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Divorce Mixed Crop-Livestock Farming to Increase Dietary Diversity?

Evidence from Smallholders in Lao PDR

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Abstract

Undernutrition and lack of micronutrients continues to remain a challenge in developing countries. As the undernourished are largely smallholder farmers, it is predominantly perceived that farm diversification and mixed crop-livestock agricultural systems can help alleviate this problem. But empirical evidence in this context is limited. Hence, this work examines whether farm production diversity as well as mixed crop-livestock farming lead to dietary diversity among smallholder farmers in Laos, using a two year panel data. Results from the fixed effects regression indicate that although farm production diversity does lead to a higher dietary diversity; the effect diminishes with continued diversification. The counterfactual analysis from the endogenous switching regression shows that following mixed crop-livestock farming system reduces household dietary diversity. We further find that markets play a significant role in enhancing the dietary diversity of the specialized farmers.

Keywords: dietary diversity, farm production diversity, mixed crop-livestock agriculture, smallholder farmers, fixed effects, Lao PDR

1. Introduction

The scale of global malnutrition is shocking. Around 2 billion people lack sufficient micronutrients, about 800 million are caloric deficient and 57 countries have serious undernourishment problems (Global Nutrition Report, 2015). This is despite the fact that the Global Hunger Index (GHI) score dropped 29% from 2015 for developing countries, at a GHI score of 21.3 in 2016 (GHI Report, 2016). Also, one in three people are malnourished (IFPRI, 2015) and poor diets are largely responsible for increasing diseases globally (Forouzanfar et al., 2015). Moreover, nutritional deficiencies also impair productivity as well as physical and mental development (Lim et al., 2013).

But, nutritional deficiencies are mostly due to lack of a diversified diet (Headley and Ecker, 2013). This implies that enhancing dietary diversity is critical in solving global undernutrition problems. In the recent years, national crop production has attenuated to specific crop species making global food supplies more homogenous (Khoury et al., 2014). Nonetheless, as most of the undernourished live in rural areas and are mostly smallholder farmers, farm production diversity is considered an important strategy to increase smallholder dietary diversity and also environmental agrobiodiversity (Fanzo et al., 2013; Frison et al., 2006; Deckelbaum et al., 2006). Also, traditionally most of the smallholder farmers in developing countries practice mixed crop-livestock agriculture (Gryseels, 1988; Hailelassie et al., 2005; Herrero et al., 2010; Parvathi and Waibel, 2015). Some studies find that mixed crop-livestock farming system can positively impact food security and increase farm production (e.g. Lemaire et al., 2014; Smith, 2013; Thornton and Herrero, 2015; Foley et al., 2011).

Yet the causality between farm production diversity and mixed crop livestock farming system directly augmenting dietary diversity of smallholder farmers remains unclear. Although it can be considered that smallholder farmers consume their own produce (Hawkes and Ruel, 2008), nevertheless as pointed out by Shibhatu et al. (2015) assuming that all smallholders are primarily subsistence farmers and do not engage with food markets is naive. In fact most smallholders practice a combination of subsistence and market-oriented production (Jones et al., 2014). It is also possible that smallholder farmers can generate adequate income and buy food from the markets to enhance their dietary diversity as found by Chege et al. (2015).

Hence, in this article we add to this literature by examining whether farm production diversity and mixed crop-livestock smallholder farming increases dietary diversity of the farm household. In this regard, we use a two year panel data collected from Lao People's Democratic Republic (hereafter as Laos). The country has a huge prevalence of undernutrition and micronutrient deficiencies. Laos is categorized as serious with a GHI score of 28.1 and 18.5% of its population are undernourished (GHI Report, 2016). It has a high stunting prevalence of 43.8% and is ranked 124 of 132 countries. Also 31% of women in reproductive age have anaemia (IFPRI, 2015). Moreover majority of farmers in Laos are smallholders who have mixed crop-livestock subsistence agriculture. Therefore it presents an optimal case study to explore our research questions.

We use fixed effects and binary switching regressions to ascertain the impact of farm production diversity on dietary diversity of the smallholder farm households. Our results from counterfactual analysis indicate that smallholder can increase their dietary diversity from access to markets and specialising in either crop or livestock farming.

The rest of the article is organized as follows. The next section discusses theoretical framework and methodology. Section 3 elaborates on the study setting in Laos and the data collection procedure. Results are presented in section 4 and section 5 concludes this article.

2. Theoretical Framework and Methodology

Dietary diversity signifies acceptable levels of nutrient consumption (Jones et al., 2014). Hence, it may also be considered as a substitute to represent food security (e.g. Pellegrini and Tasciotti, 2014; Ruel, 2003). Dietary diversity is usually estimated using food variety score and dietary diversity score (Shibhatu et al., 2015; Jones et al., 2014; Swindale and Bilinsky, 2011). Food variety score is the number of different food items consumed (Drewnowski et al., 1997) while dietary diversity score is the count of the variety of food groups eaten by a household in a 24 hour recall period (Ruel, 2003). But both these measures do not capture the frequency of consumption as well as nutritional significance of the different food groups. Therefore we use the food consumption score (FCS) predominantly used by the World Food Programme since 2000.

FCS is a composite measure representative of both quantity and quality of household diet as noted by Lovon and Mathiassen (2014). It also indicates sufficiency of micronutrients in household diet (Hatloy et al., 1998; Steyn et al., 2006). FCS generally measures the frequency of consuming different food groups in the past week. Each food group is assigned a weight based on its nutrient content and the values are summed up to generate FCS for a household. We calculate FCS drawing from the technical guidance sheet of the World Food Programme (WFP) (2008). Accordingly, we use the following food groups (weights specified in parenthesis): main staples (2), pulses (3), vegetables (1), fruits (1), meat, fish and eggs (4), milk (4), oil (0.5), sugar (0.5) and condiments (0). We then calculate the FCS at the household level by summing up the weighted food group scores.

$$FCS_i = \sum_{food\ group=1}^9 food\ group * respective\ weights \quad (1)$$

We also collect FCS data pertaining to planting, pre-harvest and post-harvest seasons. We obtain information on how many days in a week during each season (planting, pre-harvest and post-harvest) the households consumed the different food groups mentioned in the FCS technical guidance sheet of the WFP. Thereby we estimate FCS-planting, FCS-pre harvest and FCS-post-harvest for all the households along with average FCS across all seasons. This enables us to examine seasonal shortages in dietary diversity.

Another key dependent variable is the mixed crop-livestock farming dummy. We define the mixed crop-livestock farming dummy = 1 if the farm household has at least 1 crop and 1 livestock (Herrero et al., 2010; Valbuena et al., 2012; Byrne et al., 2010). If the household practices only crop or livestock farming, we equate the respective dummy variable to 0. We refer to this group as specialized in crop or livestock. Also, they could be having more than 1 crop or 1 livestock but not both crop and livestock.

Our most critical explanatory variable is farm production diversity. The most common approach used to measure crop diversity on the farm is Margalef index (Margalef, 1958; Di Falco and Chavas, 2009). The larger the index, the more diverse is the farm assumed to be. However this approach is only used to measure crop diversity. But as we measure mixed crop-livestock diversity, we follow Shibhatu et al. (2015) to calculate farm production diversity. Thereby, we count the number of crop and livestock species in each production year.

Another important explanatory variable is food purchased from local markets. In most low and lower- middle income countries, food markets are not well developed and there exists asymmetric information (Dillion and Barrett, 2014). Also most of these countries have high subsistence agriculture (Morton, 2007). Therefore farm production diversity can largely influence household dietary diversity (Pinstrup-Andersen, 2007). Nevertheless, access to food markets can enhance diets. We use the variable expenditure on food to measure the extent to which households depend on food markets to increase their dietary diversity. We also use household and farm characteristics, socioeconomic including ethnic factors that contribute to both agricultural practices used and dietary diversity (Keding et al., 2012).

To examine the impact of farm production diversity and mixed crop-livestock farming system on dietary diversity, we use fixed effects regression and a binary switching regression with counterfactual effects respectively. We measure dietary diversity in terms of FCS. To capture seasonality we also use FCS-planting, FCS pre-harvest and FCS-post harvest as well as the average FCS across all seasons.

2.1. Fixed effects regression

We run the following fixed effects panel regression model to analyse the effect of farm production diversity on dietary diversity of the smallholder farm household:

$$D_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 F_{it} + \beta_3 H_{it} + \beta_5 S_{it} + \varepsilon_{it} \quad (2)$$

D_{it} refers to dietary diversity of the i^{th} smallholder farm household at time t . P_{it} is the main variable of interest and represents farm production diversity. F_{it} , H_{it} and S_{it} denote farm, household and socio-economic characteristics respectively. β_s are coefficients to be estimated and ε_{it} is the error term.

2.2. Binary switching regression

A simple technique to ascertain the effect of mixed crop-livestock farming system on dietary diversity is an ordinary least square (OLS), where a dummy denotes the agricultural system (1 mixed crop-livestock and, 0 specialized crop or livestock). But this can lead to biased results as it treats the decision to choose a particular farming system as exogenous whereas it could possibly be endogenous. To account for this endogeneity and self-selection bias, we employ an endogenous switching regression using first information maximum likelihood estimation. The modelling is based on Dutoit (2007) and Maddala and Nelson (1975). We denote the dependent variable, FCS as FCS_{si} for specialized crop or livestock farmers (control group) and FCS_{mi} for mixed crop-livestock farmers (treatment group). The independent variables FCS_{si} and FCS_{mi} are $1 \times k_s$ and $1 \times k_m$ vectors for the two groups respectively. α_s and α_m are $k_s \times 1$ and $k_m \times 1$ vectors of specific individual parameters and μ is a $k \times 1$ parameter vector. We do not enforce $\alpha_s = \alpha_m$ as the dietary diversity effects may be individual specific. Also we have L_i as a latent variable determining which group applies and R_{ii} as a $1 \times k$ vector of independent variables explaining the possibility of being mixed crop-livestock farming household. The error terms are u_{ii} , v_{si} and v_{mi} . Hence, an endogenous switching regression can be shown as the below set of equations:

$$FCS_{si} = X_{si} \alpha_s + v_{si}, \text{ if } L_i = 0 \quad (3)$$

$$FCS_{mi} = X_{mi} \alpha_m + v_{mi}, \text{ if } L_i = 1 \quad (4)$$

$$L_i = 1 (R_{ii} \mu + u_{ii} > 0) \quad (5)$$

Equations (3) and (4) describe the variables of concern in each of the two groups, whereas (5) is a selection equations deciding which of the two groups apply. The error terms v_{si} , v_{mi} and u_{ii} are assumed to have a trivariate normal distribution with mean zero. An important implication of the error structure in this model is that because the error term, u_{ii} of the selection equation (5) is correlated with the error terms of equations (3) and (4), the expected values of v_{si} and v_{mi} conditional on the sample selection are non-zero, i.e.

$$E(FCS_{si} | X_{si}, L_i = 0) = X_{si} \alpha_s + [-e_s \frac{\phi(Z_i \alpha)}{1 - \Phi(Z_i \alpha)}] \quad (6)$$

$$E(FCS_{mi} | X_{mi}, L_i = 1) = X_{mi} \alpha_m + [e_m \frac{\phi(Z_i \alpha)}{\Phi(Z_i \alpha)}] \quad (7)$$

where, the term $\frac{\phi(Z_i \alpha)}{1 - \Phi(Z_i \alpha)}$ is the inverse mills ratio for $L_i = 0$ (specialized crop or livestock system) and $\frac{\phi(Z_i \alpha)}{\Phi(Z_i \alpha)}$ is the inverse mills ratio for $L_i = 1$ (mixed crop-livestock system). $\phi(\cdot)$ refers to the standard normal probability density function and $\Phi(\cdot)$ refers to the standard normal cumulative density function. If the covariance of the error terms $\hat{\varepsilon}_c$ and $\hat{\varepsilon}_t$ are statistically significant, it indicates that the decision to implement a particular farming system and dietary diversity are correlated. This signifies the presence of endogenous switching and rejects the null hypothesis that there is no selection bias.

For the full information maximum likelihood (FIML) estimation to be robust, exclusion restrictions need to be used. Hence, in this study we use health of the household head estimated in terms of his/her Body Mass Index (BMI) as selection instruments based on a falsification test. If the BMI is within the stipulated health standards we give this dummy variable a value of 1 and 0 otherwise. A variable is considered as a valid selection instrument if it affects the decision to implement a particular farming system but does not affect the dietary diversity of the control group i.e. the specialized crop or livestock farmers (Di Falco et. al, 2011).

This endogenous switching regression model can also be used to obtain counterfactual outcomes. The dietary diversity measured in terms of FCS of mixed crop-livestock farm households had they implemented specialized

crop or livestock system. Similarly we can estimate the FCS of specialized crop or livestock household if they had implemented a mixed crop-livestock system. Hence we will have four cases as presented in table 1. The inverse mills ratio for mixed crop-livestock and specialized crop or livestock smallholders are denoted as Ω_{ci} and Ω_{ti} in table 1, respectively.

<< Table 1 here >>

Cases (a) and (b) in table 1 refer to the observed FCS for mixed crop livestock and specialized crop or livestock households respectively. Cases (c) and (d) refer to the counterfactual FCS. As per Heckman et. al (2001), TT refers to the effect of treatment to implement mixed crop-livestock system on the treated as the difference between cases (a) and (c). TU is the effect of treatment on the untreated and is represented as the difference between cases (d) and (b). Drawing from Carter and Milon (2005), BH_t denotes the base heterogeneity for the households that decided to implement mixed crop-livestock system as the difference between cases (a) and (d) and BH_c refers to the households that did not adopt and is the difference between cases (c) and (b). We also estimate transitional heterogeneity (TH) to understand the effect of choosing a particular farming system as the difference between TT and TU.

3. Data

Laos is a mountainous landlocked country with a population of 6 million of which two-thirds live in rural areas (WFP, 2016). It is an ethnically diverse country and has 42 ethnic groups. The country has a low Gross Domestic Product (GDP) and a quarter of its population live below the national poverty line (Martin et al., 2013). Food insecurity is very high in Laos, especially in rural areas and almost every second child under five is chronically malnourished (WFP, 2016). Agriculture in an important sector and constitutes approximately 25% of its GDP and employs 75% of its labor force. 80% of the rural farmers follow subsistence mixed crop-livestock farming system. The major crops grown in Laos are rice, maize, sugarcane, cassava, coffee and sweet potato among others (FAO, 2016).

We collected data from Savannakhet province, located in the middle of Laos bordering Vietnam to the East, Thailand to the West, Khammounane Province to the North and Salavan Province to the South. It is the largest province in Laos having multiple ethnic groups. This region has a majority of rural population employed in agriculture and has a high occurrence of malnutrition. Hence it was chosen as the study area.

As Savannakhet is a heterogeneous province, we stratify it into the Mekong region in the west, the lowland region in the center and the mountain region in the east. These regions include 15 districts and 1542 villages with a total population of 830,000 people. Agriculture remains the dominant economic sector and contributes to approximately 50% of the total production value of the province (Martin et al., 2013). As a second sampling unit we directly sampled villages in the strata. The cluster size was 15 households per village in the Mekong and Lowland region and due to smaller village sizes, 10 in the mountain region. Households were selected randomly from the village lists.

We collected data using household questionnaires from 600 households in 2013. In 2014 due to attrition we collected data from 581 households. The collected data pertain to preceding years 2012 and 2013 respectively. However 44 households in 2012 and 50 households in 2013 did not engage in agricultural activities and hence we removed them from our analysis. Thereby we have 556 households in 2012 and 531 households in 2013. We collected information on agricultural activities, off-farm employment, health, income, consumption and assets. We had a detailed section on food security. It captures data on the frequency of the different food groups eaten in the past week as well as during the different agricultural seasons like planting, pre-harvest and post-harvest. This enabled us to estimate the FCS in different agricultural seasons.

4. Results

Table 1 presents the descriptive statistics of different food groups used in estimating FCS across different agricultural seasons. We find that cereals and tubers, beans and lentils and fruits are significantly different across seasons and especially higher after post-harvest. Also as generally expected FCS post-harvest is significantly higher than the other seasons. However there are no significant differences between seasons with regard to the consumption of staples, vegetables, meat, fish and dairy products.

<< Table 2 here >>

We also analyse the seasonal variations in FCS components between the mixed crop-livestock and specialized crop or livestock smallholder households in table 3. We find that the mixed crop-livestock households significantly consumer more rice but less milk and dairy products across all agricultural seasons in comparison to the specialised crop or livestock farmers. Although specialized crop or livestock smallholder households consume more meat, fish and eggs, vegetables and fruits they are not significantly more than the mixed crop-livestock households.

<< Table 3 here >>

The specialised crop or livestock farmers have higher FCS measures across seasons but not significantly higher than the mixed crop-livestock smallholders as depicted in table 4. Mixed crop and livestock farmers have higher farm production variety as well as crop and livestock variety. Thereby they appear to be less dependent on food markets as also indicated by significantly lower food expenses. 22% of the specialised crop or livestock farmers have female household heads compared to 13% female headed mixed-crop livestock households. Also the specialized crop or livestock farm households have more educated household heads with smaller household size and a lower dependency ratio. They also have a smaller farm size and only 18% sell their harvest in the market. But 52% of the specialized crop or livestock farmers are engaging in off-farm income generating activities. This indicates that most of the specialized crop or livestock farmers are engaging in subsistence agriculture to supplement their diets but majorly depend on food markets for a diversified diet. Also they are less wealthy and have a more homogenised ethnic composition compared to the mixed crop or livestock smallholders. However on average both groups have a healthy BMI.

<< Table 4 here >>

In the next section we present the econometric results. We show the impacts of farm production diversity on dietary diversity as well as whether engaging in mixed crop-livestock smallholder farming improves the diversity of diet consumed by the farm household.

4.1 Farm production diversity on dietary diversity

In this analysis, we apply FCS as a constant score in order to understand the overall nutritional enhancement of the smallholder farm household due to farm production diversity. Therefore we do not use FCS thresholds to classify households into different food security groups.

Our variable of interest, farm production diversity positively and significantly impacts dietary diversity of the smallholder household across all agricultural seasons (table 5). However the squared production variety term is negatively significant indicating that the effect on dietary diversity diminishes with increasing farm production diversity. This is in line with the findings of Shibhatu et al. (2015) and implies that the current highly diversified farms perhaps may find more value from the advantages of specialization.

Purchasing food commodities from the market also significantly increases dietary diversity. The interaction term between food expenses and farm production diversity is negatively significant indicating that the ability to buy food from markets significantly decreases the role of farm production diversity to meet dietary requirements of the household.

Other variables that affect farm production diversity are a larger household size and having an off-farm income. We further find that household head characteristics like gender, age and education does not have a significant impact on the dietary diversity of the household. Similarly farm characteristics as well as household wealth measured in terms of assets are positively related to dietary diversity but do not significantly affect it. Ethnic factors also do not seem to play a vital role.

<< Table 5 here >>

To sum up, our results show that although farm production diversity does lead to dietary diversity nevertheless continuously diversifying farm production may result in diminishing effects. Also if smallholder household has the capacity to buy food commodities from the markets it should not invest in diversifying its farm production.

4.2 Mixed crop-livestock farming on dietary diversity

In table 6, we present the endogenous switching regression model. The coefficients of correlation (ρ_s and ρ_m) are significantly different from zero between the selection and outcome equation for pre-harvest, post-harvest as well as for the overall FCS equation indicating heterogeneity. This shows that self-selection did occur in choosing a particular farming system. Hence, OLS is not an appropriate model in this context as observed and unobserved

factors affect the decision to practice a specified farming system. This also confirms that the use of a FIML endogenous switching regression is more suitable for this analysis. The significant but alternative sign of ρ_s and ρ_m point out that comparative advantage plays a key part in the choice of farming system and dietary diversity.

Selection model results show that years of schooling is negatively but significantly related to choosing a mixed crop-livestock farming. This indicates that educated farmers prefer to engage in specialized crop or livestock agriculture. A higher dependency ratio positively and significantly influences the selection of a mixed crop-livestock systems. But this could be attributed to the fact that these systems are heavily labour intensive as noted by De Koeijer et al. (1995). A larger farm size with the opportunity to sell their harvest in the market drives smallholder households to implement mixed-crop livestock farming. This could be because as seen in descriptive statistics (table 3) majority of these farmers are more dependent on agricultural income than earnings from off-farm income sources. Hence, it becomes essential for the mixed-crop livestock farmers to sell their produce to meet the different consumption needs of the household.

Likewise, we find that having an off-farm income negatively affects the decision to practice a mixed crop-livestock system as these systems are more intensive and time consuming. With regard to ethnicity, Phu Thai and Katang are more likely to implement a mixed-crop livestock farming system than the Lao ethnic group. Household heads with a healthy BMI are more likely to choose a mixed crop-livestock farming system.

With regard to the outcome equations, we first interpret the specialized crop or livestock system. We find that food expenses significantly enhance the dietary diversity of these farm households across all seasons. This emphasizes the dependence of these farmers on food markets to augment their diets. We find that male headed households under this system consumer more diverse diets. Ethnic minorities implementing this farming system have less dietary diversity in comparison to the Lao major ethnic group.

With regard to the mixed-crop livestock systems, educated farmers are more conscious of consuming a diversified diet. Selling harvest in market helps these farmers to generate agricultural income that enhances their diets along with having access to off-farm income. With regard to minorities, our results show that Katang and other minorities consume a less diversified diet than that Lao majority.

A larger farm size does increase dietary diversity of both groups of farm households across seasons. Also on average, wealth too plays a role in improving dietary diversity. The year dummy shows that there has been a significant improvement in dietary diversity in 2013 (surveyed 2014) compared to 2012 (surveyed in 2013). Also for the model to provide robust results we include the exclusion restriction dummy variable of household head having a healthy BMI as part of a falsification test (Di Falco et al., 2011). The Wald test on this variable is jointly significant in the selection model (Table 6) but does not affect the FCS of the specialized crop or livestock farmers.

<< Table 6 here >>

In table 7 we show the counterfactual results of choosing these farming systems on dietary diversity measured in terms of FCS. The average treatment effect on the treated (ATT) shows that mixed crop-livestock farm households will be able to significantly improve their FCS on average by 6% if they implement specialized crop or livestock farming across seasons. In concurrence, the average treatment effect on the untreated (ATU) shows that the specialized crop or livestock farm households will on average witness an 8% decrease in FCS if they choose to practice mixed crop-livestock systems. The BH_m is significantly positive indicating that the mixed crop-livestock farmers consume a better quality of diet in comparison to their counterparts irrespective of the farming system chosen due to potential heterogeneities. Nevertheless their dietary quality would further improve if they implement a specialised crop or livestock systems.

<< Table 7 here >>

5. Conclusion

In this article, we examine whether farm production diversity improves dietary diversity among smallholder farm households in Laos using a two year panel data and applying a fixed effects regression model. We also ascertain the impact of implementing mixed crop-livestock farming system on dietary diversity by using an endogenous switching regression model with counterfactual effects. Moreover we estimate dietary diversity during different agricultural seasons including planting, pre-harvest and post-harvest.

Our key finding is that farm production diversity does increase dietary diversity but if smallholders keep expanding their production diversity beyond a certain threshold dietary diversity will begin to diminish. We further find that purchasing food from markets significantly enhances dietary diversity. In fact smallholder farm households are better off purchasing food from markets than producing it themselves to increase the diversity of the diet consumed.

Another critical outcome from this study is that it is better for smallholder farmers to focus on either crop or livestock production. This helps to increase their dietary diversity across different agricultural seasons. This perhaps may be due to a higher income earned from agricultural specialization supplemented with other off-farm income generation activities. But as pointed out by Sibhatu et al. (2015) purchasing food from the markets does not substitute having a greater farm production diversity consisting of a mixed crop-livestock system to increase dietary diversity, especially in the case of large scale farms in developing countries.

In addition considering the seasonality of agricultural activities, subsistence farming even with a highly diversified mixed crop-livestock production, may not necessarily be the solution to augment smallholder diets. Hence, it is imperative that smallholder farmers have access to food markets where food commodities are sold at affordable prices to be nutrition secure.

Hence in conclusion, we submit that food markets need to be made accessible even in remote areas of developing countries to ensure food and nutrition security of the resource-poor households across all seasons. To facilitate this, investments in infrastructure is needed to reduce transaction costs. At the same time, policies need to be designed that can keep food price inflation and other price distortions under check.

TABLES

Table 1: Treatment and Heterogeneity Effects

Sub-Samples	Decision		Treatment Effects
	Mixed Crop-livestock	Specialised crop or livestock	
Mixed Crop-livestock	(a) $E(FCS_{mi} L_i=1)=X_{mi}\alpha_m+e_m\Omega_{mi}$	(c) $E(FCS_{si} L_i=1)=X_{mi}\alpha_s+e_s\Omega_{mi}$	ATT
Specialised crop or livestock	(d) $E(FCS_{mi} L_i=0)=X_{si}\alpha_m+e_m\Omega_{si}$	(b) $E(FCS_{si} L_i=0)=X_{si}\alpha_s+e_s\Omega_{si}$	ATU
Heterogeneity effects	BH _m	BH _s	TH

Source: Adapted from Di Falco et. al. (2011)

Table 2: Seasonal variations in FCS components

	Average	Planting	Pre-harvest	Post-harvest	F-statistic
Rice	6.55 (1.03)	6.54 (1.05)	6.53 (1.07)	6.60 (0.95)	1.56
Cereals and tubers	2.07 (1.88)	1.93 (1.81)	1.97 (1.82)	2.30 (1.98)	12.82 ***
Beans and lentils	2.40 (1.75)	2.28 (1.76)	2.32 (1.66)	2.59 (1.83)	9.53 ***
Vegetables	4.75 (2.03)	4.78 (2.04)	4.69 (2.01)	4.78 (2.04)	0.74
Fruits	3.24 (2.14)	3.30 (2.23)	3.09 (2.04)	3.34 (2.12)	4.54 **
Meat, fish and eggs	3.63 (2.17)	3.67 (2.15)	3.59 (2.15)	3.64 (2.20)	0.33
Milk and dairy	1.28 (1.70)	1.22 (1.69)	1.27 (1.69)	1.34 (1.70)	1.39
Sugar	2.74 (2.25)	2.73 (2.26)	2.71 (2.23)	2.77 (2.25)	0.22
Oil	2.35 (1.97)	2.32 (1.99)	2.34 (1.95)	2.40 (1.97)	0.49
FCS	54.62 (20.07)	53.96 (19.68)	53.71 (19.73)	56.20 (20.72)	5.08 **

Notes: F-statistic shows the tests for FCS differences across the 3 season. Standard deviation in parenthesis. *** and ** denote significance at 1% and 5% respectively.

Source: Own calculation

Table 3: Seasonal variations in FCS components between specialized crop or livestock and mixed crop-livestock smallholders

	Planting			Pre-harvest			Post-harvest		
	Specialized crop or Livestock	Mixed crop- livestock	Difference	Specialized crop or Livestock	Mixed crop- livestock	Difference	Specialized crop or Livestock	Mixed crop- livestock	Difference
Rice	6.32 (0.10)	6.59 (0.03)	-0.27 *** (0.08)	6.31 (0.11)	6.57 (0.03)	-0.26 *** (0.09)	6.48 (0.09)	6.63 (0.03)	-0.15 ** (0.08)
Cereals and tubers	1.96 (0.14)	1.92 (0.06)	0.04 (0.14)	1.99 (0.14)	1.96 (0.06)	0.03 (0.15)	2.22 (0.15)	2.32 (0.07)	-0.09 (0.16)
Beans and lentils	2.30 (0.13)	2.28 (0.06)	0.02 (0.14)	2.29 (0.12)	2.33 (0.06)	-0.04 (0.13)	2.51 (0.13)	2.60 (0.06)	0.10 (0.15)
Vegetables	4.92 (0.15)	4.76 (0.07)	0.16 (0.16)	4.80 (0.15)	4.67 (0.07)	0.13 (0.16)	4.88 (0.15)	4.75 (0.07)	0.13 (0.16)
Fruits	3.41 (0.17)	3.28 (0.07)	0.13 (0.18)	3.13 (0.16)	3.08 (0.07)	0.05 (0.16)	3.52 (0.16)	3.30 (0.07)	0.22 (0.17)
Meat, fish and eggs	3.68 (0.17)	3.66 (0.07)	0.02 (0.17)	3.63 (0.17)	3.58 (0.07)	0.05 (0.17)	3.74 (0.17)	3.62 (0.07)	0.12 (0.18)
Milk and dairy	1.71 (0.15)	1.12 (0.05)	0.59 *** (0.13)	1.66 (0.15)	1.18 (0.05)	0.48 *** (0.13)	1.71 (0.15)	1.26 (0.05)	0.45 *** (0.14)
Sugar	2.87 (0.18)	2.70 (0.07)	0.17 (0.18)	2.86 (0.18)	2.68 (0.07)	0.18 (0.18)	2.91 (0.18)	2.75 (0.07)	0.16 (0.16)
Oil	2.36 (0.16)	2.31 (0.07)	0.05 (0.16)	2.48 (0.15)	2.31 (0.06)	0.17 (0.16)	2.51 (0.16)	2.37 (0.06)	0.14 (0.15)

Notes: Standard error in parenthesis. *** and ** denotes significance at 1% and 5%, respectively

Source: Own calculation

Table 4: Descriptive differences

	Specialized crop or Livestock	Mixed crop-livestock	Difference
FCS Planting	56.17 (1.70)	53.64 (0.63)	2.53 (1.58)
FCS Pre harvest	55.45 (1.69)	53.50 (0.63)	1.95 (1.58)
FCS Post harvest	57.99 (1.74)	55.97 (0.67)	2.02 (1.66)
FCS Average	56.49 (1.63)	54.28 (0.60)	2.21 (1.51)
Farm production variety	1.96 (0.11)	4.90 (0.08)	-2.94 *** (0.19)
Crop variety	1.51 (0.13)	2.37 (0.07)	- 0.86 *** (0.16)
Livestock variety	0.46 (0.06)	2.54 (0.04)	- 2.08 *** (0.09)
Food expenses (log)	8.30 (0.09)	8.83 (0.06)	- 0.53 *** (0.13)
Gender (male = 1)	0.78 (0.30)	0.87 (0.01)	- 0.09 *** (0.03)
Age	49.35 (0.96)	49.98 (0.44)	-0.63 (1.06)
Years of schooling	4.06 (0.32)	3.20 (0.12)	0.86 *** (0.30)
Household size	2.81 (0.18)	3.55 (0.10)	- 0.74 *** (0.24)
Dependency ratio	1.49 (0.05)	1.63 (0.03)	- 0.14 ** (0.06)
Farm size (in ha)	1.12 (0.10)	2.12 (0.06)	- 1.00 *** (0.13)
Harvest sold in market (yes =1)	0.18 (0.03)	0.35 (0.02)	- 0.17 *** (0.04)
Have off-farm income (yes = 1)	0.52 (0.04)	0.37 (0.02)	0.15 *** (0.04)
Assets (log)	7.04 (0.16)	7.53 (0.06)	- 0.49 *** (0.14)
Ethnicity	3.15 (0.13)	3.29 (0.05)	- 0.14 *** (0.13)
Healthy BMI (yes = 1)	0.69 (0.03)	0.75 (0.01)	- 0.06 * (0.04)
Observations	189	898	

Notes: 1087 observations. Standard errors in parenthesis. ***, ** and * denote significance at 1%, 5% and 10% respectively. We do t-tests for continuous and dummy variables and chi-square test for categorical variables.

Source: Own calculation

Table 5: Farm Production Diversity Model

	FCS Planting	FCS Pre Harvest	FCS Post Harvest	FCS Average
Farm production variety	6.585 *** (2.073)	6.551 *** (2.154)	6.701 *** (2.174)	6.590 *** (1.982)
Farm production variety squared	-0.161 *** (0.056)	-0.137 ** (0.064)	-0.139 ** (0.063)	-0.145 ** (0.056)
Food expenses (log)	3.304 *** (1.118)	3.730 *** (1.193)	3.791 *** (1.163)	3.602 *** (1.085)
Food expenses (log) * Farm production variety	-0.378 * (0.202)	-0.434 ** (0.215)	-0.444 ** (0.217)	-0.417 ** (0.198)
Gender (male = 1)	-3.653 (9.893)	-1.836 (10.585)	-6.576 (10.506)	-4.282 (9.921)
Age	-0.129 (0.155)	0.025 (0.186)	0.042 (0.180)	-0.019 (0.159)
Years of schooling	-0.766 (0.571)	-0.187 (0.644)	0.130 (0.703)	-0.266 (0.584)
Household size	1.416 *** (0.257)	1.375 *** (0.271)	1.355 *** (0.283)	1.373 *** (0.254)
Dependency ratio	-2.967 (2.190)	-1.433 (2.488)	-1.065 (2.417)	-1.873 (2.209)
Farm size (in ha)	0.345 (0.543)	0.381 (0.584)	0.267 (0.625)	0.323 (0.527)
Harvest sold in market (yes =1)	-0.987 (1.882)	-0.161 (1.893)	0.406 (2.036)	-0.221 (1.799)
Have off-farm income (yes = 1)	2.513 (1.993)	3.507 * (2.098)	4.578 ** (2.306)	3.559 * (1.965)
Assets (log)	0.706 (0.666)	0.341 (0.731)	0.393 (0.799)	0.474 (0.692)
<i>Ethnicity</i>				
Phu Thai	-9.434 (7.255)	-4.734 (7.210)	-9.717 (9.236)	-8.067 (7.247)
Katang	5.902 (7.115)	-2.692 (7.852)	3.575 (9.008)	2.483 (7.584)
Bru Mekong	1.872 (18.753)	7.596 (18.649)	-4.393 (17.209)	2.146 (17.911)
Others	2.556 (8.630)	-5.016 (8.257)	-8.566 (9.335)	-3.718 (8.364)
Constant	22.076 (15.970)	8.077 (18.802)	12.695 (17.660)	14.508 (16.204)

Notes: Robust standard error in parenthesis. ***, ** and * denote significance at 1%, 5% and 10% respectively.

Source: Own calculation

Table 6: Mixed Crop-Livestock and Specialized Crop or Livestock Farming Model

Table of Mixed Crop Livestock and Specialized Crop or Livestock Farming Model													
FCS Planting				FCS Pre Harvest				FCS Post Harvest				FCS Average	
		Outcome model		Selection Model	Outcome model		Selection model	Outcome model		Selection Model	Outcome model		
	Selection Model	Specialized crop or Livestock	Mixed crop-livestock		Specialized crop or Livestock	Mixed crop-livestock		Specialized crop or Livestock	Mixed crop-livestock		Specialized crop or Livestock	Mixed crop-livestock	
Food expenses (log)		4.441 *** (1.205)	0.005 (0.392)		5.115 *** (1.251)	0.212 (0.416)		4.895 *** (1.187)	0.193 (0.442)		4.771 *** (1.160)	0.147 (0.381)	
Gender (male = 1)	0.203 (0.138)	4.306 (4.550)	-0.971 (1.839)	0.173 (0.134)	10.619 ** (4.739)	-1.384 (1.897)	0.192 (0.137)	10.051 ** (4.675)	-1.573 (2.120)	0.192 (0.136)	8.293 * (4.408)	-1.292 (1.810)	
Age	0.003 (0.003)	-0.004 (0.133)	0.016 (0.046)	0.003 (0.003)	0.055 (0.133)	0.055 (0.049)	0.004 (0.003)	0.074 (0.127)	0.070 (0.051)	0.004 (0.003)	0.042 (0.126)	0.047 (0.045)	
	-0.036						-0.036						
Years of schooling	*** (0.012)	0.285 (0.466)	0.636 *** (0.166)	-0.038 *** (0.012)	-0.215 (0.512)	0.511 *** (0.166)	*** (0.012)	-0.260 (0.454)	0.526 *** (0.190)	-0.036 *** (0.012)	-0.086 (0.433)	0.511 *** (0.160)	
Household size	0.038 (0.032)	-1.628 (1.039)	-0.104 (0.323)	0.038 (0.032)	-0.526 (1.111)	0.036 (0.339)	0.037 (0.032)	-2.097 * (1.154)	0.306 (0.377)	0.038 (0.032)	-1.424 (1.011)	0.081 (0.324)	
Dependency ratio	0.138 * (0.073)	0.500 (2.861)	0.087 (0.824)	0.135 * (0.071)	0.140 (2.751)	0.425 (0.814)	0.138 * (0.074)	-1.651 (2.711)	0.914 (0.871)	0.134 * (0.073)	-0.241 (2.650)	0.468 (0.770)	
	0.234						0.234						
Farm size (in ha)	0.234 *** (0.052)	3.058 (2.051)	1.015 *** (0.388)	0.237 *** (0.050)	4.273 ** (1.904)	0.975 ** (0.390)	*** (0.051)	3.261 * (1.855)	0.576 (0.441)	0.235 *** (0.051)	3.571 ** (1.804)	0.845 ** (0.359)	
Harvest sold in market (yes =1)	0.281 ** (0.116)	1.495 (5.300)	2.162 * (1.292)	0.295 ** (0.116)	6.363 (5.326)	2.655 ** (1.316)	0.279 ** (0.116)	2.999 (5.374)	3.852 *** (1.462)	0.281 ** (0.116)	3.921 (5.258)	2.923 ** (1.253)	
Have off-farm income (yes = 1)	-0.323 *** (0.100)	3.752 (3.987)	4.009 *** (1.283)	-0.346 *** (0.098)	3.059 (3.650)	4.684 *** (1.278)	-0.329 *** (0.100)	3.002 (3.643)	4.746 *** (1.441)	-0.334 *** (1.000)	3.086 (3.485)	4.518 *** (1.229)	
Assets (log)	0.037 (0.029)	1.260 (0.881)	0.725 * (0.391)	0.035 (0.028)	1.342 (0.868)	1.020 ** (0.394)	0.036 (0.029)	1.818 ** (0.867)	0.919 ** (0.436)	0.036 (0.029)	1.498 * (0.816)	0.882 ** (0.386)	
Ethnicity							0.358						
Phu Thai	0.362 *** (0.123)	-0.652 (4.829)	-1.868 (1.399)	0.385 *** (0.122)	3.653 (4.417)	-1.239 (1.398)	*** (0.123)	5.390 (4.682)	-0.758 (1.583)	0.369 *** (0.122)	2.988 (4.131)	-1.249 (1.336)	
Katang	0.521 **	-0.799	-5.865 ***	0.525 ***	-0.188	-6.299 ***	0.515 **	-1.139	-4.307 **	0.522 **	-3.031	-5.494 ***	

	(0.203)	(9.166)	(1.747)	(0.201)	(9.073)	(1.869)	(0.204)	(9.384)	(2.112)	(0.202)	(8.574)	(1.745)
Bru Mekong	0.121	3.684	-4.253 **	0.114	10.390	-4.744 **	0.113	8.062	-2.930	0.114	7.645	-3.918 *
	(0.191)	(7.546)	(2.050)	(0.190)	(7.224)	(2.156)	(0.193)	(7.629)	(2.291)	(0.192)	(7.340)	(1.995)
Others	-0.270	-12.226 *	-9.120 ***	-0.265	-14.112 *	-5.647 **	-0.264	-12.132 *	-5.771 **	-0.261	-12.923 **	-6.832 ***
	(0.192)	(6.529)	(2.077)	(0.185)	(6.683)	(2.282)	(0.192)	(6.339)	(2.467)	(0.189)	(6.125)	(1.978)
<i>Exclusion restriction</i>												
Healthy BMI (yes =1)	0.197 *			0.232 **			0.248 **			0.226 **		
	(0.102)			(0.091)			(0.104)			(0.095)		
Year Dummy 2013 (yes = 1)	0.016	18.972 ***	13.676 ***	0.025	18.108 ***	11.482 ***	0.116	25.535 ***	9.663 ***	0.014	21.026 ***	11.518 ***
	(0.174)	(5.752)	(2.122)	(0.174)	(5.809)	(2.203)	(0.175)	(5.911)	(2.416)	(0.174)	(5.548)	(2.096)
Constant	-0.495	13.833	38.199 ***	-0.476	9.495	32.798 ***	-0.520	6.955	33.837 ***	-0.497	10.702	34.812 ***
	(0.360)	(13.814)	(5.228)	(0.349)	(14.787)	(5.379)	(0.356)	(14.104)	(6.397)	(0.353)	(13.465)	(5.134)
σ_s		22.528 ***			27.836 ***			23.987 ***			23.847 ***	
		(4.038)			(4.103)			(4.088)			(4.140)	
σ_m			16.778 ***			17.195 ***			18.362 ***			16.114 ***
			(0.458)			(0.480)			(0.482)			(0.447)
ρ_s		0.559			0.845 ***			0.697 **			0.758 ***	
		(0.298)			(0.083)			(0.177)			(0.147)	
ρ_m			-0.169			-0.288 ***			-0.117			-0.207 *
			(0.104)			(0.101)			(0.219)			(0.120)
Wald test on exclusion restriction variable Healthy BMI		$\chi^2 = 0.055 *$			$\chi^2 = 0.011 **$			$\chi^2 = 0.018 **$			$\chi^2 = 0.019 **$	

Notes: Robust standard error in parenthesis. ***, ** and * denote significance at 1%, 5% and 10% respectively.

Source: Own calculation

Table 7: Counterfactual Results

		Mixed Crop-livestock	Specialised crop or livestock	Treatment Effects
Mixed Crop-livestock		55.97 (0.27)	59.88 (0.55)	ATT = -3.91 *** (0.41)
Specialised crop or livestock	Post-Harvest	54.14 (0.60)	57.99 (1.04)	ATU = -3.85 *** (0.69)
		BH _m = 1.83 *** (0.66)	BH _s = 1.89 (1.18)	TH = -0.06 (0.80)
Mixed Crop-livestock		53.50 (0.29)	56.86 (0.53)	ATT = -3.36 *** (0.37)
Specialised crop or livestock	Pre Harvest	50.58 (0.63)	55.45 (0.96)	ATU = -4.87 *** (0.61)
		BH _m = 2.92 *** (0.69)	BH _s = 1.41 (1.10)	TH = 1.51 ** (1.51)
Mixed Crop-livestock		53.64 (0.29)	56.85 (0.46)	ATT = -3.21 *** (0.29)
Specialised crop or livestock	Planting	51.59 (0.67)	56.17 (0.90)	ATU = -4.58 *** (0.47)
		BH _m = 2.05 *** (0.73)	BH _s = 0.68 (1.01)	TH = 1.35 ** (0.56)
Mixed Crop-livestock		54.28 (0.28)	57.80 (0.51)	ATT = -3.52 *** (0.35)
Specialised crop or livestock	FCS Average	52.00 (0.63)	56.49 (0.96)	ATU = -4.49 *** (0.57)
		BH _m = 2.28 *** (0.69)	BH _s = 1.31 (1.09)	TH = 0.97 (0.67)

Note: Standard errors in parenthesis. *** and ** denotes significance at 1% and 5% respectively based on t-tests. ATT: Average Treatment effect on the Treated. ATU: Average Treatment effect on the Untreated. TH: Transitional Heterogeneity. BH: Base Heterogeneity

Source: Own calculation

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