Title

Gender matters in farm investment:

Implications for land tenure security and household welfare

Abstract

The gender gap in rural development has received attention from researchers and practitioners, and it is necessary for women empowerment to better understand how gender intersects with land tenure and farm investment. However, there is a lack of discourse on the relationship among women's managerial rights, farm investment, and household welfare. This paper studies the nexus among land tenure security, farm investment, household welfare and their interactions with gender in Zambia, one of the most ethnically diverse countries in Sub-Saharan Africa. To this end, we use datasets from a new and nationally representative panel survey in Zambia and taking advantage of two distinct societies in Zambia i.e., matrilineal vs. patrilineal. We find that land tenure is positively associated with farm investment, and women with land tenure are more likely to invest in tree planting to protect harvest from weather shocks. Furthermore, tree planting is found to enhance farm income and alleviate food insecurity. Dividing households into matrilineal and patrilineal societies, the result shows that households led by women benefit from land tenure security and farm investment only in patrilineal societies. This heterogeneity suggests that the gender gap in rural areas would stem from a male's dominance in land stewardship. Therefore, the findings provide insights into the underpinnings of policies empowering women and increasing their bargaining power within households through land reforms.

1. Introduction

Agriculture has long been a critical component of Sub-Saharan Africa's (SSA) economies in terms of economic value and labor structure, and Zambia is no exception. The share of employment in Agriculture is still over 50% in 2019 as shown in Figure 1 and the share of agriculture, forestry, and fishing value added in GDP remains 2.7% in 2020 (Mulenga et al., 2021). In an agrarian sector, women play a crucial role to increase food security, but social norms would force women to say that they work at home, even when they are heavily involved in agriculture (Deere, 2005). Moreover, when new opportunities are created, through changes in markets or technologies, women's labor burdens in household work and food production may limit their ability to exploit these opportunities (Doss, Meinzen-Dick, Quismbing, & Theis, 2018). Therefore, we need build up women's access to the resources needed for productive agriculture to attain gender equality and empowerment of all women and girls, as declared in the sustainable development goals (SDGs) number 5.

[Figure 1 here]

Despite the consensus on the role of women in agriculture, studies consistently find the gender gap in agricultural productivity in SSA. Ali et al. (2016) and United Nations Women (2019) identifies drivers of gender gaps in agricultural productivity. These include the fact that women have less access to male family labor and land, have lower use of contemporary farm technologies, plant less high-value crops and have high burdens of unpaid household care and domestic work. One significant cause of the gender gap is women's lack of access to land rights, which has received increasing attention from development practitioners and activists (Doss, 2018). As such, narrowing the gender inequality in land rights can be one way to narrow gender gaps in agricultural productivity and improve household welfare consequently.

Women's land rights (WLR) have several definitions; 1) land ownership; 2) right to make planting decisions; and 3) right to make decisions on outputs (Kang et al., 2020). Ownership,

for example, is found to be linked to farmer investment in soil quality improvement, terracing, bun walls, creating irrigation channels, purchasing irrigation equipment, fallowing, and so on (Agarwal & Mahesh, 2023). However, empirical works on the right to make planting decisions and farm investment are sparse. Taking advantage of the trait of our dataset, we identify planting decision makers on plots (women vs. men) and households' decision making process a (sole- vs. joint-decision making). This information is more reliable than the information such as gender of household head or plot holders to represent WLR (Campos, Covarrubias, & Patron, 2016).

In this paper, we answer three research questions; First, we investigate whether land tenure security increases farm investment. Second, we examine whether there are any gender differences in associations between land tenure and farm investment. Eventually, we look at whether there are any heterogeneous associations among land tenure, farm investment, farm income and food insecurity across kinship systems. To these ends, we use a new panel data designed to get a comprehensive picture of Zambia's small- and medium-scale farming sector using the 2010 Census sampling frame followed by the 2022 Census (Indaba Agricultural Policy Research Institute, 2016). Furthermore, we exploit the facts that Zambia has both patrilineal and matrilineal societies to examine if the gender gaps in agricultural productivity stem from inequality in land tenure and agricultural decision making due to differences in the societal system.

There is substantial literature looking at the relationship between land tenure and farm investment in rural areas of developing economies (Hayes, Roth, & Zepeda, 1997; Bellemare et al., 2020). On the one hand, land is often the most important natural capital for supporting agricultural production and providing food security (FAO, 2018). On the other hand, Place (2009) argues continuing debates if land tenure security enhances agricultural productivity. Although past studies find that increasing women's bargaining power in farming associates

with increased household food consumption in SSA (Doss, 2006; Muchomba, 2017), Meinzen-Dick et al. (2019) state that there is less agreement and insufficient evidence on the association between WLR and livelihoods including household food (in)security as opposed to bargaining power and decision making on consumption and human capital investment. In addition, Kang et al., (2020) conclude that females supply more of their own labor to plots they control, the gender inequality in labor allocation varies with each structure-domain combination. However, little is known if observed agricultural gender inequality are innate or derived from societal differences.

The main contribution of this paper is threefold. First, we provide novel evidence about a linkage among land tenure, farm investment decision and household welfare in Zambia where matrilineal societies co-exist with patrilineal societies. To the best of our knowledge, there are few empirical studies looking at whether sole decision-making and joint decision-making matter in the association between farm investment and WLR (Meinzen-Dick et al., 2019). This is because the linkage depends on local context and the overarching macro and sectoral conditions (Place, 2009). Second, we examine the association between farm investment and not only farm income but also household food insecurity across genders of decision makers. Finally, we provide an insight into the underpinnings of the observed gender differences in agricultural decision making across men and women, comparing patrilineal with matrilineal households.

Our results reveal that land tenure security increases farm investment in soil and land management. Land tenure security increases more investment in tree planting if decision makers on farm plots are women. Moreover, tree planting increases farm income and improves food insecurity. We also find that women in only patrilineal societies benefit over proportionanlly from land tenure securtiy and farm investment. Such insights might also have relevance in the policy community where the gender gap in agriculture is poorly understood.

The remainder of our study proceeds as follows. In Section 2, we provide some backgrounds on the Zambian agrarian sector. Section 3 shows the data and presents descriptive statistics. In Section 4, we present the conceptual and empirical framework to answer our research questions. Section 5 presents and discusses our estimation results. We conclude in Section 6 with policy implications.

2. Land tenure systems and matrilineal society in Zambia

2.1. Land tenure systems

In Zambia, there are two land tenure systems. They are the customary system and the statutory system. Under the customary system, the traditional establishments such as the chief and/or the village headman allocate vacant land to families and individuals, on recommendation of village headmen or headwomen, as first persons of contact at village level. However, such customary land does not have legal security of tenure according to Zambia's land laws. This situation renders usufruct land users vulnerable to displacements by more powerful individuals and corporations (Chu, Young, and Phiri, 2015). Customary land has its own advantages to many farmers at village level. Under the system, for example, land is easy to acquire because the process is short and affordable by many usufructs.

In 1995, Zambia government implemented the Lands Act to allow for individual ownership rights and other formal land rights transfer. If households want formal access to customary lands through the statutory system, they must be devolved from customary to statutory status (Chamberlin & Ricker-Gilbert, 2016). Moreover, once land is converted to statutory tenure, it cannot return to customary tenure (Hall et al., 2017). Under the statutory system, landowners own title deeds to their land and can sell, rent, mortgage, or transfer that land (Chapoto et al., 2011). According to the statutory law, women in Zambia can apply for any land in the country, as their male counterparts do. In the event of divorce or widowhood, if the husband dies without leaving a will and if he held state land, the Intestate Succession Act stipulates that the surviving

spouse inherits 20% of the deceased's property, including land, and together with the children, the house (Kapihya, 2017) . However, this Act is not applied generally on customary land. If the deceased husband held customary land, the widow may be permitted to continue to utilize the land. But the widow may also be ejected from the land by the relatives of the deceased (Kapihya, 2017). Thanks to data availability, we consider land title to be tenured by the customary system or the statutory system. However, in Zambia, as in almost all SSA, women rarely own or are on charge of land (UNECA Southern Africa Office, 2003). Therefore, understanding how the interaction between gender of plot decision maker and land tenure security is related to both investment and household welfare would encourage policy makers to plan interventions empowering women in rural economies.

2.2. Matrilineal systems

Because Zambia is one of the most ethnically diverse countries in SSA (Posner, 2004), social norms in societies can vary across the regions of Zambia. In a matrilineal society, an individual traces descent through a female line (Mizinga, 2000) and inheritance of property, including land, passes through the female line (Hall et al., 2017). Women acquire rights to land through their husbands when they get married. Under the statutory system, women have the rights of land ownership, but titles tend to be transited through male relatives in both matrilineal and patrilineal societies (Republic of Zambia, (2005), as cited in Chapoto et al., (2011)). Although women in matrilineal societies have the legal right to make decisions of land, men still rule most of the decisions as clan leaders. For instance, when in regard to land sales, even though women own the land, they must turn to their maternal uncles who have the final say in decisions. Hence, considering gender roles in the patrilineal (matrilineal) systems provides further understanding women empowerment and rural development in SSA.

3. Data

We use Rural Agricultural Livelihood Survey (RALS) is a two-round household panel

survey that was carried out in 2012 and 2015 by the Indaba Agricultural Policy Research Institute (IAPRI) together with the Central Statistical Office (CSO) and the Ministry of Agriculture in Zambia (Fung et al., 2020). The RALS covers the 2010/2011 and 2013/2014 agricultural years and in accordance with maize marketing years (2011/2012 and 2014/2015). A total of 8571 household in the first wave, and 7579 households in the second wave were surveyed in 442 Standard Enumeration Areas[1] (SEAs) in all districts of the country, after getting rid of observations with missing values. The sample was designed to represent the rural farm households cultivating less than 20 ha of land for farming and/or livestock production (Sitko et al., 2014). This survey enables us to look into a variety of questions about the smallholder farmers that have land title and its effect on farm investment. It is an advantage that land tenure information in this survey is observed at the plot level. To take advantage of the availability of plot-level characteristics, we conduct both household-level analysis and plot-level analysis. In our household-level analysis, the title is considered to equal to one if one or more of a farm household's plots are titled. The description of variables used in this study are provided in Table 1. Because we explore both plot-level relationships and household (HH)-level relationships, plot and household characteristics are shown in Table 1. Regarding plot-level characteristics, differences in all the variables between 2012 and 2015 are statistically significant. Regarding, farm investment variables, in terms of household-level characteristics, there is no statistical difference in farm income but food insecurity. Moreover, the share of matrilineal households is around 32 to 36%. While the number of plots decreases, the number of households planting cash crops and obtaining credit increases over time.

[Table 1]

3.1. Measurement of key variables

The variables we are mainly interested in are land tenure, soil and land management, tree planting, irrigation, total household income, farm income, and agricultural productivity. The

plot-level land tenure security measures 1 if the plot is tenured by the government, 0 otherwise. The HH-level tenure security measures 1 if the household owns at least one plot secured by the government, 0 otherwise. Regarding the gender of decision makers, it captures 1 if the decision makers are women, 0 otherwise in the plot-level. In the HH-level, joint decision making means that households have both men and women decision makers, while women decision making means that only women participate in decision making in land management. Moreover, three farm investments are included in the analysis, soil and land management, tree planting, and irrigation. They are also measured by application areas of plot-level and HH-level. Lastly, two outcome variables are included in the analysis. The first outcome variable is farm income which captures the income from farm products such as maize, cassava, other crops, vegetables, and fruits. The unit of values is Zambia Kwacha (ZMW). The values are deflated to real 2017 terms[2]. Another outcome variable is the food insecurity measuring the months when a household is without enough food to meet its needs in.

3.2. Descriptive statistics

Table 2 represents that women decision makers are more likely to own secured land, regardless of gender of household heads. The result is opposite to our intuition that females have less access to land. The plausible explanation is that women can decide how to use a plot should be relatively central to the networks of social and political power that permeate a community (Goldstein and Udry, 2008). Table 3 reports a relationship among kinship, mean plot size, and gender of decision makers. Women are more likely to make a decision in the matrilineal system than the patrilineal system. However, men tend to use larger land than women. Table 4 shows that the ratio of land title possessed by smallholder farmers is slightly less than the ratio of medium farmers. Figure 2 presents the geographical distribution of farmers with land title, household income, farm investment management, based on the RALS 2012, and 2015. Panel A shows the geographical distribution of farmers with land tenure (%).

Moreover, Panel B presents the geographical distribution of average annual farm income (ZMW). The Copperbelt province, Central province, and the Southern Province have the highest farm income where they are the pivot of the Zambian rural economy (Zambia Statistics Agency, 2015). Furthermore, Panel C, D, and E show the geographical distributions of farm investment areas (ha) in our samples. From the graphical analysis, we are not able to distinguish linkages among land tenure security, farm investment, and household welfare. Therefore, we empirically examine the nexus in the following section.

[Table 2 here]

[Table 3 here]

[Table 4 here]

[Figure 2 here]

4. Methodology

To address our research questions, we construct a conceptual framework and employ empirical approaches. The conceptual framework presents a concise and potential mechanism for the link between land tenure security, farm investment, income, and agricultural productivity through graphical and mathematical representations. The empirical approaches outline the method for estimating the model specified in the conceptual framework using the dataset.

4.1. Conceptual framework

The aim of the analysis is to provide insights in the nexus among land tenure security, farm investment, and household welfare. Within many African settings, agricultural production is simultaneously conducted on many plots controlled by different members of households. Typically, many studies of gender and agricultural labor use household level information, which ignore within-household plot-level ownership variation (Doss, 2018), and women's plot ownership does not always imply managerial rights to women (Doss et al., 2015). Therefore,

it is worth noting that we conduct plot-level analysis for farm investment decisions, not assuming a unitary household. Figure 3 shows the conceptual framework about links among land tenure security, farm investment, and household welfare. Land tenure security is believed to improve household welfare through increasing farm investment (Goldstein and Udry, 2008; Bellemare et al., 2020; Issahaku and Abdulai, 2020). Moreover, Babatunde and Qaim (2010) show that increase in farm income which is supposed to be associated with farm investment is positively correlated with household food security. Although Deininger et al. (2021) find that women's rights affect investment, little is known about the relationship between land ownership and productivity from a gender perspective in most regions (Agarwal and Mahesh, 2023). In Africa, customary systems such as patrilineal succession restrict or even exclude women's access to ownership and control over land (Najjar et al., 2020). It relates to fewer female labor supply in farming without ownership for land (Palacios-Lopez et al., 2017). Therefore, it would induce less farm output since adult male labor is found to contribute more agricultural production at the margin than adult female labor (Jacoby, 1991). Furthermore, as theory predicts that women prefer to devote resources to improving nutritional status (Thomas, 1990), households with land tenure that are solely held by a woman, compared to those without land tenure, allocate more of their family budget to food (Menon et al., 2014). Our study add to a slim body of literature on land tenure security and farm investment from gender perspectives. Based on the discussion from past studies above, we propose two hypotheses to test by our empirical approach.

Hypothesis I. Land tenure security enhances farm investment. Particularly, women are more likely to invest than men when a plot has tenure security.

Hypothesis II. Farm investment improves household welfare, farm income and food security. The effect of farm investment is more sizable for farmers with women decision making because women get empowered within a household in this case.

[Figure 3 here]

4.2. Empirical model

We use plot-level variables to explore the nexus between land tenure security and farm investment. However, land tenure security may be related to plot and household characteristics which affect farm investment behavior. Therefore, we explicitly account for the selection on observable factors and match farmers with similar characteristics. Past studies on decision making in agriculture have used such estimation methods, including propensity score matching (PSM), inverse probability weighting (IPW), and the doubly robust (DR) method, when other plausible instruments are not available (Bellemare and Novak, 2017; Lawin and Tamini, 2019; Issahaku and Abdulai, 2020). We apply the DR method, or more accurately, an inverse-probability weighted regression adjustment, that combines the regression and propensity score weighting[3]. It is more robust than the PSM estimator and the IPW estimator because it can provide a consistent estimator when either the propensity score for land tenure security or the outcome regression in terms of tenure characteristics is correctly specified (Mano et al., 2022). To estimate the propensity of owning land tenure, we first estimate the binary model as follows:

$$T_{pi}^{*} = \alpha_1 x_{pi} + \alpha_2 X_i + \rho_t + v_g + e_{pi}, \qquad with\ T_{pi} = \begin{cases} 1\ if\ T_{pi}^{*} > 0 \\ 0\ if\ T_{pi}^{*} \leq 0 \end{cases} \tag{1}$$

where T_{pi}^{*} is the latent variable of land tenure security of plot *p* of household *i*, x_{pi} is the vector of plot *p*'s characteristics of household *i* in year *t*, X_i is the vector of household *i*'s characteristics, ρ_t is the year dummy to control time trend, v_g is province dummy to account for geographical characteristics, and e_{pi} is the error term. From Equation (3), we calculate the propensity of plots with tenure using Probit model. The probability of titled plots conditional on plot and household characteristics can be expressed as:

$$P\left(T_{pi} = 1 \middle| x_{pi}, X_i\right) \equiv p\left(x_{pi}, X_i\right)$$

where, $p(x_{pit}, X_{it})$ is the propensity score of tenured plots. Using the estimated

propensity $\hat{p}(x_{pit}X_{it})$, we estimate the average treatment effect on the treated (ATT) of the land tenure security on farm investment I_{pit} representing area of farm investment:

$$\widehat{E(I_1)} = \frac{1}{n}\sum_{\{i=1\}}^{n}\left[\frac{T_i}{\hat{p}(x_{pit}X_{it})}I_{1pi} + \left(1 - \frac{T_i}{\hat{p}(x_{pit}X_{it})}\right)\hat{I}_{1pi}\right]$$
$$\widehat{E(I_0)} = \frac{1}{n}\sum_{\{i=1\}}^{n}\left[\frac{1-T_i}{1-\hat{p}(x_{pit}X_{it})}I_{0pi} + \left(1 - \frac{1-T_i}{1-\hat{p}(x_{pit}X_{it})}\right)\hat{I}_{0pi}\right] \quad (2)$$
$$\hat{\tau}_{ATT.DR} = \widehat{E(I_1)} - \widehat{E(I_0)}$$

where $\hat{I}_{1pi}$ and $\hat{I}_{0pi}$ are the predicted farm investment from of what will happen under $T_{pi} = 1, T_{pi} = 0$ conditioned on x_{pi}, X_i, and n is the number of sample plots. $\hat{\tau}_{ATT.DR}$ is the doubly robust estimator of ATT which is an unbiased estimate of the statistical association between the land tenure and farm investment. The outcome variables are farm investment I_{pi}, soil and land management, tree planting, and irrigation.

In addition to the DR methods, we utilize PSM and fixed effect to investigate the heterogeneous association between land tenure security and farm investment over gender and crop type by incorporating the interaction term. The reason to employ PSM and fixed effect is that we can address the endogeneity bias due to observed characteristics and time-invariant unobserved characteristics. Moreover, this can work as a robustness check for the DR method. Thus, the specified econometric models can be written as follows

$$I_{pit} = \beta_1 T_{pit} + \beta_2 T_{pit} * gender_{pit} + \beta_3 x_{pit} + \beta_4 X_{it} + a_i + \sigma_t + v_g + u_{pit} \quad (3)$$

where I_{pi} is farm investment of plot-level p of household i, T_{pit} is the dummy variable of land tenure status of plot p of household i in year t, $a_i$is the household fixed effect, σ_t is the time fixed effect, and u_{pit} is the error term.

Beyond the relationship between land tenure security and farm investment, we also examine factors affecting household welfare using HH-level data. We estimate the fixed effect model to account for the time-constant unobservable factors which affect farm investment decision

and household welfare. Nonetheless, no study that relies on observational data can claim decisively to have fully controlled for all unobservable factors, It is possible that land tenure and farm investment could be endogenous due to potential correlation with leftover unobservable time-varying factors. Therefore, our statements about causality are made cautiously.

The specification model is written as follows:

$$Y_{it} = \gamma_1 + \gamma_2 T_{it} + \gamma_3 I_{it} + \gamma_4 X_{it} + a_i + \sigma_t + v_g + \epsilon_{it} \quad (4)$$

where, Y_{it} is the outcome variable farm income and months of food insecurity, T_{it} is the land tenure which indicates a dummy variable that if household *i* has at least one cultivated plot with tenure, $I_{it}$is the cultivated areas with farm investments, a_i is the household fixed effect, and ϵ_{it} is the error term. Furthermore, to investigate if the association between land tenure security or farm investment and household welfare (Y_{it} in Equation (4)) may change depending on sole- or joint-decision making, we include the interaction term between land tenure or farm investment and sole- or joint- decision making in Equation (4).

5. Results and discussions

5.1. Determinants of land tenure security

Although our primary interest is on the causal effect of tenure security on farm investment behavior, we first examine determinants of land tenure security by estimating Equation (1). Table 5 shows the results of Equation (3), estimated by Probit model and Linear Probability Model (LPM)[4]. Regarding the plot-characteristics, the purchased land is more likely to be secured in both Column (1) and (2). In addition, the coefficient of women on maker is positively significant. It indicates that if the decision maker of a plot is a woman, the plot is more likely to be secured. One potential explanation is that women who possess land rights are likely to have bargaining power within households, and bargaining power is correlated with decision making (Meinzen-Dick et al., 2019). Moreover, if the household head has higher education

experience, the plot is more likely to be secured. It is also consistent with the study in the setting of Zambia by Sitko et al., (2014). Age of household head and asset index are significantly correlated with land tenure security. It is reasonable that older or wealthier households are more likely to have tenured plots because they may hold influential positions in a local political hierarchy and such people are likely to have more secure tenure rights (Goldstein and Udry, 2008).

[Table 5 here]

5.2. Effect of land tenure on farm investment

Table 6 summarizes the result from the DR estimation for the whole sample and subsamples by estimating Equation (2). The result in Column (1) shows that land tenure security is positively associated with soil and land management to prevent soil erosion and flash flooding. It indicates that land tenure security induces farm investment, especially soil and land management. When we divide the whole sample into the two sub-sample groups which are women decision makers and male decision makers. The coefficient of land tenure is positively significant for soil and land management. If a plot is registered with de jure tenure security, the areas invested in soil and land management increase around 0.07ha. It indicates that the land tenure encourages both males and women to invest in improvement of land fertility. The result is consistent with Goldstein & Udry, (2008); Abdulai et al., (2011); Ali et al., (2014); Lovo, (2016); and Lawin & Tamini (2019). Column (2) shows that the only coefficient of land tenure of plots operated by women is significant. The result indicates that land tenure security increases tree planting by women decision makers. As insecure rights for women can undercut growth and productivity (Dillon & Voena, 2018), the results highlight the importance that women involves decision making in agriculture for sustainable agricultural development.

[Table 6 here]

Moreover, Table 7 shows the heterogeneous effect of land tenure on farm investment over

gender of decision makers by estimating Equation (3). In Column (2), the coefficient of the interaction term is positively significant, indicating that women decision makers of plots with land tenure are more likely to invest in planting trees to protect yield than male decision makers with land tenure. The result corroborates our findings in Table 5, and it is the consistent with Otsuka et al. (2003); Dillon & Voena (2018). The result shows that our Hypothesis I is confirmed and emphasizes that land tenure security encourages women decision makers to invest in agricultural practices enhancing output, especially for tree planting.

[Table 7 here]

5.3. Potential mechanism among land tenure, farm investment, and household welfare

As we discussed in Section 4, our main research objective is to examine the empirical linkage among land tenure, farm investment and household welfare. Table 8 presents the factors related to household welfare including farm income and food insecurity by estimating Equation (4). Coefficient estimates for factors relating to the farm income are presented in Column (1), (3), and (5). The results derived by OLS-FE with control variables indicate that soil and land management has a positive and significant association with farm income. It indicates that an additional hectare invested in soil and land management leads to 10.5% increase in farm income on average. Moreover, the tree planting is significantly associated with farm income, indicating that an additional hectare invested in tree planting provides the households with increase in 17.6% of farm income on average. Land tenure and irrigation have significant associations with the farm income in Column (1), but the coefficients of them are insignificant in Column (5).

In terms of food insecurity (Column (2), (4), and (6)), the benefit of tree planting is negative and significant. It indicates that an additional hectare of tree planting reduces 0.03 months of food insecurity. Although the estimates of land tenure security, soil and land management and irrigation are significant, the coefficients turn into insignificant after controlling covariates and

fixed effects.

In Column (7), farm income is treated as independent variables so that we can investigate the mechanism that it is improving food insecurity as depicted in Figure 3. The coefficient of farm income is statistically significant. The results indicate that 1% increase in farm income reduces 0.09 months of household food insecurity. The results are reasonable because the farm investment in agricultural practice increase farm income and efficiency, showing an indirect effect of the farm investment on the food security through farm income. In all columns, the estimation results by OLS work as a sort of robustness checks, respectively. Overall, the welfare benefits from tree planting in Zambia are generally consistent with those of past studies by Abdulai & Huffman (2014); Nkomoki et al. (2018); and Issahaku & Abdulai (2020). Our findings contribute to the vast literature about farm investment and household welfare, from the viewpoint of not only income but also food security.

[Table 8 here]

5.4. Does gender matter in farm investment and household welfare?

Many views in development communities take it as given that causality between agricultural intervention and women's productivity are rational, and donors increasingly call for that gender issues be addressed in development projects and proposals. Others keep casting doubt on a women-focused blueprint in agrarian sector—or at least suggest that there may be trades associated with targeting interventions at women (Doss, 2018). To assess women's agricultural productivity, one approach that has been widely acknowledged is to consider the 'household farm enterprise' as the production unit and to compare the productivity of different households, differentiating between male- and female-headed households. While this approach is relatively easy, it neglects the contributions that women make to farms in men-headed households (and conversely the contributions that men make to farms in women-headed households) (Doss, 2018). To address this gap, we utilize the data about who make a decision in a plot so that we

can even consider the women's contribution to a farm in households headed by men. This section investigates if farm households benefit more from farm investment when women involve in decision making in households.

Table 9 summarizes the estimation results for the heterogeneous association between farm investment and household welfare among households with decision making by women, joint decision making, decision making by men. Column (1) and (2) show the estimation results for patrilineal households while Column (3) and (4) present the ones for matrilineal households. After controlling for confounding factors, soil and land management significantly increases farm income for households with only women decision makers in Column (1). However, the significant relationship disappears for matrilineal societies in Column (3). The result plausibly explains that the investment in soil and land may make up for the less labor input from household members and fertilizer for women's plots, especially in the patrilineal societies where the women bargaining power is relatively lower than the matrilineal societies (Udry, 1996; Fenske, 2011). Moreover, acquisition of land tenure security alleviates food insecurity for households with decision making by women in Column (2). Same as Column (2), the significant association is not found in Column (4). It indicates that the households that women solely involve in decision making benefit from land title for food insecurity. We find that land tenure security for women itself increase bargaining power of women within households taking care of more food consumption and nutrition, as our Hypothesis II states. Throughout our analysis, irrigation is not significantly correlated with household welfare. Since there are few application areas of irrigation in our observations as showed in Table 1, we may be not able to capture the variations of irrigation adoption.

Overall, it is important to note that the land tenure security and farm investments provide benefit for the farm income and household food security, especially when women participate in decision making in male dominant societies. From the perspective of women empowerment,

these are encouraging results because they imply that policy makers should promote farm investments through strengthening land tenure security for women decision makers in Zambia.

[Table 9 here]

5.5. Robustness checks

In this section, we carry out a robustness check to see whether the results change when we use a different measurement method. The effect of land tenure security on the farm investments may vary with different measures of the farm investment. Therefore, in this section, we replace application areas of the farm investments with dummy variables of the investment. The estimated results are in Table A3 and Table A4. Similar to those reported in Table 6, the result presents that the effect of land tenure security on soil and land management is robust, indicating that land tenure security increases the farm investment. Regardless of gender of decision makers, the significant relationships are uniformly observed in Table A3. Moreover, Table A4 shows the heterogeneous association between land tenure security and farm investment. The results confirm that the significant difference in gender of decision makers regarding the association between land tenure security and tree planting, as shown in Table 7. It indicates that plots with women decision makers are more likely to be invested in tree planting.

6. Summary and concluding remarks

This paper makes two main contributions to the literature. First, it assesses the impact of land tenure security on farm investments and how the effect differs in gender of decision makers. To this end, we take advantage of the informative RALS datasets including the information on gender of decision makers on plots. Although there have been mixed empirical findings about the relationship between land tenure security and farm investments, we find that women tend to invest in more tree planting when plots have land tenure. Empirical analysis of Zambian farmers provides robust evidence in support of the hypothesis, given the conceptual framework stating the positive association between greater tenurial security and further farm

investment. Second, we investigate a mechanism about how household welfare is improved through farm investment with land tenure security. Our findings corroborate the past evidence that farm investment increases farm income, then improves food insecurity, ultimately household welfare. Moreover, we provide further understanding about associations among land tenure security, farm investment, and household welfare from gender perspectives. The heterogeneous analysis shows that land tenure security improves food security as well as soil and land management increases farm income in only patrilineal societies when decision makers are women. Since there are few studies looking at the mechanism using nationally representative surveys in Zambia and addressing descent systems, the results and implications would help policy makers considering sustainable agricultural development and land policies and avoid mistargeting.

Although our econometric estimations remain endogeneity concerns stemming from the unobservable time-varying factors due to characteristics of the dataset, the lessons learned in our study are valuable for future directions in rural development and women empowerment in Zambia. This is the first study to examine how different in gender of decision makers the relationship among land tenure, farm investment and household welfare among patrilineal and matrilineal households. We suggest that households that women have the final say in household decisions increase the household welfare through the farm investments and land tenure security. Furthermore, the robustness checks accounting for alternative measurement support our main findings.

This study highlights the significance of land tenure security and suggests that it can promote gender equality in agricultural production. Although our study use datasets from Zambia, we may draw policy recommendations for countries near Zambia such as Malawi, Mozambique, and Angola where environmental settings are similar, and both patrilineal and matrilineal

societies co-exist. Land policies securing women's rights could potentially improve household welfare through enhancing farm investment especially by women in male-dominant societies.

Reference

Abdulai, A., & Huffman, W. (2014). The Adoption and Impact of Soil and Water Conservation Technology: An Endogenous Switching Regression Application. *Land Economics, 90*(1), 26-43.

Abdulai, A., Owusu, V., & Goetz, R. (2011). Land tenure differences and investment in land improvement measures: Theoretical and empirical analyses. *Journal of Development Economics, 96*(1), 66-78.

Agarwal, B., & Mahesh, M. (2023). Does the Landowner's Gender Affect Self-Cultivation and Farm Productivity? An Analysis for India. *The Journal of Development Studies, 59*(5), 758-777.

Ali, D., Bowen, D., Deininger, K., & Duponchel, M. (2016). Investigating the Gender Gap in Agricultural Productivity: Evidence from Uganda. *World Development, 87*, 152-170.

Ali, D., Deininger, K., & Goldstein, M. (2014). Environmental and gender impacts of land tenure regularization in Africa: Pilot evidence from Rwanda. *Journal of Development Economics, 110*, 262-275.

Babatunde, R. O., & Qaim, M. (2010). Impact of off-farm income on food security and nutrition in Nigeria. *Food Policy, 35*, 303-311.

Bellemare, M., & Novak , L. (2017). Contract Farming and Food Security. *American Journal of Agricultural Economics, 99*(2), 357-378.

Bellemare, M., Chua, K., Santamaria, J., & Vu, K. (2020). Tenurial security and agricultural investment: Evidence from Vietnam. *Food Policy, 94*, 101839.

Campos, A. D., Covarrubias, K., & Patron, A. (2016). How Does the Choice of the Gender Indicator Affect the Analysis of Gender Differences in Agricultural Productivity? Evidence from Uganda. *World Development, 77*, 17-33.

Chamberlin, J., & Ricker-Gilbert, J. (2016). Participation in Rural Land Rental Markets in Sub-

Saharan Africa: Who Benefits and by How Much? Evidence from Malawi and Zambia. *American Journal of Agricultural Economics, 98,* 1507-1528. doi:https://doi.org/10.1093/ajae/aaw021

Chapoto, A., Jayne, T., & Mason, N. (2011). Widows' Land Security in the Era of HIV/AIDS: Panel Survey Evidence from Zambia. *Economic Development and Cultural Change, 59*(3), 511-547.

Chu, J., Young, K., & Phiri, D. (2015). *large-scale land acquisitions, dispalcement and resettlement in Zambia.* Cape Town, South Africa: Institute of Poverty, Land and Agrarian Studies, University of Western Cape.

Deere, C. (2005). The feminization of agriculture? Economic restructuring in rural Latin America. *UNRISD Occasional Paper No. 1*.

Deininger, K., Xia, F., Kilic, T., & Moylan, H. (2021). Investment impacts of gendered land rights in customary tenure systems: Substantive and methodological insights from Malawi. *Word Development, 147,* 105654.

Dillon, B., & Voena, A. (2018). Widows' land rights and agricultural investment. *Journal of Development Economics, 135,* 449-460.

Doss, C. (2006). The Effects of Intrahousehold Property Ownership on Expenditure Patterns in Ghana. *Journal of African Economies, 15*(1), 149-180.

Doss, C. (2018). Women and agricultural productivity: Reframing the Issues. *Development Policy Review*, 36:35-50.

Doss, C., Kovarik, C., Perterman, A., Quisumbing, A., & Bold, M. (2015). Gender inequalities in ownership and control of land in Africa: myth and reality. *Agricultural Economics, 46*(3), 403-434.

Doss, C., Meinzen-Dick, R., Quismbing, A., & Theis, S. (2018). Women in agriculture: Four myths. *Global Food Security, 16,* 69-74.

FAO. (2018). *The gender gap in land rights.* Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). Retrieved from https://www.fao.org/3/i8796en/I8796EN.pdf

Fenske, J. (2011). Land tenure and investment incentives: Evidence from West Africa. *Journal of Development Economics, 95*(2), 137-156.

Fung, W., Liverpool-Tasie, L., Mason, N., & Oyelere, R. (2020). Do crop purchase programs improve smallholder welfare? The case of Zambia's Food Reserve Agency. *Agricultural Economics, 51*(4), 519-533.

Goldstein, M., & Udry, C. (2008). The Profits of Power: Land Rights and Agricultural Investment in Ghana. *Journal of Political Economy, 116*(6), 981-1022.

Hall, M., Murombedzi, J., Nkonkomalimba, M., Sambo, P., & Sommerville, M. (2017). *Zambia Customary Lannd Documentation Tenure Assessment.* Lusaka, Zambia: USAID Tenure and Global Climate Change Program.

Hayes, J., Roth, M., & Zepeda, L. (1997). Tenure Security, Investment and Productivity in Gambian Agriculture: A Generalized Probit Analysis. *American Journal of Agricultural Economics, 79*, 369-382. doi:https://doi.org/10.2307/1244136

Indaba Agricultural Policy Research Institute. (2016). *Rural Agricultural Livelihoods Survey; 2015 Survey Report.* Lusaka, Zambia: Indaba Agricultural Policy Research Institute. Retrieved from http://www.iapri.org.zm/

Issahaku, G., & Abdulai, A. (2020). Household welfare implications of sustainable land management practices among smallholder farmers in Ghana. *Land Use Policy, 94*, 104502.

Jacoby, H. (1991). Productivity of men and women and the sexual division of labor in peasant agriculture of the Peruvian Sierra. *Journal of Development Economics, 37*(1-2), 265-287.

Kang, M., Schwab, B., & Yu, J. (2020). Gender differences in the relationship between land ownership and managerial rights: Implications for intrahousehold farm labor allocation. *World Development, 125*, 104669.

Kapihya, L. (2017). *A comparative study on women's land rights in Zambia: Access, ownership, control, and decision-Making.* Washington DC: USAID Tenure and Global Climate Change Program.

Lawin, K., & Tamini, L. (2019). Land Tenure Differences and Adoption of AgriEnvironmental Practices: Evidence from Benin. *The Journal of Development Studies, 55*(2), 177-190.

Lawry, S., Camii, C., Hall, R., Leopold, A., Hornby, D., & Mtero, F. (2017). The impact of land property rights interventions on investment and agricultural productivity in developing countries: asystematic review. *Journal of Development Effectiveness, 9*(1), 61-81.

Lovo, S. (2016). Tenure Insecurity and Investment in Soil Conservation. Evidence from Malawi. *World Development, 78*, 219-229.

Mano, Y., Njagi, T., & Otsuka, K. (2022). An inquiry into the process of upgrading rice milling services: The case of the Mwea Irrigation Scheme in Kenya. *Food Policy, 106*, 102195.

Meinzen-Dick, R., Quismbing, A., Doss, C., & Theis, S. (2019). Women's land rights as a pathway to poverty reduction: Framework and review of available evidence. *Agricultural Systems, 172*, 72-82.

Menon, N., Rodgers, Y., & Nguyen, H. (2014). Women's Land Rights and Children's Human Capital in Vietnam. *World Development, 54*, 18-31.

Mizinga, F. (2000). Marriage and Bridewealth in a Matrilineal Society: The Case of the Tonga of Southern Zambia: 1900-1996. *African Economic History, 28*, 53-87.

Morris, M. (2007). *Fertilizer Use in African Agriculture : Lessons Learned and Good Practice Guidelines.* Washington DC, USA: World Bank.

Muchomba, F. (2017). Women's Land Tenure Security and Household Human Capital: Evidence from Ethiopia's Land Certification. *World Development, 98*, 310-324.

Mulenga, B., kabisa, M., & Chapoto, A. (2021). *Zambia Agricultural Status Report 2021.* Lusaka, Zambia: Indaba Agricultural Policy Research Institute.

Najjar, D., Baruah, B., & Garhi, A. (2020). Gender and Asset Ownership in the Old and New Lands of Egypt. *Feminist Economics, 26*(3), 119-143.

Nkomoki, W., Bavorova, M., & Banout, J. (2018). Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia. *Land Use Policy, 78*, 532-538.

Otsuka, K., Quismbing, A., & Payongayong, E. (2003). Land tenure and the management of land and trees: the case of customary land tenure areas of Ghana. *Environmental and Development Economics, 8*(1), 77-104.

Palacios-Lopez, A., Christiaensen, L., & Kilic, T. (2017). How much of the labor in African agriculture is provided by women? *Food Policy, 67*, 52-63.

Place, F. (2009). Land Tenure and Agricultural Productivity in Africa: A Comparative Analysis of the Economics Literature and Recent Policy Strategies and Reforms. *World Development, 37*(8), 1326-1336. doi:https://doi.org/10.1016/j.worlddev.2008.08.020

Posner, D. (2004). Measuring Ethnic Fractionalization in Africa. *American Journal of Political Science, 48*(4), 849-863.

Republic of Zambia. (2005). *Baseline Survey on women's access to agricultural land in Zambia*. Lusaka, Zambia: Republic of Zambia. Retrieved from https://catalog.ihsn.org/citations/35683

Sitko, N., Chamberlin, J., & Hichaambwa , M. (2014). Does Smallholder Land Titling Facilitate Agricultural Growth? An Analysis of the Determinants and Effects of Smallholder Land Titling in Zambia. *World Development, 64*, 791-802.

Thomas, D. (1990). Intra-Household Resource Allocation: An Inferential Approach. *Journal of Human Resources, 25*(4), 635-664.

Udry, C. (1996). Gender, agricultural production and theory of the household. *Journal of Political Economy, 104*(5), 1010-1046.

UNECA Southern Africa Office. (2003). *Land Tenure Systems and Sustainable Development in Southern Africa.* Lusaka, Zambia: UN Economic Commission for Africa.

United Nations Women. (2019, 7 9). The Gender Gap in Agricultural Productivity in Sub-Saharan Africa. *UN Women Policy Briefs*, p. 5.

World Bank. (2022). *World Bank Open Data*. Retrieved from World Bank Open Data: https://data.worldbank.org/

Zambia Statistics Agency. (2015, December 31). *Agriculture Statistics of Zambia, 2014*. Retrieved from Zambia Data Portal: https://zambia.opendataforafrica.org/ZMAGRISTAT2016/agriculture-statistics-of-zambia-2014

1. SEAs are the lowest geographical sampling units used by CSO and were the primary sampling units in the RALS. An SEA typically contains 100-200 households.
2. 2017 exchange rate: 9.5 ZMW/US$
3. We used *teffects ipwra* in STATA to run the DR method.
4. Our main interpretation is from the estimation by Probit model, but we use LPM to account for the unobservable heterogeneity of households.

Table 1 Description of plot and household variables

Variable	Description	N	Mean	SD	N	Mean	SD	Dif
Plot characteristics			2012			2015		
Land tenure	1 if a plot has secured tenure, 0 otherwise	26,022	0.0867	0.281	21,517	0.0564	0.231	-0.003***
Soil and land management	Areas of preventing soil erosion and/or flash flooding (ha)	26,022	0.157	0.578	21,517	0.169	0.690	-0.007***
Tree planting	Areas of planting trees to protect yield (ha)	26,022	0.024	0.238	21,517	0.764	1.104	0.078***
Irrigation	Irrigated areas (ha)	26,022	0.004	0.074	21,517	0.007	0.126	-0.078***
Purchased	1 if the plot is acquired by purchasing, 0 otherwise	26,022	0.060	0.237	21,517	0.067	0.249	0.0460***
Inherited	1 if the plot is acquired by inheritance, 0 otherwise	26,022	0.115	0.319	21,517	0.193	0.395	-0.0170***
Allocated	1 if the plot is acquired by allocation, 0 otherwise	26,022	0.730	0.444	21,517	0.652	0.476	0.175***
Possibility to change the tenure status	1 if the plot's status is possibly changed, 0 otherwise	25,763	0.328	0.470	21,517	0.282	0.450	0.016***
Decision maker	1 if the decision maker of the plot is woman, 0 otherwise	25,973	0.248	0.432	21,517	0.265	0.441	-0.003***
Cash crop	1 if a cash crop is planted, 0 otherwise	25,821	0.108	0.310	21,460	0.092	0.288	-0.007***
Hectare	Hectare of plot	26,021	0.819	1.194	21,517	0.851	1.904	-0.032**
Household characteristics								
Farm income	Total Farm income (ZMW)	8,566	4,869	12,771	7,579	4,908	18,379	-38.948
Food insecurity	Number of months of food insecurity	8,571	1.335	1.915	7579	1.515	2.118	-0.180***
Educational level of HH	Educational year of household head	8,571	6.222	3.940	7,579	5.805	4.015	0.417***
Matrilineal household	1 if the household is matrilineal, 0 otherwise	8,553	0.364	0.481	7,579	0.313	0.464	0.051***
Local household	1 if the household head is local,	8,566	0.888	0.315	7,579	0.895	0.307	-0.007

head	0 otherwise							
Number of plots	Number of plots	8,571	3.019	1.592	7,579	2.896	1.391	0.124***
Cash crop	1 if the household plant a cash crop, 0 otherwise	8,571	0.126	0.332	7,579	0.195	0.397	-0.068***
Credit	1 if the household can obtain credit, 0 otherwise	8,571	0.166	0.372	7,579	0.192	0.394	-0.027***
Age of HH	Age of household head	8,568	45.64	14.97	7,416	49.16	14.97	-3.525***
Adult equivalent	Number of adult equivalents	8,571	3.688	1.903	7,579	4.692	2.458	-1.003***
Asset index	Asset index based on principal component analysis	8,571	-0.000	2.209	7,578	0.008	2.318	-0.008
Tropical Livestock Unit	Tropical livestock unit based on	8,571	2.515	7.955	7,579	2.692	8.779	-0.177
Time to the nearest paved road	Time from homestead to the nearest paved road (minutes)	8,366	117.9	256.7	7,578	106.2	178.3	11.755***

Source: RALS2012, 2015.

Note: Zambian Kwacha (ZMW) values are in real 2017 terms. 2017 exchange rate: 9.5 ZMW/US$. The calculation of Tropical livestock Unit is based: cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01. We excluded households who earn less than 0 ZMW as outliers. It is important to note that costs of production are partially observed. Thus, net crop income accounts for fertilizer costs and the costs of transportation, but not for labor, transaction, seed, or other input expenditures. ***, **, * denote level of significance at 1%, 5% and 10% respectively.

Table 2 Gender of decision maker and tenure security (plot-level)

	Land title		
Decision maker	No	Yes	
Men	32,854	2,505	35,359
	92.92%	7.08%	100%
Women	11,167	964	12,131
	92.05%	7.95%	100%
Total	44,021	3,469	47,490
	92.7%	7.3%	100%

Note: The difference in gender is significant at 5% level.
Source: Authors' calculation using the RALS2012 and 2015 data.

Table 3 kinship system, plot size, and gender of decision maker

	Gender of decision makers		
	Men	Women	Total
Patrilineal	8,429	2,222	10,651
	79.14%	20.86%	100%
Matrilineal	4,065	1,416	5,481
	74.17%	25.83%	100%
Total	12,494	3,638	16,132
	77.45%	22.55%	100%
			Diff
Mean plot size (ha)	1.24	0.79	0.45***
SD	(0.02)	(0.03)	(0.04)

Note: The difference in gender is significant at 5% level. ***, **, * denote level of significance at 1%, 5% and 10% respectively.
Source: Authors' calculation using the RALS2012 and 2015 data.

Table 4 Cultivated land size and land titled (household-level)

	Land title		
	No	Yes	Total
5 to 19.99 ha	3,391	392	3,783
	89.64%	10.36%	100%
0 to 4.99 ha	11,369	992	12,361
	91.97%	8.03%	100%
Total	14,760	1,384	16,144
	91.43%	8.57%	100%

Note: Small-scale household is defined as a household cultivating 4.99 hectares of area under crops or less. Households cultivating between 5 and 19.99 hectares of area under crops are classified as Medium-scale households.
Source: Authors' calculation using the RALS2012 and 2015 data.

Table 5 Determinants of land tenure security (plot-level)

	(1) Probit	(2) LPM
Purchased	1.240***	0.300***
	(0.072)	(0.011)
Allocated	-0.108*	-0.004
	(0.060)	(0.005)
Inherited	-0.051	-0.013**
	(0.075)	(0.006)
Possibility to change the tenure status	0.227***	0.026***
	(0.042)	(0.004)
Women decision maker	0.126***	0.013***
	(0.041)	(0.003)
Educational level of HH	0.038***	0.006***
	(0.005)	(0.001)
Cash crop planted	0.002	-0.001
	(0.036)	(0.003)
Matrilineal household	-0.016	0.005
	(0.043)	(0.003)
Local household head	-0.127**	-0.012**
	(0.060)	(0.006)
Hectare	-0.000	-0.001
	(0.008)	(0.001)
Age of HH	0.005***	0.001***
	(0.001)	(0.000)
Adult equivalent	-0.006	-0.001
	(0.010)	(0.001)
Asset index	0.061***	0.010***
	(0.009)	(0.001)
Tropical Livestock Unit	0.002	0.000
	(0.002)	(0.000)
Time to the nearest paved road	-0.000	-0.000
	(0.000)	(0.000)
Household FE	No	Yes
Province FE	Yes	Yes
Year FE	Yes	Yes
Observations	45,868	45,868

Note: Robust standard errors clustered by households in parentheses. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Only the plots where crops are planted are used for the estimation. Garden, natural fallow, rented/borrowed out, orchard, and virgin plots are removed because the crops planted in these plots are not identified. Full regression table is available upon request. Source: Authors' calculation using the RALS2012 and 2015 data.

Table 6 Effect of land tenure security (Plot-level, Doubly Robust)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
ATT	0.068***	0.005	-0.008
N=45,878	(0.021)	(0.021)	(0.007)
Women decision makers' ATT	0.052**	0.040*	-0.002
N=11,771	(0.022)	(0.023)	(0.001)
Men decision makers' ATT	0.063**	-0.031	-0.012
N=34,107	(0.028)	(0.027)	(0.010)

Note: ATT is the average treatment effect on treated. Robust standard errors clustered by households in parentheses. Land tenure security is a dummy variable. The unit of the outcome variables is hectare. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available upon requests. Source: Authors' calculation using the RALS2012 and 2015 data.

Table 7 Heterogeneous association between land tenure and farm investment (Plot-level, PSM-FE)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
Land tenure	-0.024	-0.144	0.017
	(0.090)	(0.153)	(0.026)
Land tenure *women decision maker	0.098	0.219**	-0.014
	(0.063)	(0.099)	(0.012)
Control variables	Yes	Yes	Yes
Household FE	Yes	Yes	Yes
Province dummy	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Observations	33,947	33,947	33,947

Note: Bootstrap robust standard errors in parenthesis. Full regression table is available upon requests. Land tenure security is a dummy variable. The unit of the outcome variables is hectare. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available upon requests. Source: Authors' calculation using the RALS2012 and 2015 data.

Table 8 Determinants of household welfare (Household-level)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Farm income	Months of food insecurity	Farm income	Months of food insecurity	Farm income	Months of food insecurity	Months of food insecurity
	OLS	OLS	OLS	OLS	OLS-FE	OLS-FE	OLS-FE
Land tenure	0.641***	-0.373***	0.010	0.009	-0.094	-0.106	-0.116
	(0.100)	(0.051)	(0.100)	(0.054)	(0.146)	(0.088)	(0.087)
Soil and land management	0.344***	-0.107***	0.132***	-0.007	0.105***	-0.010	-0.000
	(0.041)	(0.013)	(0.023)	(0.009)	(0.036)	(0.015)	(0.015)
Tree planting	0.337***	-0.059***	0.146***	-0.027***	0.176***	-0.037***	-0.021*
	(0.024)	(0.008)	(0.021)	(0.009)	(0.025)	(0.013)	(0.013)
Irrigation	0.236***	-0.060***	0.056	0.009	0.101	-0.003	0.005
	(0.044)	(0.017)	(0.044)	(0.018)	(0.073)	(0.034)	(0.033)
Women decision making			-0.559***	0.198***	-0.512***	0.205***	0.156**
			(0.067)	(0.041)	(0.103)	(0.062)	(0.062)
Joint decision making			0.192**	0.102**	0.348***	0.067	0.097
			(0.076)	(0.049)	(0.127)	(0.077)	(0.076)
Farm income							-0.092***
							(0.008)
Control variables	No	No	Yes	Yes	Yes	Yes	Yes
Household FE	No	No	No	No	Yes	Yes	Yes
Province FE	No	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	No	Yes	Yes	Yes
Observations	16,116	16,150	15,603	15,631	15,603	15,631	15,603

Note: Robust standard errors clustered by households in parenthesis. Outcome variables are log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available in Table A1. Source: Authors' calculation using the RALS2012 and 2015 data.

Table 9 Heterogeneous association on different decision making processes (Household-level OLS FE)

	(1) Patrilineal	(2)	(3) Matrilineal	(4)
	Farm income (log)	Months of food insecurity	Farm income (log)	Months of food insecurity
Land tenure	-0.536	-0.012	-0.055	-0.647
	(0.333)	(0.200)	(0.876)	(0.525)
Soil and land management	0.090	0.009	0.142	-0.015
	(0.056)	(0.033)	(0.183)	(0.107)
Tree planting	0.173***	0.006	0.374***	-0.045
	(0.049)	(0.029)	(0.126)	(0.079)
Irrigation	0.179	-0.042	-0.070	-0.128
	(0.160)	(0.067)	(0.325)	(0.244)
Women decision making	-0.727***	0.367***	-0.639	0.399
	(0.249)	(0.142)	(0.552)	(0.331)
Joint decision making	0.481*	0.068	0.910	0.315
	(0.291)	(0.181)	(0.691)	(0.484)
Land tenure*Decision making by women	0.301	-0.741*	0.124	-0.281
	(0.685)	(0.397)	(1.944)	(1.052)
Land tenure*Joint decision making	-0.405	0.173	0.088	0.508
	(0.749)	(0.482)	(1.986)	(1.221)
Soil and land management * Decision making by women	0.346**	-0.018	0.371	0.052
	(0.171)	(0.089)	(0.515)	(0.296)
Soil and land management * Joint decision making	-0.059	0.013	-0.044	-0.110
	(0.141)	(0.083)	(0.406)	(0.332)
Tree planting * Decision making by women	0.003	-0.019	0.012	-0.027
	(0.135)	(0.057)	(0.379)	(0.166)
Tree planting * Joint decision making	-0.070	-0.040	-0.370*	0.012
	(0.078)	(0.045)	(0.200)	(0.122)
Irrigation* Decision making by women	0.236	0.335	0.135	0.009
	(0.614)	(0.276)	(0.836)	(0.479)
Irrigation * Joint decision making	-0.178	-0.030	0.151	0.249
	(0.226)	(0.123)	(0.516)	(0.378)
Control variables	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observation	10,288	10,305	5,366	5,377

Note: Robust standard errors clustered by households in parenthesis. Outcome variables are log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available at Table A2. Source: Authors' calculation using the RALS2012 and 2015.

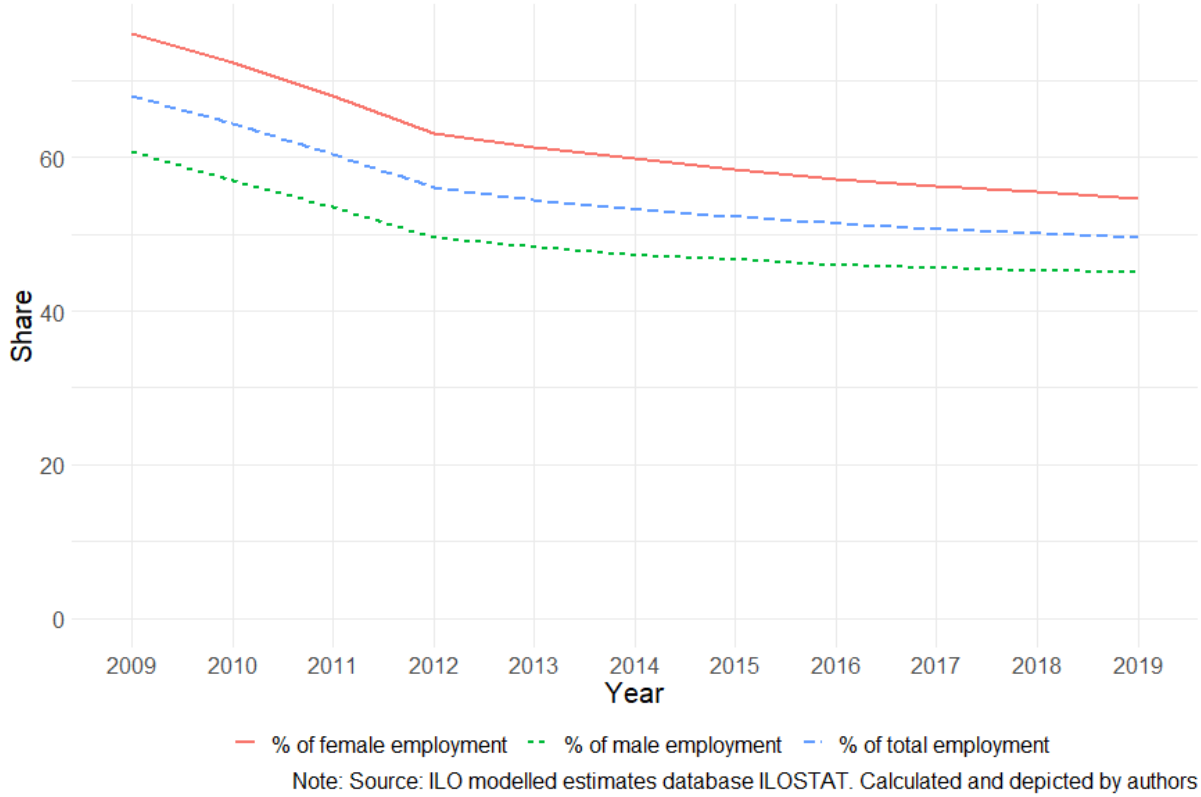

Figure 1 Employment in agriculture in Zambia

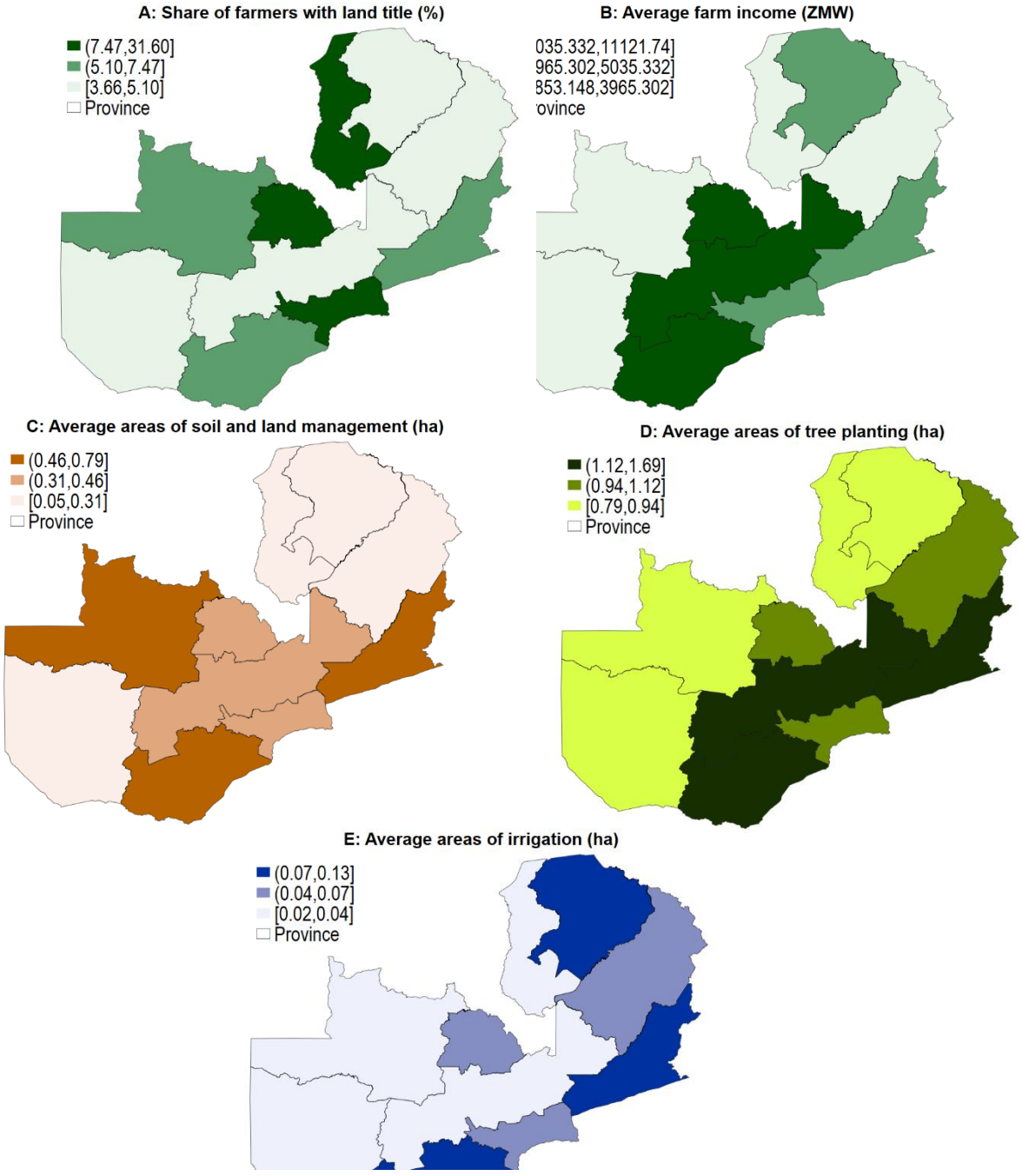

Figure 2 Land tenure, farm income, and farm investment in Zambia

Panel A shows the proportion of households with land title by province. Panel B shows the average farm income by province. Panel C shows the average areas of soil and land management per household by provinces. Panel D shows the average areas of tree planting per household by province. Panel E shows the average areas of irrigation per household by province. Source: Authors' compilations using the RALS2012 and 2015 data

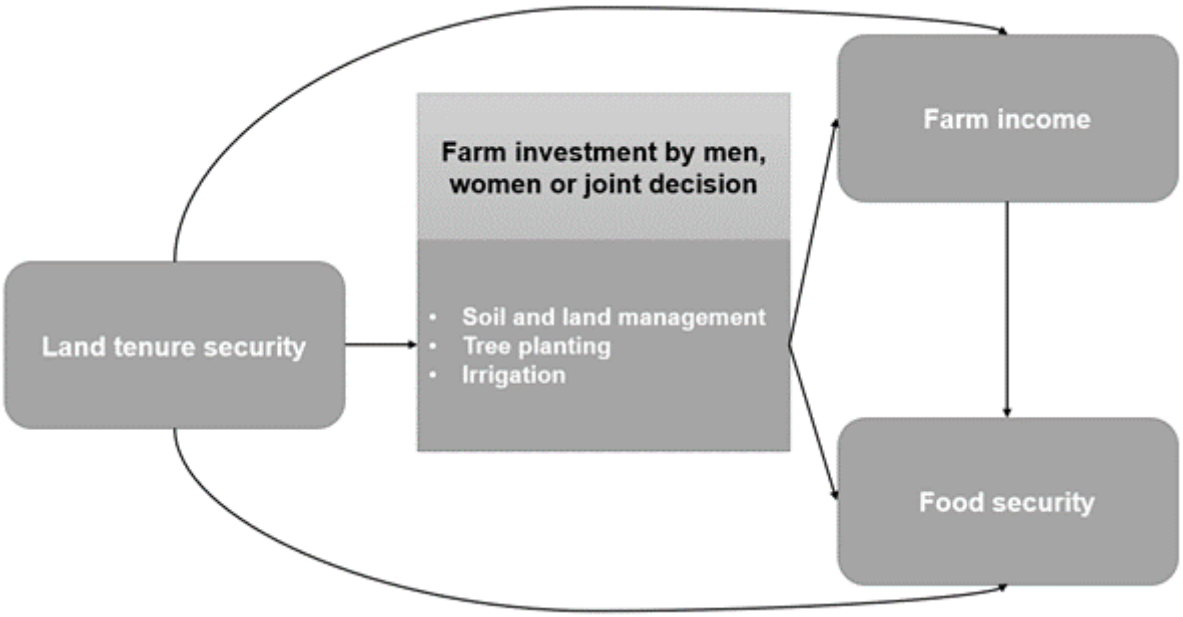

Figure 3 Conceptual framework about nexus among land tenure, farm investment, and household welfare

Appendix

Table A 1 Determinants of household welfare (HH-FE)

	(1) Farm income (log)	(2) Months of food insecurity	(3) Farm income (log)	(4) Months of food insecurity	(5) Farm income (log)	(6) Months of food insecurity	(7) Months of food insecurity
Land tenure	0.641***	-0.373***	0.010	0.009	-0.094	-0.106	-0.116
	(0.100)	(0.051)	(0.100)	(0.054)	(0.146)	(0.088)	(0.087)
Soil and land management	0.344***	-0.107***	0.132***	-0.007	0.105***	-0.010	-0.000
	(0.041)	(0.013)	(0.023)	(0.009)	(0.036)	(0.015)	(0.015)
Tree planting	0.337***	-0.059***	0.146***	-0.027***	0.176***	-0.037***	-0.021*
	(0.024)	(0.008)	(0.021)	(0.009)	(0.025)	(0.013)	(0.013)
Irrigation	0.236***	-0.060***	0.056	0.009	0.101	-0.003	0.005
	(0.044)	(0.017)	(0.044)	(0.018)	(0.073)	(0.034)	(0.033)
Women decision making			-0.559***	0.198***	-0.512***	0.205***	0.156**
			(0.067)	(0.041)	(0.103)	(0.062)	(0.062)
Joint decision making			0.192**	0.102**	0.348***	0.067	0.097
			(0.076)	(0.049)	(0.127)	(0.077)	(0.076)
Matrilineal household			-0.086	0.097***	-0.076	0.085*	0.080
			(0.057)	(0.034)	(0.088)	(0.052)	(0.051)
Age of household head			-0.012***	0.004***	-0.010***	0.005***	0.004**
			(0.002)	(0.001)	(0.003)	(0.002)	(0.002)
Local household head			0.170**	0.072	0.037	0.064	0.064
			(0.084)	(0.049)	(0.129)	(0.074)	(0.073)
Number of plots			0.479***	-0.122***	0.467***	-0.098***	-0.056***
			(0.019)	(0.011)	(0.030)	(0.018)	(0.018)
Adult equivalent			-0.001	0.013*	0.002	0.010	0.010

			(0.014)	(0.008)	(0.020)	(0.012)	(0.012)
Cash crop			0.165**	-0.008	0.098	-0.034	-0.020
			(0.080)	(0.043)	(0.124)	(0.067)	(0.066)
Smallholder farmers			-0.610***	0.215***	-0.493***	0.237***	0.191***
			(0.067)	(0.035)	(0.100)	(0.059)	(0.058)
Educational level of HH			0.045***	-0.046***	0.035***	-0.046***	-0.043***
			(0.008)	(0.004)	(0.012)	(0.007)	(0.007)
Credit			0.556***	0.032	0.630***	0.062	0.119*
			(0.074)	(0.040)	(0.116)	(0.065)	(0.065)
Tropical Livestock Unit			0.010**	-0.005***	0.006	-0.004	-0.002
			(0.004)	(0.001)	(0.006)	(0.003)	(0.003)
Asset index			0.338***	-0.111***	0.337***	-0.092***	-0.063***
			(0.019)	(0.008)	(0.026)	(0.013)	(0.013)
Time to the nearest paved road			-0.001***	0.000***	-0.001***	0.000***	0.000***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Farm income							-0.092***
							(0.008)
Household FE	No	No	No	No	Yes	Yes	Yes
Province FE	No	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	No	Yes	Yes	Yes
Observations	16,116	16,150	15,603	15,631	15,603	15,631	15,603

Note: Robust standard errors clustered by households in parenthesis. Outcome variables are log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Source: Authors' calculation using the RALS2012 and 2015 data.

Table A 2 Heterogeneous association on different decision making processes (Household-level OLS FE)

	(1)	(2)	(3)	(4)
	Patrilineal		Matrilineal	
	Farm income (log)	Months of food insecurity	Farm income (log)	Months of food insecurity
Land tenure	-0.536	-0.012	-0.055	-0.647
	(0.333)	(0.200)	(0.876)	(0.525)
Soil and land management	0.090	0.009	0.142	-0.015
	(0.056)	(0.033)	(0.183)	(0.107)
Tree planting	0.173***	0.006	0.374***	-0.045
	(0.049)	(0.029)	(0.126)	(0.079)
Irrigation	0.179	-0.042	-0.070	-0.128
	(0.160)	(0.067)	(0.325)	(0.244)
Women decision making	-0.727***	0.367***	-0.639	0.399
	(0.249)	(0.142)	(0.552)	(0.331)
Joint decision making	0.481*	0.068	0.910	0.315
	(0.291)	(0.181)	(0.691)	(0.484)
Land tenure*Decision making by women	0.301	-0.741*	0.124	-0.281
	(0.685)	(0.397)	(1.944)	(1.052)
Land tenure*Joint decision making	-0.405	0.173	0.088	0.508
	(0.749)	(0.482)	(1.986)	(1.221)
Soil and land management * Decision making by women	0.346**	-0.018	0.371	0.052
	(0.171)	(0.089)	(0.515)	(0.296)
Soil and land management * Joint decision making	-0.059	0.013	-0.044	-0.110
	(0.141)	(0.083)	(0.406)	(0.332)
Tree planting * Decision making by women	0.003	-0.019	0.012	-0.027
	(0.135)	(0.057)	(0.379)	(0.166)
Tree planting * Joint decision making	-0.070	-0.040	-0.370*	0.012
	(0.078)	(0.045)	(0.200)	(0.122)
Irrigation*	0.236	0.335	0.135	0.009

Decision making by women				
	(0.614)	(0.276)	(0.836)	(0.479)
Irrigation * Joint decision making	-0.178	-0.030	0.151	0.249
	(0.226)	(0.123)	(0.516)	(0.378)
Matrilineal household (=1 if yes)	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)
Age of HH	-0.008	0.003	-0.008	0.009
	(0.006)	(0.003)	(0.013)	(0.009)
Local household head (=1 if yes)	0.074	-0.046	0.009	0.243
	(0.256)	(0.135)	(0.599)	(0.355)
Number of plots	0.452***	-0.075**	0.617***	-0.201**
	(0.061)	(0.036)	(0.123)	(0.080)
Adult equivalent	0.004	0.019	-0.005	-0.038
	(0.038)	(0.023)	(0.094)	(0.059)
Cash crop planted (=1 if yes)	-0.001	0.036	0.101	-0.150
	(0.234)	(0.123)	(0.690)	(0.374)
Smallholder	-0.333*	0.312***	-0.795*	-0.052
	(0.183)	(0.106)	(0.472)	(0.358)
Educational level of HH (years)	0.044**	-0.039***	0.054	-0.037
	(0.022)	(0.013)	(0.052)	(0.033)
Obtaining credit (=1 if yes)	0.491**	0.089	0.774	-0.076
	(0.212)	(0.118)	(0.571)	(0.319)
Tropical Livestock Unit	-0.005	0.001	0.098*	-0.021
	(0.007)	(0.004)	(0.058)	(0.030)
Asset index	0.371***	-0.118***	0.319**	-0.100
	(0.044)	(0.022)	(0.141)	(0.078)
Time to the nearest paved road (min)	-0.001*	0.000	-0.002	0.002*
	(0.000)	(0.000)	(0.001)	(0.001)
Household FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observation	10,288	10,305	5,366	5,377

Note: Robust standard errors clustered by households in parenthesis. Outcome variables are log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Source: Authors' calculation using the RALS2012 and 2015 data.

Table A 3 Effect of land tenure security on farm investment (Doubly robust)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
ATT	0.055***	0.003	0.001
N=45,878	(0.009)	(0.006)	(0.003)
Women decision makers' ATT	0.045***	0.015	0.002
N=11,771	(0.017)	(0.011)	(0.003)
Men decision makers' ATT	0.053***	-0.007	0.001
N=34,107	(0.011)	(0.006)	(0.004)

Note: ATT is the average treatment effect on treated. Robust standard errors clustered by households in parenthesis. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available upon requests. Source: Authors' calculation using the RALS2012 and 2015 data.

Table A 4 Heterogeneous associations on decision maker and cash crop (Probit-PSM)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation	(4) Soil and land management	(5) Tree planting	(6) Irrigation
Land tenure security	0.167***	-0.099*	0.105	0.159***	-0.048	0.055
	(0.033)	(0.057)	(0.078)	(0.035)	(0.060)	(0.092)
Land titled* women decision maker	0.024	0.242**	-0.255			
	(0.066)	(0.110)	(0.178)			
Land titled*Cash crop				0.121	0.128	0.019
				(0.094)	(0.231)	(0.229)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Province dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	45,458	45,458	45,458	45,458	45,458	45,458

Note: Bootstrap robust standard errors clustered by households in parenthesis. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available upon requests. Source: Authors' calculation using the RALS2012 and 2015 data.