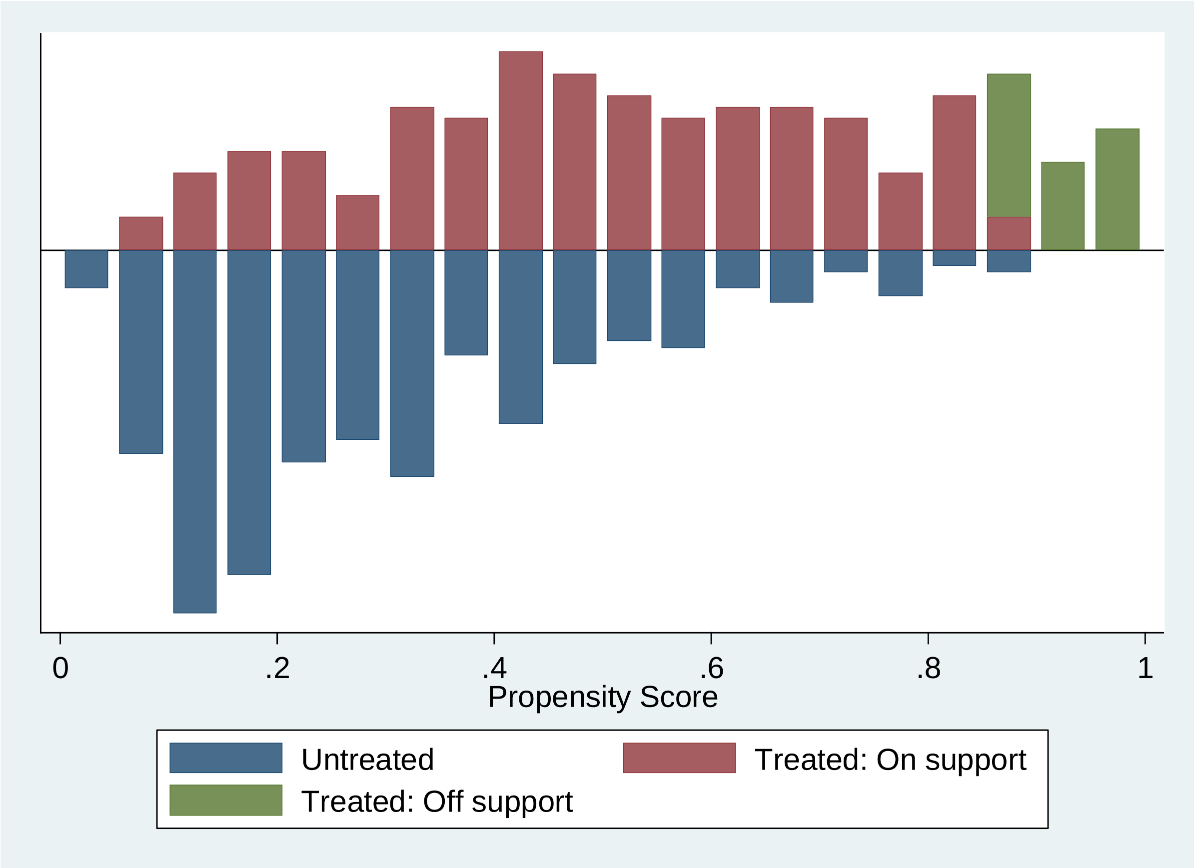
Variable	VIF	1/VIF
Household level		
land_size	1.20	0.83
age	1.23	0.81
gender	1.16	0.86
education	1.22	0.82
hh_size	2.21	0.45
hh_labor	2.53	0.40
tractor	1.30	0.77
motorbike	1.56	0.64
livestock_unit	1.23	0.81
remittance	1.10	0.91
access_credit	1.11	0.90
SPO	1.07	0.93
mobile	1.70	0.59
shock	1.13	0.88
Village level		
road_type	1.12	0.89
distance_market	1.26	0.79
Regional level		
Mekong	1.51	0.66
Mountain	1.47	0.68
Mean	**1.39**	

Table A3. Estimation the propensity score (Probit regression)

Variables	Coefficient	Standard error
Household level		
land_size	-0.040	0.038
age	-0.002	0.005
gender	-0.035	0.202
education	0.107***	0.021
hh_size	-0.074	0.049
hh_labor	0.135*	0.070
tractor	0.088	0.165
motorbike	0.257**	0.116
livestock_unit	0.025	0.023
remittance	0.226*	0.133
access_credit	-0.122	0.159
SPO	-0.103	0.132
mobile	0.250***	0.075
shock	-0.037	0.048
Village level		
road_type	0.328	0.246
distance_market	-0.009***	0.003
Regional level		
Mekong	-0.081	0.171
Mountain	-0.330	0.233
constant	-0.645*	0.380
Observations	521	
Log likelihood	-278.34	
LR chi2	147.41	
Prob. > chi^2	0.000	
Pseudo R^2	0.209	

* Significant at 10%, ** significant at 5%, *** significant at 1%.

Figure A1. Propensity score distribution and common support for propensity score estimation by groups.



Note: "Treated: on support'' presents the households with nonfarm employment that have a suitable match, while ''Treated: off support'' presents the households with nonfarm employment that do not have a suitable match, and "Untreated" presents the households without nonfarm employment.

Table A4. Quality test for propensity score matching

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
N_5[a]	0.209	0.014	0.000	0.990	24.59	4.01	83.68
K_6[b]	0.209	0.008	0.000	1.000	24.59	4.44	81.96
R_6[c]	0.209	0.008	0.000	1.000	24.59	4.39	82.13

[a] N_5 = five nearest neighbor matching with common support and replacement, [b] K_6 = Kernel based matching with common support and band width 0.06, [c] R_6 = Radius matching with common support and band width 0.06.

Table A5. The fixed effects estimates of the impact of nonfarm employment on food security

Variable	DAPAE	DRCAE	HDDS	MAHFP	HFIAS	HDDC
treatment#time	-0.010	-0.091	0.468***	0.528*	-1.533**	-7.203***
(ATE)	(0.097)	(0.075)	(0.169)	(0.295)	(0.626)	(2.022)
treatment	0.145	0.099	0.164	-0.072	0.126	2.578
	(0.108)	(0.082)	(0.198)	(0.346)	(0.737)	(1.914)
time	-0.073	-0.038	-0.504***	-0.088	7.303***	4.997***
	(0.112)	(0.081)	(0.132)	(0.197)	(0.424)	(1.788)
other variables	yes	yes	yes	yes	yes	yes
constant	1.270*	1.020*	9.216***	9.802***	-3.837	-63.495**
	(0.667)	(0.589)	(1.291)	(1.345)	(2.947)	(24.477)
Number of obs.	1121	1121	1121	1121	1121	1121
F(19, 29)	1.96	7.82	22.93	4.15	155.60	1.81
Prob. > F	0.052	0.000	0.000	0.000	0.000	0.074
R^2: within	0.040	0.051	0.145	0.058	0.675	0.090
between	0.031	0.005	0.028	0.004	0.103	0.013
overall	0.017	0.001	0.044	0.000	0.398	0.016

* Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A6. The fixed effects estimates of the impact of nonfarm employment on food security (2)

variable	FCS	FCG	CSI	rCSI	CSG
treatment#time	4.137**	-20.800***	-3.006**	-0.832*	-20.573***
(ATE)	(2.019)	(4.747)	(1.199)	(0.427)	(5.638)
treatment	0.524	-3.578	1.452	0.034	17.279***
	(2.249)	(5.811)	(1.613)	(0.541)	(6.081)
time	-18.732***	34.828***	9.900***	3.311***	33.717***
	(1.320)	(3.789)	(0.933)	(0.280)	(4.080)
other variables	yes	yes	yes	yes	yes
constant	58.101***	38.958	-10.769	-4.002	-75.901**
	(11.003)	(25.965)	(7.324)	(2.834)	(28.562)
Number of obs.	1121	1121	1121	1121	1121
F(19, 29)	33.84	23.58	114.42	95.47	17.37
Prob. > F	0.000	0.000	0.000	0.000	0.000
R^2: within	0.617	0.357	0.482	0.457	0.254
between	0.124	0.039	0.045	0.022	0.004
overall	0.318	0.162	0.210	0.162	0.057

* Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A7. Nonfarm activities and their income of the households with nonfarm employment by gender of household head in 2013-2014

Activity	Income of female head (n=55)		Income of male head (n=396)	
	Mean	Standard deviation	Mean	Standard deviation
Off- farm wage-employment				
working in factories	825.85	2217.13	483.94	1460.59
working in services	193.14	846.19	58.09	389.79
working in the public sector	1318.67	2215.10	1200.21	1845.26
Nonfarm self-employment				
agriculture service and livestock trade	146.86	1089.13	204.84	1525.38
home production	0.00	0.00	52.84	451.67
trade, transport and communication	2438.46	4058.12	1381.55	2731.29
hotel and food service	973.97	3406.81	301.22	1751.25
crafts and other services	53.85	399.34	380.91	1903.75

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