# STRUCTURAL TRANSFORMATION FROM A MICROECONOMIC VIEW: EVIDENCE FROM SUB-SAHARAN AFRICAN COUNTRIES

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**ABSTRACT**

STRUCTURAL TRANSFORMATION FROM A MICROECONOMIC VIEW: EVIDENCE FROM SUB-SAHARAN AFRICAN COUNTRIES

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Structural transformation and corresponding labor productivity growth are fundamentals of economic development. This dissertation, titled *Structural Transformation from A Microeconomic View*, explores the path of the structural transformation in Sub-Saharan Africa (SSA). In the last 20 years in SSA, structural transformation was not always accompanied by overall labor productivity growth. The first essay of this dissertation, titled *Education, Profitability, and Household Labor Allocation in Rural Uganda*, explores the microeconomic factors that explain non-growing-productivity structural change with a focus on the role of education. I jointly estimate household hourly profit (wage) and labor supply functions. The estimation result is supportive of the hypothesis that the level of education, profitability of an activity, and time allocation to that activity can be not positively correlated while education positively increases total household profit from the activity.

To trigger structural transformation, the governments of SSA and donors have allocated a vast amount of resources into agricultural programs for over 20 years. Aggregate agriculture productivity, however, has shown little growth in the last 20 years. Yet the share of employment in agriculture has constantly decreased since 2000. Whether agriculture productivity growth advances the labor shift from the agriculture sector to the non-agriculture sector is still an open question and of great interest for efficient investment in agriculture development and the economic growth of the countries. The second essay, titled *Land and Labor Bias of Farm Technology and the Household's Labor Allocation Decisions*, explores the effect of land- and

labor-augmenting farm technologies on the household's labor decisions. I provide a theoretical model to describe the household responses to land- and labor-augmenting farm technical change. I classify agricultural households into six regimes based on the participation in on- and off-farm labor markets and the constraint of off-farm work opportunities. I derive propositions to examine the behaviors of the households in each regime. In the empirical part of the study, I apply the model to microeconomic data from Tanzania to test the propositions. The estimation results show that for Tanzanian maize farmers, the adoption of land-augmenting technology, that is organic fertilizer, inorganic fertilizer, or irrigation, increases on-farm labor and decreases off-farm labor while the adoption of labor-augmenting technology, including sprayers, pesticides, herbicides, animal traction, or tractors, decreases on-farm labor and increases off-farm labor when the elasticity of substitution between labor and land is sufficiently large.

Taken together, these essays shed light on important policy implications for the acceleration of structural transformation in SSA. The estimation result from the first essay suggests that the expansion of the industry in which higher levels of education increase profitability of work would pull laborers from farming into nonfarm activities. Relaxing the labor market constraints of individuals, especially from relatively less educated households, would shift hours of labor allocation from less profitable activities towards more profitable activities. Also, raising household incomes or standard of living would increase the preference of individuals for leisure relative to income, and increase the optimal marginal productivity of labor, and consequently the profitability of labor. The second essay provides evidence that depending on the conditions of a country such as the level of elasticity of substitution between land and labor and the constraints around off-farm work opportunities, labor-augmenting agricultural technologies have a good potential for speeding up the structural transformation.

This dissertation is dedicated to my dear daughter and son, Emiko Kagwiria and Kotaro Muguna.

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## KEY TO ABBREVIATIONS

| | |
|---|---|
| AI | Aridity Index |
| CES | Constant Elasticity of Substitution |
| CRE | Correlated Random Effects |
| CV | Coefficient of Variation |
| EA | Enumeration Area |
| EOS | Elasticity of Substitution |
| FOC | First Order Condition |
| GDD | Growing Degree Days |
| GDP | Gross Domestic Product |
| GMM | Generalized Method of Moments |
| GYGA | Global Yield Gap Atlas |
| HH | Household Head |
| IMR | Inverse Mills Ratio |
| IV | Instrumental Variable |
| LIML | Limited Maximum Likelihood |
| LN | Log-Normal |
| MAE | Mean Annual Potential Evapotranspiration |
| MAP | Mean Annual Precipitation |
| MLE | Maximum Likelihood Estimation |
| MV | Modified Variety |
| NAIVS | National Agricultural Input Voucher Scheme |

| | |
|---|---|
| NLLS | Non-Linear Least Squares |
| PPP | Purchasing Power Parity |
| RE | Random Effects |
| SACCO | Savings and Credit Co-Operative |
| SD | Standard Deviation |
| 2SGMM | Two-Stage Generalized Method of Moments |
| 2SLS | Two-Stage Least Squares |
| SSA | Sub-Saharan Africa |
| TNPS | Tanzania National Panel Survey |
| TS | Temperature Seasonality |
| UNHS | Uganda National Household Survey |
| UNPS | Uganda National Panel Survey |
| USD | United States Dollar |
| VAT | Value-Added Tax |

# CHAPTER 1

## Education, Profitability, and Household Labor Allocation in Rural Uganda: Joint Estimation of Returns to Education and Labor Supply

### 1.1 Introduction

Economic development is the process of structural transformation and corresponding increase in per capita output in the economy. How farm households allocate more time away from farming and increase hourly returns is one of the important indicators of rural economic development. In the last 20 years structural transformation has occurred in Sub-Saharan African countries; agriculture’s share in GDP declined from 23 percent in 1995 to 17 percent in 2015 (World Bank, 2017), and the share of agricultural employment fell during the 2000s by 10 percent (Barrett et al., 2017). The structural transformation was, however, not always accompanied by overall labor productivity growth even with labor shifts from subsistence to non-subsistence sectors (McMillan & Headey, 2014; McMillan et al., 2014). From a macroeconomic viewpoint, a revealed comparative advantage in primary industry, overvalued currencies, and inflexible labor markets are the major factors inducing structural change without overall labor productivity growth (McMillan et al., 2014).

This chapter explores non-growing-productivity structural change from a microeconomic perspective. I test the hypothesis that the level of education, profitability of an activity, and time allocation to that activity can be not positively correlated while education positively increases total profit from the activity. The estimation of either the household profit function or the labor supply function on its own provides the total effect of education on either household profit or labor supply. This combines the direct effect that education has on household profit or labor supply with an indirect effect from the re-allocation of household labor induced by profitability changes. Therefore, I jointly estimate the household hourly profit (wage) and labor supply functions to examine the impact of education on profitability of each activity and to determine whether the effect of education on household labor supply is associated with a difference in the education-induced profitability effects.

Studies on rural nonfarm activities in Sub-Saharan Africa emerged in the 1980s. The evidence from the field surveys in the late 1970s and 1980s changed a widespread view that rural Africans mainly farmed and undertook little activity off-farm, except when they left rural areas to migrate (Hill, 1982). 20 studies from 10 Sub-Saharan African countries showed that Africa's rural inhabitants typically drive from 25 to 30 percent of their income from nonfarm sources, and nonagricultural income regularly accounts for from 30 to 50 percent of rural cash incomes (Haggblade et al., 1989).

In the 1990s empirical studies explored the systematic determinants and the effects of the rural off-farm activities of African farm households. Four-year panel data from Burkina Faso showed that shortfalls in cropping income push, while terms of trade pull, the households towards nonfarm activities, but a land constraint does not drive the participation in nonfarm activities (Reardon et al., 1992). Nonfarm activities are associated with higher and more stable income and consumption over years (Reardon et al., 1992). Agricultural productivity growth was also promoted by households' reinvesting nonfarm earnings into farming (Savadogo et al., 1994). However, for those who lack access to off-farm activities, off-farm income increases inequality and fails to shield poor households against agroclimatic risks (Reardon & Taylor, 1996).

By the end of the 1990s, education captured the spotlight in rural nonfarm employment studies. As new technologies developed, the relative impact of human capital on the marginal product of labor in farm and non-farm work changed, which determined the allocation of an increment in human capital services between farm production and off-farm work (Huffman, 2001). The experience of the Philippines during the Green Revolution showed that because the adoption of modern varieties in rice farming increases the demand for labor in cropping activities but does not increase the return to human capital as much as in nonfarm earnings, educated farm households tend to allocate more time away from farming to nonfarm employment (Estudillo & Otsuka, 1999).

The results from SSA are consistent in the positive effect of education on nonfarm earning and time allocation of rural farm households (Abdulai & Delgado, 1999; Abdulai & CroleRees, 2001). Because a large share of nonfarm activities is in urban areas and in migration, an emphasis is put on the increase in access by the poor to assets. The latter include not only education but also information, financial capital, and infrastructure, all of which allow them to overcome non-farm entry barriers (Reardon et al., 2000; Barrett et al., 2001).

For farm households, the returns to education are not limited to educated individuals but include all household members because of the knowledge spillover effects through both farm and off-farm activities (Yang, 1997). Also, farm households reap rewards from schooling not only directly by enhancing profitability of their activities but also indirectly by reallocating educated household labor from one activity to another in which the returns from schooling are high (Taylor & Yúnez-Naude, 2000). The data from rural Ghana showed that while direct effect of education is positive and high in both farm and off-farm activities, the indirect effect of labor reallocation is negative in farming but positive in off-farm activities.

Hence, in total, much of the value from increasing the educational attainment of farm households is found in its impact on off-farm activities, including the reallocation of time away from farm work (Jolliffe, 2004). For household-based nonfarm self-employment ventures, the household members jointly determine supply of labor given the shadow wage of the family activity where the shadow wage is unobservable. The joint estimation of the households' shadow wage and labor supply equations incorporates the effect of education on household earnings through the marginal productivity of labor, labor allocation across activities, and its production externality effects (Laszlo, 2005, 2008).

Most of the human capital literature estimates the direct and indirect effect of education on profit and labor supply with the underlying assumption that the shadow wage and labor supply are positively correlated, but the labor supply functions are not jointly estimated with endogenously determined shadow wages. In developing countries, however, many households face strict constraints in the labor market, which can induce negative correlations between the shadow wage and labor supply due to the allocative inefficiency of labor.

In this study, I jointly estimate the hourly profit (wage) and labor supply equations to incorporate the different channels through which education affects total profit: profitability of hours of labor, labor allocation across activities, and labor re-allocation through the education-induced profitability effects. I combine multiple models to overcome the difficulties of joint estimation. First, following Laszlo (2008), because a marginal shadow wage is unobservable for family self-employment, I use an adequate instrument for the marginal shadow wage to estimate the effect of education on labor supply.

Second, education itself is time-invariant for a majority of households and most likely to be correlated with unobserved heterogeneities because the decision on education is influenced by family and community background. I exploit the variation of household person-year exposure to free primary education policy implemented by the Ugandan government and use it as an instrumental variable of education. Unlike the season of birth (Angrist & Keueger, 1991), sex of siblings (Butcher & Case, 1994), policy intervention (Harmon & Walker, 1995; Duflo, 2001; Brunello et al., 2009), and topological features (Cutler & Glaeser, 1997; Hoxby, 2000), this unique household variable explains both household and individual years of education and education qualification variables well, is perfectly exogenous, and does not directly explain hourly profit (wage) or labor supply. Conventional IVs such as parents' education hardly meet the exclusion condition. Using the spouse's education qualification limits the sample to those who are already married.

Third, the hourly profit (wage) and labor supply equations are double censored. The hours of labor supply are censored at zero since observed hours of labor supply are always zero for those who are not participating in the activity. Also, the wage is observed only when the household allocates positive hours of labor to the activity. To overcome this problem, I test the preeminence of the models and combine Double Hurdle and Type III structural Tobit models to apply for the estimation. The structural feature of the model allows us to decompose the effect of education on profit into the direct effect of education on profitability, labor allocation across activities, and the indirect effect on re-allocation of labor through the education-induced profitability effect.

The remainder of the paper is organized as follows. Section 1.2 describes the data set and the preliminary findings from the descriptive analyses. Section 1.3 explains the conceptual and estimation models. Section 1.4 reports the model specification and the validity test of instrumental variables followed by the estimation results of reduced form and two-stage estimates, joint estimates, and intra-household estimates in Section 1.5. Section 1.6 concludes with a summary of the key findings and discussion.

## 1.2 Data

The data used in this chapter come from the Uganda national panel survey (UNPS) 2009/2010, 2010/2011, and 2011/2012. UNPS is a nationwide household survey implemented by the Uganda Bureau of Statistics. The sample is implicitly stratified by geographic region. 322 Enumeration Areas (EAs) were selected out of the 783 EAs that had been visited by the Uganda National Household Survey (UNHS) in 2005/2006. They cover all 34 EAs visited by the UNHS 2005/2006 in Kampala District, and 72 EAs (58 rural and 14 urban) in each of the: (i) Central Region with the exception of Kampala District; (ii) Eastern Region; (iii) Western Region; and (iv) Northern Region.

UNHS featured 10 households selected randomly from each EA. The realized sample size was 2,975 households. From the full sample, I select all households in rural areas. Only the household members aged 20 to 65 are included in my sample. This selection criterion results in a sample of 2,195 households (5,813 individuals), among which 305 households (2,107 individuals) are in one-year panels, 347 households (1,045 individuals) are in two-year panels, and 1,543 households (2,661 individuals) form three-year panels. The average level of education of the pooled sample shows 5.55 years of completed education where seven years of education correspond to completion of primary school.

### 1.2.A Higher Education, Longer Hours, and Higher Per Hour Labor Productivity in Rural Nonfarm Activities Compared to Farming

Labor activities are classified into four sectors: own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment. Farming is defined as International Standard Industrial Classification (ISIC) code 1 and 2, i.e., agriculture, hunting, forestry, and fishing. Nonfarm is defined as all other activities. The hours of labor supply are defined as the time allocation of the main job and, if there is one, the second job in the last 12 months. In case the main or second job in the last seven days is different from that in the last 12 months, the main or second job in the last seven days is also included. Hence, if the main and second jobs in the last 12 months and seven days are all different, a maximum of four jobs are considered per individual. The hours of labor supply per week are computed based on the hours of labor supply in the last 12 months and the average months per year and weeks per month of working days in the last 12 months. Therefore, it excludes the seasonality of the labor supply. Household non-labor income is the sum of the property income, interest, and dividends from investments, pensions, and remittances.

Table 1.1 presents the education, hours of labor supply, hourly profits (wages)[1], and characteristics of individuals in each sector. In rural Uganda, in aggregate, around 40 percent of the hours of labor are supplied to nonfarm activities and 60 percent of the hours of labor are provided to farming. The individuals who provide positive hours of labor to nonfarm activities, on average, have higher education than those who provide positive hours of labor to farming.

[1] Hourly wage is the weighted sum of wage within a sector using hours of labor supply of each job as weight. Hourly profit from self-employed activities is the total household profit divided by total hours of labor supply of all household members age 20 to 65 who are engaged in the activity. Total profit is the total value of output subtracted by the total value of input. The total values of output and input are the total quantity of output and input multiplied by the median prices of each at district-urban/rural level. In case there are less than 10 observations of prices, the larger locality level such as sub-region, region, or nation, is applied.

**Table 1.1 Education, hours of labor supply, hourly profit or wage, and characteristics of individuals by sector**

| | Own-farming | | | Farm-wage-labor | | | Nonfarm self-employment | | | Nonfarm wage-employment | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | p50 | cv | mean | p50 | cv | mean | p50 | cv | mean | p50 | cv |
| Education (years) | 5.0 | 5.0 | 0.7 | 3.7 | 4.0 | 0.8 | 6.0 | 6.0 | 0.6 | 8.2 | 8.0 | 0.6 |
| Labor supply (hours/week) | 21.3 | 19.4 | 0.7 | 15.1 | 6.8 | 1.4 | 32.3 | 23.1 | 0.9 | 35.4 | 31.6 | 0.8 |
| Multiple sectors = 1 | 0.3 | 0.0 | 1.4 | 0.8 | 1.0 | 0.6 | 0.7 | 1.0 | 0.7 | 0.5 | 1.0 | 1.0 |
| Hourly profit or wage (USD/hour) | 1.6 | 0.4 | 12.3 | 1.7 | 0.7 | 2.7 | 5.3 | 0.7 | 16.4 | 3.2 | 1.1 | 4.6 |
| Experience (years) | 21.4 | 20.0 | 0.6 | 9.3 | 7.0 | 1.1 | 9.3 | 6.0 | 1.0 | 7.6 | 4.0 | 1.1 |
| Age | 37.9 | 37.0 | 0.3 | 36.9 | 36.0 | 0.3 | 38.0 | 37.0 | 0.3 | 35.8 | 35.0 | 0.3 |
| Female = 1 | 0.6 | 1.0 | 0.9 | 0.5 | 0.0 | 1.1 | 0.5 | 0.0 | 1.0 | 0.3 | 0.0 | 1.5 |
| Household land holdings (acres) | 4.8 | 2.5 | 2.4 | 4.4 | 2.0 | 2.5 | 4.2 | 2.0 | 2.6 | 4.4 | 1.9 | 3.5 |
| Value of household farm asset (100 USD) | 0.7 | 0.2 | 2.5 | 0.7 | 0.2 | 3.0 | 0.6 | 0.2 | 2.6 | 0.5 | 0.2 | 3.0 |
| Household nonlabor income (100 USD/year) | 0.6 | 0.0 | 5.8 | 0.3 | 0.0 | 4.8 | 1.9 | 0.1 | 3.7 | 1.4 | 0.0 | 6.2 |
| Ownership = 1 | 0.2 | 0.0 | 1.9 | - | - | - | 0.8 | 1.0 | 0.6 | - | - | - |
| Formal job = 1 | 0.02 | 0.00 | 6.58 | 0.03 | 0.00 | 5.89 | 0.04 | 0.00 | 4.99 | 0.25 | 0.00 | 1.74 |
| Share of hours of labor supply | | 0.55 | | | 0.06 | | | 0.23 | | | 0.16 | |
| Number of obs. (individual-year pairs) | | 8149 | | | 1286 | | | 2225 | | | 1393 | |

*Notes:* USD used in the table is 2011 PPP USD. Experience of own-farming is the year of experience of the household. Multiple sectors mean having at least one additional job in another sector. Formal job refers to having a formal job as the main job in the sector. A formal wage job is defined as the job for which the employer applies at least one of the following: pension or retirement funds, paid leaves, medical benefits, or income taxes. A formal self-employed job is defined as the business registered for VAT or subject to income tax.

The average hours of labor supply to own-farming are 21.3 hours per week, which is much shorter than 32.3 hours in nonfarm self-employment and 35.4 hours in nonfarm wage-employment. Although the hours of labor supply in farming are fewer than in the nonfarm sectors, only 30 percent of individuals in own-farming allocate their time to multiple sectors while 70 percent in nonfarm self-employment and 50 percent in nonfarm wage-employment work in multiple sectors. The hours of labor supply in farm-wage-labor are 15.1 hours per week, which is shortest among all sectors, as 80 percent of individuals in farm-wage-labor are engaged in multiple sectors. The mean of hourly profit (wage) shows the largest value, 5.3 USD per hour, in nonfarm self-employment, followed by 3.2 USD per hour in nonfarm wage-employment, 1.7 USD per hour in farm-wage-labor, then 1.6 USD per hour in won-farming. The median of hourly profits (wages) is, however, higher in nonfarm wage-employment, that is 1.1 USD per hour, than in nonfarm self-employment, which shows 0.7 USD per hour. The variance of per hour profit is larger in nonfarm self-employment than in nonfarm wage-employment.

Despite the longer years of average experience in farming than nonfarm activities, hourly profit (wage) suggests that rural nonfarm activities have the higher per hour labor productivity than farming. The average age and share of female workers are not significantly different from the aggregate average age, 37, and the aggregate share of female, 53 percent, in all sectors except the share of female workers in nonfarm wage-employment, where only 30 percent of workers are female. The median of household land holdings indicates that individuals in own-farming, on average, have larger household land holdings than those in other sectors. There is no significant difference in medians of value of household farm assets and household nonlabor income across sectors. However, the highest 25 percent of household nonlabor income exhibits significantly higher amounts of nonfarm activity than in farming, resulting in higher means of household nonlabor income in nonfarm sectors than in farming sectors.

In terms of the ownership, 80 percent of workers in nonfarm self-employment own their business while just 20 percent of workers in own-farming have the ownership. Most income generating activities are informal; just 2, 3, 4, and 25 percent of individuals in own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment respectively have a formal job[2] as the main job.

### 1.2.B Education Qualification Plays a Role in Sector Choice of Individual Labor Allocation

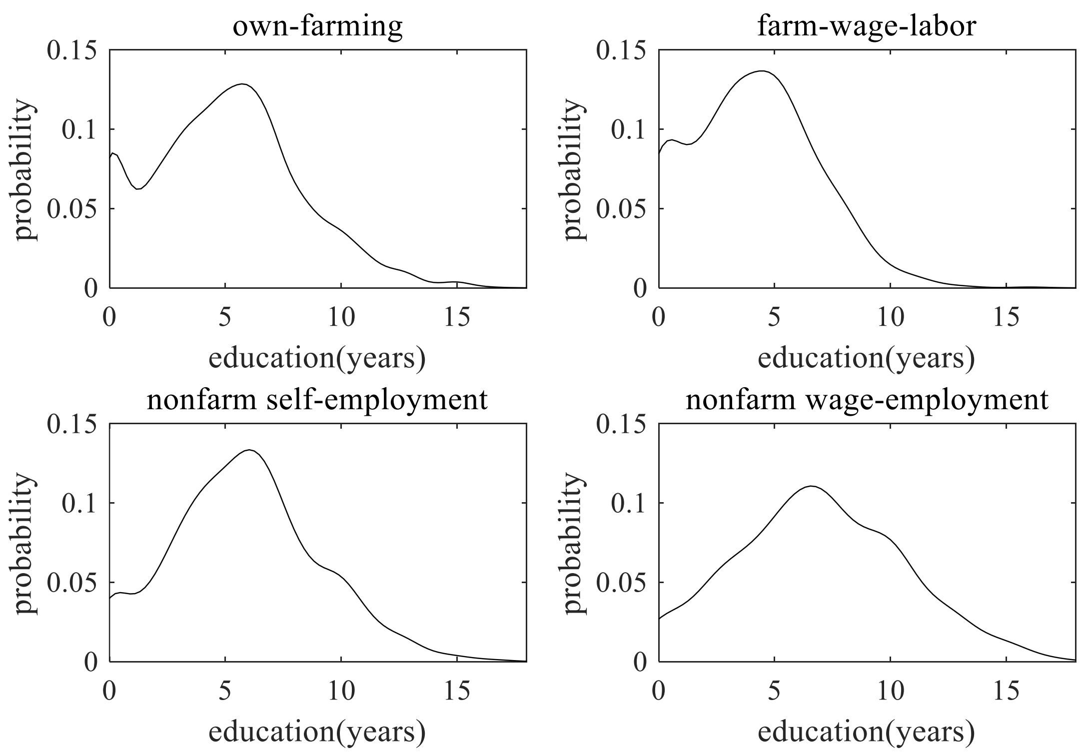


**Figure 1.1 Kernel density estimates of education by sector**

[2] A formal wage job is defined as the job for which the employer applies at least one of pension or retirement funds, paid leaves, medical benefits, or income taxes. A formal self-employed job is defined as the business registered for VAT or subject to income tax.

Figure 1.1 displays the probability distribution of individual years of education in each sector. As shown in Table 1.1, the average education is lowest in farm-wage-labor, followed by own-farming, nonfarm self-employment, and then nonfarm wage-employment.

In Uganda, 7 and 13 years of education correspond to completion of primary school and secondary school respectively. The probability distribution shows the different traits across sectors for the equal or lower than 7 years of education, between 7 and 13 years of education, and equal to or higher than 13 years of education. It suggests that not only years of education but also education qualification play some role in individual decisions on labor allocation.

Table 1.2 highlights the sector choice of labor supply by education qualification. The values in the brackets show the share of number of observations and the share of hours worked respectively. The share of hours of labor shows that those who have higher education qualification allocate smaller share of time to own-farming or farm-wage-labor and larger share of time to nonfarm wage-employment. The share of hours worked in nonfarm self-employment, on the other hand, increases as education qualification increases for those whose education qualification is lower than some secondary but decreases as education increases for those whose education is higher than completed secondary. The gap between 1.00 and the sum of the shares of observations in all sectors and not working is the share of observations who are engaged in multiple sectors. Because some observations allocate hours of labor to more than two sectors, the share of observations in multiple sectors shows a little smaller value than the gap; 0.22, 0.26, 0.25, 0.21, 0.08, and 0.31 for the education qualification of no primary, some primary, completed primary, some secondary, completed secondary, and post-secondary respectively. It implies that the likelihood of income diversification shows a U-shaped form; individuals whose education qualification is some primary, completed primary or post-secondary show relatively higher

**Table 1.2 Education qualification and sector choice of labor supply**

| Education qualification | | Total | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment | Not working |
|---|---|---|---|---|---|---|---|
| No primary | Obs. | 2,071 | 1,529 | 330 | 246 | 107 | 342 |
| | | (1.00) | (0.74) | (0.16) | (0.12) | (0.05) | (0.17) |
| | Hours | 47,523 | 34,764 | 4,846 | 5,722 | 2,192 | 0 |
| | | (1.00) | (0.73) | (0.10) | (0.12) | (0.05) | (0.00) |
| Some primary | Obs. | 5,228 | 3,811 | 693 | 969 | 393 | 785 |
| | | (1.00) | (0.73) | (0.13) | (0.19) | (0.08) | (0.15) |
| | Hours | 130,176 | 81,558 | 9,512 | 28,547 | 10,560 | 0 |
| | | (1.00) | (0.63) | (0.07) | (0.22) | (0.08) | (0.00) |
| Completed primary | Obs. | 1,568 | 1,101 | 124 | 358 | 162 | 234 |
| | | (1.00) | (0.70) | (0.08) | (0.23) | (0.10) | (0.15) |
| | Hours | 44,803 | 24,520 | 2,214 | 12,040 | 6,028 | 0 |
| | | (1.00) | (0.55) | (0.05) | (0.27) | (0.13) | (0.00) |
| Some secondary | Obs. | 2,419 | 1,370 | 111 | 504 | 423 | 558 |
| | | (1.00) | (0.57) | (0.05) | (0.21) | (0.17) | (0.23) |
| | Hours | 65,066 | 27,009 | 1,754 | 19,613 | 16,690 | 0 |
| | | (1.00) | (0.42) | (0.03) | (0.30) | (0.26) | (0.00) |
| Completed secondary | Obs. | 320 | 93 | 3 | 37 | 51 | 163 |
| | | (1.00) | (0.29) | (0.01) | (0.12) | (0.16) | (0.51) |
| | Hours | 5,280 | 1,512 | 195 | 1,351 | 2,223 | 0 |
| | | (1.00) | (0.29) | (0.04) | (0.26) | (0.42) | (0.00) |
| Post-secondary | Obs. | 394 | 175 | 6 | 70 | 219 | 51 |
| | | (1.00) | (0.44) | (0.02) | (0.18) | (0.56) | (0.13) |
| | Hours | 14,709 | 2,467 | 128 | 2,484 | 9,629 | 0 |
| | | (1.00) | (0.17) | (0.01) | (0.17) | (0.65) | (0.00) |
| Total | Obs. | 12,000 | 8,082 | 1,267 | 2,185 | 1,356 | 2,134 |
| | | (1.00) | (0.67) | (0.11) | (0.18) | (0.11) | (0.18) |
| | Hours | 307,556 | 171,829 | 18,649 | 69,756 | 47,322 | 307,556 |
| | | (1.00) | (0.56) | (0.06) | (0.23) | (0.15) | (1.00) |

*Notes:* The values in the brackets show the share of number of observations and the share of hours worked, respectively. Hour shows the total average weekly hours of work supplied to each sector based on the total hours of work supplied in a year. No primary refers completing less than 1 primary grade or having never attended school. Some secondary includes post primary specialized training.

likelihood of income diversification than those whose education is no primary, some secondary, or completed secondary. The driver of income diversification would be different between those who did not proceed to secondary school and those who have post-secondary education. The share of observations of those not engaged in any income generating activities is also significant. The most common reason for not working for those who have not attended secondary school is sickness or disability, which accounts for 16 percent of people who are not engaged in any income generating activities. It is, then, followed by taking care of house or family, which accounts for 8 percent. For those who attended secondary school but did not proceed to post-secondary education, the most common reason for not working is attending school, which accounts for 33 percent, followed by taking care of house or family, which accounts for 10 percent. The reason for those who have post-secondary education, is mainly looking for a job, which accounts for 24 percent of individuals who are not engaged in any income generating activities.

### 1.2.C Hourly Return and Hours of Labor Supply Negatively Correlated in All Activities

Figure 1.2 and Figure 1.3 illustrate the correlations between education, hourly profit (wage), and hours of labor supply in farming and in nonfarm activities respectively. The surface of the figure shows the multivariate kernel density estimates of the combinations of two variables. The figures show the relatively clear relations between hourly profit (wage) and hours of labor supply in all activities. Hourly returns and hours of labor supply are negatively correlated. From the multivariate kernel density estimates, both the education and hourly returns and education and hours of labor supply do not show explicit correlations in farming. Compared to farming, nonfarm activities display relatively higher probability in the area where higher education and higher hourly returns intersect and the area in which higher education and longer hours of labor supply intersect. However, the correlations between education and hourly return and education and hours of labor supply are not very distinct as some with high education show low hourly returns or short hours of labor supply in nonfarm activities. The figures suggest that separately estimating the effect of education on total profits instead of hourly profits and the effect of education on labor supply tends to overestimate the positive effect of education by masking the

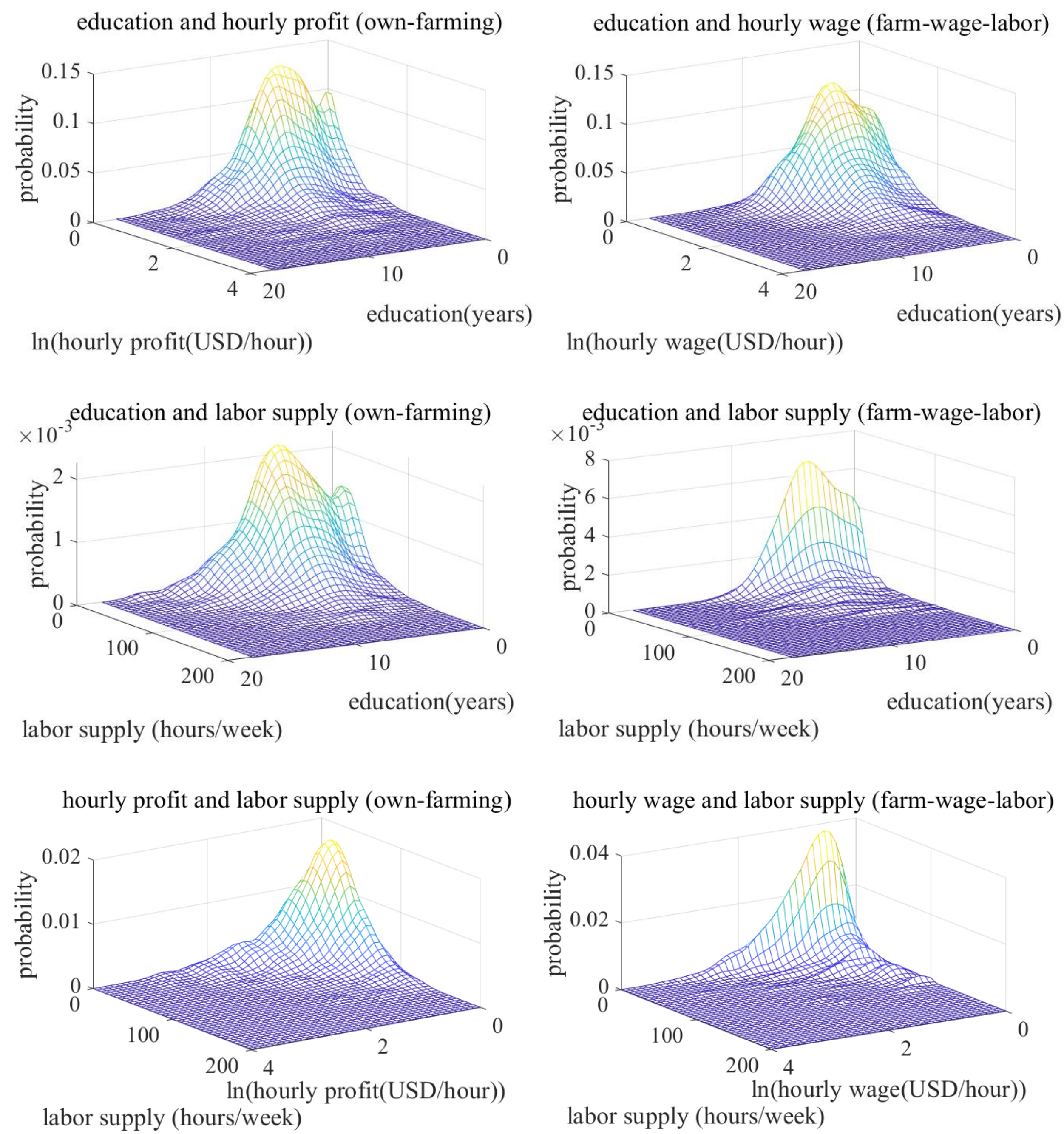


**Figure 1.2 Multivariate kernel density estimates of education, hourly profit or wage, and hours of labor supply to farming**

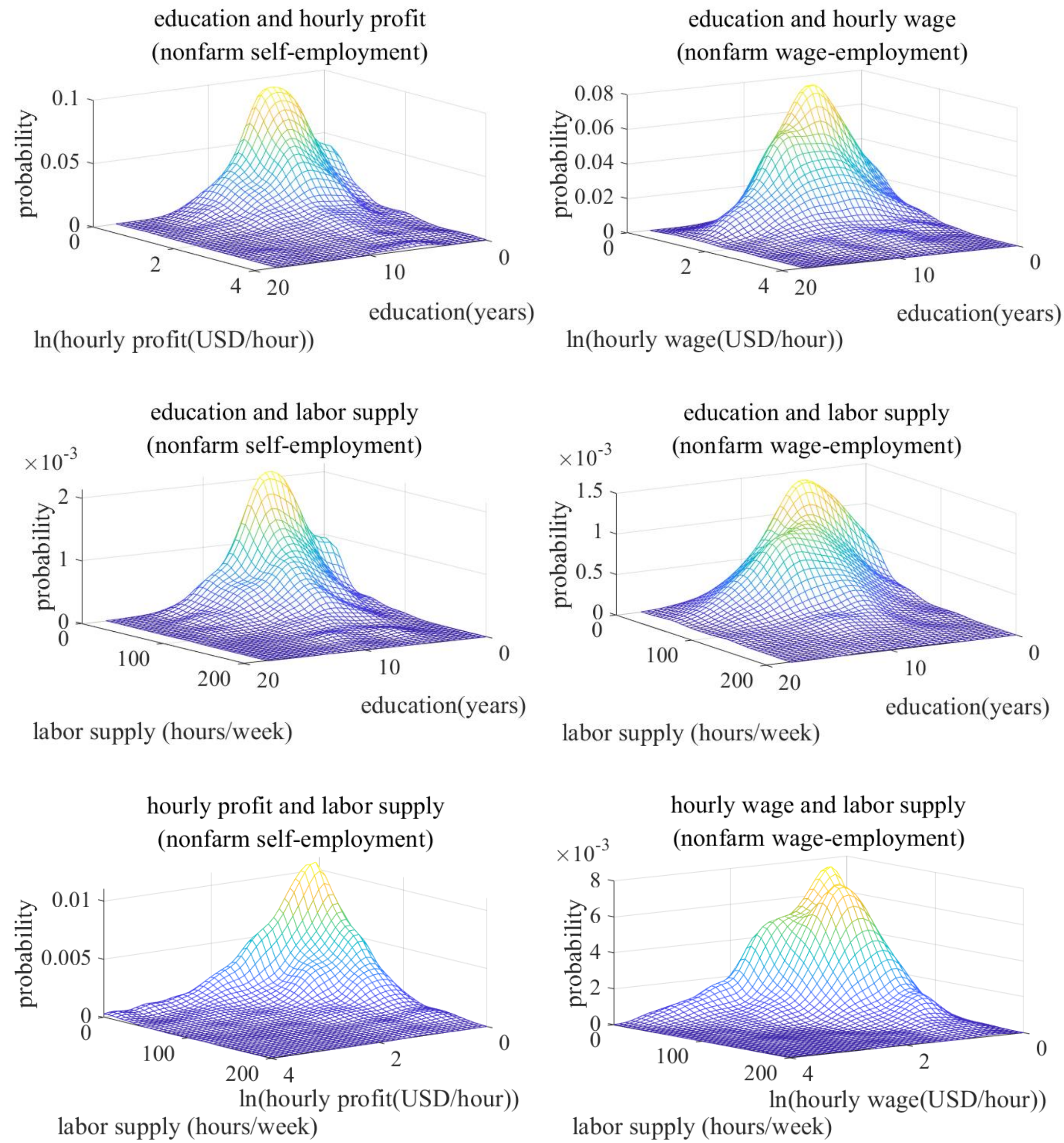


**Figure 1.3 Multivariate kernel density estimates of education, hourly profit or wage, and hours of labor supply to nonfarm sectors**

negative relations between education, hourly returns, and hours of labor supply. To fully discern the outcomes, empirical analyses are required.

## 1.3 Model

To find out the joint determination of household hourly profit (wage) and hours of labor supply, it is necessary to examine how education affects household profits, shadow wages, and labor supply in both farming and nonfarm activities. The agricultural household model, originally developed by Singh et. al. (1986), is in the line of the joint determination studies. The household members share income within the household and jointly determine supply of labor given the shadow wages of the on-farm and off-farm activities (Jacoby, 1993; Newman & Gertler, 1994). This approach allows estimation of the effect of education on household labor allocation through the shadow wage, that is, the hourly return of each activity.

### 1.3.A The Farm Household's Utility Maximization Problem

Suppose that a unitary household maximizes the utility of all family members over consumption and leisure, subject to budget and time constraints. Consumption is considered only on consumption of money, and household's preferences are defined over income (*Y*) and leisure (*l*); $U(Y,l;X_u)$ where $X_u$ is the set of exogenous factors which affect household preferences such as the number of adults and children and their gender. The utility function satisfies the standard assumptions: twice continuously differentiable and strictly quasi-concave. The household is endowed with hours of labor $\bar{h}$ and allocates endowed labor $\bar{h}$ into *M* possible activities and leisure (*l*); $\bar{h} = \sum_{m=1}^{M} h_m + l$. When household income (*Y*) comes from *M* activities and nonlabor income, the farm household's utility maximization problem can be stated as:

$$\max_{h_1, h_2, \dots, h_M} \; U\left\{\sum_{m=1}^{M} Y_m(E, h_m, X_m, p_m, \theta_m) + R, \bar{h} - \sum_{m=1}^{M} h_m \,; X_u\right\}$$

$$\text{subject to: } \; \bar{h} \geq \sum_{m=1}^{M} h_m, \quad h_m \geq 0 \tag{1.1}$$

where $Y$ measures profit, that is total expenditures subtracted from gross income; $E$ is education; $X_m$ represents household quasi-fixed assets required in each activity such as experience, landholdings, geographical situation, and capital stock; $p$ is a vector of prices of inputs; $\theta$ measures risk of earning profits from the activity; and $R$ is nonlabor income. If activity *m* is wage work, then *Y* is the wage income earned by the family. I assume that family labor and hired labor are not perfect substitutes so that hired labor is determined just like the other variable inputs given the exogenous prices. Also, following Jolliffe (2004), I assume that education cannot be purchased on the labor market, which means that the household cannot hire a manager to make the decisions on household activities.

The first order conditions to solve equation (1.1) consist of non-negativity conditions of hours of labor supply and uniformity of marginal product of labor in all activities:

$$h_m \geq 0, h_m\left(\frac{U_l(X_u)}{U_Y(X_u)} - \frac{\partial Y_m(E, h_m, X_m, p_m, \theta_m)}{\partial h_m}\right) = 0 \quad \forall m \tag{1.2}$$

The household does not participate in activity *m* if the family's marginal rate of substitution of income for leisure is greater than marginal return, or shadow wage, in activity *m*, evaluated at zero hours of labor in activity *m*. If the marginal return is greater, then the household provide hours of labor to activity *m* so that the value of the marginal product of labor equals the marginal rate of substitution of income for leisure. To assure the possibility of an interior solution for wage work, which has constant marginal return to hours of labor supply, the marginal rate of substitution must increase with hours of labor. Also, to assure that the household can be engaged in multiple sectors, the profit (wage income) functions must satisfy the positive and non-increasing marginal product of hours of labor.

Theoretically, if all markets are complete, the wage rate is completely exogenously determined, and time is sufficiently endowed such that the time constraint is not binding at the optimal solutions, the household supplies labor to wage work as well as self-employment activities up to the point where the marginal rate of substitution of income for leisure equals the price of leisure (which is represented by the exogenous wage rate). In case the highest wage rate offered to the household is lower than the family's marginal rate of substitution of income for leisure evaluated at zero hours of labor, the household members allocate their time only to self-employment activities. However, markets are hardly complete especially in developing countries. Market failures are rampant because of: (1) high transaction costs, which include distance from the market and poor infrastructure; (2) high marketing margins due to merchants with local monopoly power; (3) high search and recruitment costs due to imperfect information; (4) high supervision and incentive costs on hired labor; (5) shallow local markets, which imply a high negative covariation between household supply and effective prices; (6) price risk aversion, which influences the effective price used for decision making; and (7) limited access to working capital credit (Sadoulet & de Janvry, 1995).

With market failure, the corresponding good or factor becomes a non-tradable. Its price is no longer determined by the market but internally to the household as a shadow price (Sadoulet & de Janvry, 1995). When labor markets are not complete, the shadow wage is given by the function of household characteristics and all factors that affect household profit (de Janvry et al., 1991). An allocation of household labor is, then, such that the marginal product of labor is equated to an endogenously determined shadow wage, $w_s$. The solution to equation (1.2) is given as:

$$h_m^* = \left\{0, h_m\left(w_{sm}\left(X_u, E, X_{1,2,\ldots M}, p_{1,2,\ldots M}, \theta_{1,2,\ldots M}\right), Y_m(E, h_m, X_m, p_m, \theta_m)\right)\right\} \quad m = 1,2, \ldots, M \tag{1.3}$$

In this case, the optimal profit and the hourly profit are given as:

$$Y_m^* = Y_m\left(X_u, E, X_{1,2,\ldots M}, p_{1,2,\ldots M}, \theta_{1,2,\ldots M}\right) \quad m = 1,2, \ldots, M \tag{1.4}$$

$$\overline{w}_m^* = Y_m^*/h_m^* = \overline{w}_m\left(X_u, E, X_{1,2,\ldots M}, p_{1,2,\ldots M}, \theta_{1,2,\ldots M}\right) \quad m = 1,2, \ldots, M \tag{1.5}$$

Note that a market may fail only for some particular households (Sadoulet & de Janvry, 1995). For simplifying the estimation, and because the objective of this study is not to determine which households face the market failure, I assume that the labor market is incomplete for all households.

As stated in section 1.2.C, estimating equation (1.4) to measure the effect of education on total profit from each activity tends to overestimate the positive returns to education in case there are negative correlations between education, hourly profit (wage), and hours of labor supply. I will jointly estimate equations (1.3) and (1.5) to reveal how hourly profit (wage) and labor allocation to off-farm work respectively contribute to the households' returns to education. The difficulties of joint estimation and how to overcome the difficulties are explained in section 1.3.B.

### 1.3.B Joint Estimation of Household Returns to Education and Labor Allocation

The aim of this chapter is to show that whether farm households' returns to education are increased by higher hourly profit (wage) or allocating more households labor into nonfarm work. In the latter case, it is possible that a labor shift from farming to nonfarm activities is not accompanied by an increase in the household hourly returns even if the total gain in household profits is positive. To separate out the effect of education on hourly profit (wage) and the effect of education on hours of labor supply, I jointly estimate household hourly profit (wage) and household hours of labor supply.

There are three obstacles to jointly estimating household hourly profit (wage) and hours of labor supply. First, because household labor supply is not a function of the average return, but a function of the shadow wage, the estimation model necessarily includes the relation between marginal shadow wage and the hourly return. For wage work, a marginal return is constant and equal to hourly wage. However, for family self-employment, a marginal shadow wage is not constant and unobservable. Second, education is time-invariant for most households and most likely to be correlated with the unobserved heterogeneities because the decision on education is influenced by family and community background. In the presence of endogeneity of education, estimations that do not take care of endogeneity result in inconsistent estimators of all parameters. Third, the hourly profit (wage) and labor supply equations are double censored. The hours of labor supply are censored at zero since observed hours of labor supply are always zero for those who are not participating in the activity. Also, the wage is observed only when the household allocates positive hours of labor to the activity.

Three obstacles are overcome by combining multiple estimation models. Suppose that household hours of labor supply in equation (1.4) can be expressed as:

$$h = \max\left(0, Z_1\beta_1 + \eta \log \widehat{w} + \rho E + u_1\right) \tag{1.6}$$

where $h$ is hours of labor supply; $\widehat{w}$ is marginal return to hours of labor, that is shadow wage; $\rho$ represents the effect of education $E$ independent of its effect through the shadow wage; the vector $Z_1$ includes household and regional exogenous variables affecting hours worked; $u$ is a stochastic disturbance term. For family self-employment, a marginal shadow wage is unobservable. However, by using an adequate instrument for $\widehat{w}$, it is possible to estimate the effect of education on labor supply (Laszlo, 2008). A household hourly profit (wage) equation (1.5) is given as:

$$\log \overline{w} = Z_2\beta_2 + \mu E + u_2 \tag{1.7}$$

where $\overline{w}$ is hourly profit for family self-employment or hourly wage for wage employment; $\mu$ represents the hourly profit (wage) return to education $E$; and the vector $Z_2$ includes demographic, market, and regional characteristics affecting hourly profit (wage). For household self-employment activities, the vector $Z_2$ must include a set of variables that is excluded from $Z_1$, which plays as instrumental variables for $\widehat{w}$. The instrumental variables predict the marginal product of labor (shadow wage) but are orthogonal to the error term in equation (1.6).

Also, for both wage employment and self-employment, years of schooling are potentially endogenous. I use a linear projection of education given as:

$$E = Z_3\beta_3 + u_3 \tag{1.8}$$

where $Z_3$ is the vector which consists of the set of all exogenous variables in the hourly profit (wage) equation and instrumental variables for education $E$. I exploit the variation of person-year exposure of the household to the free primary education program and use it as instrumental variable for the household average years of education. The detail of hypothesis tests of endogeneity and validity of instrumental variables are in section 1.4.A. For simplicity of further modeling, education is modeled as affecting hourly profit (wage) and labor supply linearly and with no interaction effects. However, as shown in section 1.2.B, not only years of education but also education qualification plays some role in individual labor allocation decisions. Therefore, this restrictive assumption is eased in the intra-household estimations in section 1.5.C.

To overcome the double censored problem of estimating equations (1.6) and (1.7), I combine the two commonly used censored models; the Double Hurdle and Type III structural Tobit models. The Double Hurdle model, which is often applied to the estimation of labor supply equations, is a modified version of the Type I Tobit model (Cragg, 1971). The 1st stage of the Double Hurdle model estimates the probability of participation, which is followed by the 2nd stage estimation of the hours of labor supply given the probability of participation. While the Type I Tobit model imposes restrictions on the coefficients of first and second stage estimations, the Double Hurdle model does not impose those restrictions. The preeminence of the model is tested by comparing the log-likelihood of both models (Vuong, 1989). For the estimation of the wage equation, although the most widely used method is Heckit, which employs Type II Tobit model (Heckman, 1976), the Type III Tobit model is preferred when not only participation status but also hours of labor supply data are available. The Type III Tobit model uses the residuals from the 1st stage estimation instead of the Inverse Mills Ratio (IMR) (Amemiya, 1985). Because residuals contain more information than IMR, there is efficiency gain over the Type II Tobit model. Additionally, the Type III Tobit model relaxes the nonlinearity restriction of IMR imposed under the Type II Tobit model.

First, I estimate the reduced form labor supply equation as:

$$h = \max(0, Z\gamma + u) \tag{1.9}$$

where $Z$ is the vector of all exogenous variables in $Z_1$, $Z_2$, and $Z_3$. Then I obtain the IMRs from the 1st stage and the residuals from the 2nd stage estimation. Second, after estimating hourly profit (wage) equation (1.7) and education equation (1.8) by adding the IMRs and the residuals as the additional explanatory variables, I obtain fitted values of $\bar{w}$ excluding the parts explained by the IMRs and the residuals, which I denote as $\widetilde{w}$, and fitted values of $E$, which I denote as $\tilde{E}$, that I then use in a final stage where I estimate:

$$h = \max\left(0, Z_1\beta_1 + \eta \log \widetilde{w} + \rho\tilde{E} + u_1\right) \tag{1.10}$$

The estimate of $\mu\overline{w}$ in the hourly profit (wage) equation (1.7) provides the hourly profit (wage) return to education, and the final stage estimate of $\rho$ in equation (1.10) gives the effect of education directly on labor supply. The effect of education on hours through the (shadow) wage is estimated as $\eta$ in equation (1.10) multiplied by $\mu$ in equation (1.7).

## 1.4 Model Specification and Validity Tests of Instrumental Variables

### 1.4.A Specification of Variables and Estimation Equations

The work is classified into four activities: own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment. After estimating the reduced form labor supply equation (1.9), I jointly estimate the hourly profit (wage), equation (1.7), the education equation (1.8), and the labor supply equation (1.10). The vector of $Z$ includes time-variant and time-invariant household and district variables. $Z$ also includes a vector of year dummies which represent year-specific changes of hourly profit (wage) and labor supply. The stochastic disturbance term, $u$, consists of a stochastic error term and unobserved household and district heterogeneities which are correlated with time-variant explanatory variables. For each activity, the estimation equations are specified as:

$$h_{ijt} = \max\left(0, Z_{ijt}\gamma + a_i + a_j + e^1_{ijt}\right) \tag{1.11}$$

$$\log \overline{w}_{ijt} = Z^2_{ijt}\beta_2 + \mu E_{ijt} + b_i + b_j + e^2_{ijt} \tag{1.12}$$

$$E_{ijt} = Z^3_{ijt}\beta_3 + c_i + c_j + e^3_{ijt} \tag{1.13}$$

$$h_{ijt} = \max\left(0, Z_{ijt}^1\beta_1 + \eta \log \widetilde{w}_{ijt} + \rho\tilde{E}_{ijt} + a_i + a_j + e_{ijt}^1\right) \tag{1.14}$$

where $i$ is the subscript for household; $j$ is the subscript for district; $t$ is the subscript for year; $a, b$ and $c$ are unobserved heterogeneities; $e$ is a stochastic error term. The household average years of education of members 20 years of age and older serves as a measure of $E$. The $Z^2$ vector contains the vector of household composition ($X_u$) such as the household average age, the number of children aged 0-6 and 7-12, the share of female workers, and the share of married workers, the vector of household quasi-fixed assets required in all activities ($X_{1,2,\ldots,M}$) such as year of experience in own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment, square of years of experience, household landholdings, value of farm assets, distance to the nearest transport, and nonlabor income, and the vector of prices of inputs ($p_{1,2,\ldots,M}$) such as regional average hourly profits in own-farming and nonfarm self-employment, the regional average hourly wage in farm-wage-labor and nonfarm wage-employment, the consumer price index of food products, and the land rental rate. The $Z^3$ vector is the vector which consists of the set of all exogenous variables in $Z^2$ and instrumental variables for education $E$. The $Z^1$ vector includes all exogenous variables in $Z^2$. For own-farming, the value of farm assets is excluded from $Z^1$ so that the shadow wage is instrumented. For nonfarm self-employment, nonlabor income is excluded from $Z^1$ to instrument the shadow wage. Whether the value of farm assets and nonlabor income are not directly explaining the household labor supply to each activity but explaining household labor supply through the shadow wage is tested in section 1.4.C. The $Z$ vector consists of all exogenous variables in $Z^1$, $Z^2$, and $Z^3$. The summary statistics of the variables used for the estimations are reported in Table 1.A.1 in the Appendix.

Table 1.3 presents the results of the Vuong test for estimating reduced form labor supply equation (1.11) by either the Type I Tobit model or the Double Hurdle model. The preeminence

**Table 1.3 Results of Vuong test**

| Activity | Models tested | Coefficient | Preferred model |
|---|---|---|---|
| Own-farming | Lognormal Hurdle – Type I Tobit | 0.255*** (0.025) | Lognormal Hurdle |
| Farm-wage-labor | Lognormal Hurdle – Type I Tobit | 1.582*** (0.057) | Lognormal Hurdle |
| Nonfarm self-employment | Lognormal Hurdle – Type I Tobit | 1.047*** (0.049) | Lognormal Hurdle |
| Nonfarm wage-employment | Lognormal Hurdle – Type I Tobit | 1.116*** (0.046) | Lognormal Hurdle |

*Notes:* Coefficient shows the mean of difference of log-likelihood (Lognormal hurdle model minus Type I Tobit model). Standard errors clustered at household level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

of the model is tested by comparing the log-likelihood of both models (Vuong, 1989). The coefficient shows the mean of the difference of log-likelihood between Double Hurdle lognormal model and the Type I Tobit model. The result shows that in all activities, the Double Hurdle lognormal model has statistically significantly higher log-likelihood at the one percent confidence level. Hence, I apply the Double Hurdle lognormal model for the estimation of labor supply, equation (1.11) and equation (1.14). The endogeneity test of education confirms that there is no clear evidence that education is exogenously determined. The detail of the test is reported in section 1.4.B. I adopt two stage least square estimator (2SLS) for the estimation of hourly profit (wage), equation (1.12).

Although fixed effect estimators of hourly profit (wage), equation (1.12), and labor supply, equation (1.14), are consistently estimated under less restrictive assumptions, I employ correlated random effects (CRE) estimators because education is time-invariant for most households. Under CRE model, Mundlak's assumption holds (Mundlak, 1978) as:

$$het_i = \psi + \bar{Z}_i\omega + v_i, v_i |\, Z_i \sim Normal(0, \sigma_v^2), het = a, b, c \qquad (1.15)$$

where $\bar{Z}_i$ is a set of time means of the time-variant household or district explanatory variables in the corresponding equation. The heterogeneities are correlated with time-variant explanatory variables only through their time means. The consistency assumptions of Double Hurdle and

Type III Tobit models (Wooldridge 2010) provide the consistency conditions: (1) $(e^2, e^1)$ is independent of $Z$; (2) $e^1$~$\text{Normal}(0, \sigma^2)$; and (3) $Z^2$ contains at least one element whose coefficient is different from zero that is not in $Z^1$.

The estimation procedure of the consistent estimators is as follows.

Step 1. Estimate reduced form labor supply, equation (1.11), by the Double Hurdle lognormal model and get the IMRs from the 1st stage and the residuals, $\hat{\lambda}_{ijt}$, from the 2nd stage estimations.

Step 2. Estimate 2SLS CRE estimators of hourly profit (wage), equation (1.12), by including IMRs and $\hat{\lambda}_{ijt}$ as the additional explanatory variables. Collect the fitted values, $\widehat{ln(w_{ijt})}$ and $\hat{E}_{ijt}$ from the estimations of the hourly profit (wage) equation and the reduced form education equation where the parts explained by IMRs and $\hat{\lambda}_{ijt}$ are extracted from the fitted values.

Step 3. Estimate labor supply, equation (1.14), using $\widehat{ln(w_{ijt})}$ and $\hat{E}_{ijt}$ as the explanatory variables by a Double Hurdle lognormal model.

### 1.4.B Validity Tests of Instrumental Variables in Household Hourly Profit (Wage) and Labor Supply Estimations

The government of Uganda abolished primary school fees on January 1, 1997 as part of a universal primary school policy. The policy was introduced for all primary grades simultaneously. The cost of textbooks was also abolished. The tuition fee in late 1996 was 5,000 Ugandan shillings per student per year for the first 3 grades of schooling, and 8,100 Ugandan shillings for the 4th to 7th grades. In 1999, a teacher earned a monthly salary at a government-aided school of 75,000 shillings (Uganda, 1999), and average household expenditure on food, clothing, and living in rural Uganda was 86,700 shillings per month (Uganda, 2001). The policy resulted in a dramatic increase in net enrolment rate, from 57 percent in 1996 to 85 percent in 1997, and over 90 percent in 1999 (Uganda, 1999).

I exploit the variation of the sum of person-years of exposure to free primary education across households to explain household average years of education. In our sample, the individuals who were exposed to free primary education are those aged 5 to 12 in 1997 (20 to 27 in 2012), that is, 29.4 percent of individuals in our sample. The duration of exposure varies from one year to seven years depending on their birth years. By summing person-years of exposure to free primary education within a household, the variation goes from one person-year to 40 person-years of exposure. In our sample, 47 percent of households were exposed to free primary education. To control the effect of the district environment on the policy, I utilize the information on the distance to the nearest market in the community in 1995. I matched the individual district of birth data in UNPS with community-level service availability data from the Uganda demographic and health survey[3] (UDHS) 1995. The average individual distance to the nearest market in the community in 1995 among household members aged 20 to 65 is used as another instrumental variable to explain household average years of education.

To instrument the household average education, it is necessary that instrumental variables be correlated with household average education while not directly determining household hourly profit (wage) or labor allocation. The inclusion restriction is tested by estimating the reduced form education, equation (1.13). Because equation (1.15) of Mundlak's assumption holds for the estimation of hourly profit (wage) equation, and all time-variant exogenous explanatory variables

[3] UDHS was conducted by the Ministry of Finance and Economic Planning.

in the hourly profit (wage) equation are used as their own IVs in the reduced form education equation, I apply the CRE model rather than the pooled model to estimate equation (1.13).

Table 1.4 reports the estimation result of the reduced form household education equation. The coefficients of person-year exposure to free primary education are all significant at the one percent confidence level. The coefficient of average distance to the nearest market in the district of birth in 1995 is also statistically significant, and it is significant at the five percent confidence level. The signs of the coefficients are as expected; the person-year of exposure to free primary education increases the household average years of education, and the average distance to the nearest market in the district of birth in 1995 negatively affects the household average years of education. $\chi^2$-statistics indicate instrumental variables (IVs) in the reduced form education equation are jointly significant at the one percent confidence level in both estimations.

**Table 1.4 Household education reduced form estimates (correlated random effects)**

| | Average years of schooling | | Average years of schooling | |
|---|---|---|---|---|
| | Estimate | Standard error | Estimate | Standard error |
| *Instrumental variables* | | | | |
| Person-year under free primary policy | 0.065*** | (0.014) | 0.065*** | (0.014) |
| Average distance to nearest market in district of birth in 1995 (km) | -0.036** | (0.017) | - | - |
| $\chi^2$-statistic[a] (H$_0$: IVs violate inclusion restriction) | 28.41*** | | 22.10*** | |
| Number of observations | 4,724 | | 4,753 | |
| Number of households | 2,008 | | 2,014 | |
| R-squared | 0.329 | | 0.328 | |

*Notes:* In all estimations, all other exogenous variables in the profit or hourly profit equations are included as explanatory variables but not reported in the table. All estimations used the correlated random effects model. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a] $\chi^2$-statistic shows the joint significance of all IVs in the schooling reduced form equation.

Table 1.5 presents the results of endogeneity and overidentification restriction tests. The result of hourly profit (wage) and 2nd stage labor supply estimations shows the estimation results both with and without controlling selection bias. For the hourly profit (wage) estimation,

**Table 1.5 Validity tests of instrumental variables in the household hourly profit (wage) and labor equations**

| | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment |
|---|---|---|---|---|
| *Endogeneity test*[a] | | | | |
| ($H_0$: education is exogenous) | | | | |
| Using two IVs | | | | |
| Household hourly profit (wage) | -0.028**(0.014) | 0.064**(0.029) | 0.018(0.027) | -0.035(0.024) |
| with selection bias controlled | -0.035**(0.014) | 0.052*(0.028) | -0.004(0.026) | -0.048**(0.022) |
| Household labor 1st stage | 36.46*** | 37.32*** | 15.90*** | 28.57*** |
| Household labor 2nd stage | -0.045***(0.016) | -0.056(0.048) | -0.050*(0.028) | -0.044(0.029) |
| with selection bias controlled | -0.038**(0.016) | -0.050(0.048) | -0.047*(0.028) | -0.031(0.030) |
| Using one IV | | | | |
| Household hourly profit (wage) | -0.028*(0.014) | 0.066**(0.029) | 0.015(0.027) | -0.033(0.024) |
| with selection bias controlled | -0.034**(0.014) | 0.052*(0.028) | -0.005(0.026) | -0.047**(0.021) |
| Household labor 1st stage | 35.04*** | 53.29*** | 21.64*** | 39.65*** |
| Household labor 2nd stage | -0.041***(0.016) | -0.060(0.048) | -0.043(0.028) | -0.046(0.029) |
| with selection bias controlled | -0.034**(0.016) | -0.052(0.048) | -0.044(0.028) | -0.033(0.030) |
| *Overidentifying restriction test*[b] | | | | |
| ($H_0$: IVs are jointly valid) | | | | |
| Using two IVs | | | | |
| Household hourly profit (wage) | 5.52** | 0.63 | 0.67 | 1.80 |
| with selection bias controlled | 7.04*** | 1.06 | 0.73 | 4.19** |
| Household labor 1st stage | 2.15 | 12.73*** | 5.49** | 10.88** |
| Household labor 2nd stage | 4.54** | 0.27 | 4.21* | 14.82*** |
| with selection bias controlled | 3.84* | 0.47 | 3.28* | 10.79*** |

*Notes:* Household hourly profit (wage) and labor 2nd stage estimations show correlated random effects estimates. Household labor 1st stage estimations used a pooled probit model with time means of all time-variant explanatory variables. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a] Household hourly profit (wage) and labor 2nd stage show the significance of the coefficient of the residual from the reduced form education equation. Household labor 1st stage shows chi-square statistics of Wald test of exogeneity.

[b] Household hourly profit (wage) and labor 2nd stage show Sargan-Hansen statistics from two stage least squares estimations. Household labor 1st stage shows Amemiya-Lee-Newey minimum chi-square statistics from probit two-stage instrumental variable estimations.

selection bias is controlled by including the IMR and residual from estimating the 1st stage reduced-form labor supply estimation. For the 2nd stage labor supply estimation, the IMR from the 1st stage labor supply equation is included as an additional explanatory variable to control for selection bias. The null hypothesis of the endogeneity test is that education is exogenously determined. The results of endogeneity test for household hourly profit (wage) and 2nd stage labor supply estimations show the significance of the coefficient of the residual from the reduced form of education in the regression of the household hourly return or hours of labor supply on all exogenous variables, education, and the residual from the reduced-form education estimation using correlated random effects.

The test result for the household 1st stage labor supply estimation shows the $\chi^{2}$-statistics of Wald test of exogeneity in the pooled probit two stage regression of the binary participation variable on all exogenous variables and education, which is instrumented by instrumental variables. The result of endogeneity tests shows that for all equations the null hypothesis that education is exogenous is rejected at the 10 percent or less confidence level in at least one activity. Hence, there is no statistically significant evidence that education is exogenously determined.

The null hypothesis of the overidentifying restriction test is that the multiple IVs are jointly valid in the estimations. The result of the overidentifying restriction test for household hourly profit (wage) and 2nd stage labor supply estimations shows Sargan-Hansen statistics from 2SLS CRE estimations. The result for 1st stage labor supply estimation shows Amemiya-Lee-Newey minimum $\chi^{2}$-statistics from pooled probit two stage instrumental variable estimations. The results show that the null hypothesis of joint validity of IVs are not rejected for more than half of the hourly profit (wage) estimations. However, the null hypothesis of joint validity of IVs is rejected for more than half of 1st and 2nd stage labor supply estimations. Therefore, in the further estimations, I use two IVs for the estimation of the household hourly profit (wage) but exclude the average distance to the nearest market in the district of birth in 1995 for the estimation of household labor supply.

Because those in our sample were all born before 1997, there is no reasonable explanation that household person-year exposure to the free primary education directly explains household hourly profit (wage) or labor supply. The potential concern to use household average distance to the nearest market in district of birth in 1995 is that it might correlate with the current household hourly profit (wage) if the household is non-migrant. To dispel the concern, I estimated the household hourly profit (wage) equation with a subsample of non-migrants by using average distance to the nearest market in the district of birth in 1995 and other exogenous variables as explanatory variables. Table 1.6 shows the estimation results of hourly profit (wage) using a subsample of non-migrants. The full set of parameter estimates are presented in Table 1.A.2 in the Appendix. The coefficients of the average distance to the nearest market in the district of birth in 1995 are all not statistically significantly different from zero. The estimation result confirms that there is no statistically significant evidence that the average distance to the nearest market in the district of birth in 1995 directly explains the current household hourly profit (wage) of non-migrants.

**Table 1.6 Household hourly profit (wage) of non-migrants**

| Dependent variable:<br>Household hourly profit or wage (USD/hour)<br>Explanatory variables | Own-farming<br>CRE | Farm-wage-labor<br>CRE | Nonfarm self-employment<br>CRE | Nonfarm wage-employment<br>CRE |
|---|---|---|---|---|
| *With selection bias controlled* | | | | |
| Average distance to nearest market in district of birth in 1995 | 0.029<br>(0.020) | 0.001<br>(0.044) | 0.006<br>(0.037) | -0.040<br>(0.044) |
| Observations (household-year pairs) | 2,496 | 487 | 883 | 512 |
| Number of households | 1,275 | 386 | 596 | 379 |
| R-squared | 0.289 | 0.362 | 0.331 | 0.432 |

*Notes:* The full set of parameter estimates are presented in Table 1.A.2. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

## 1.5 Estimation Results

### 1.5.A Reduced and Two-Stage Estimates: Much Greater Returns to Education in Household Profit, Labor Participation, and Hours in Nonfarm Work than in Farm Work

First, I estimated the reduced-form and two stage instrumental variable estimates of farm and nonfarm household profit and labor supply functions, equations (1.4) and (1.3). All dependent variables are regressed on the same set of regressors which include household education, household composition variables, farm and nonfarm quasi-fixed assets, and input prices. Household average years of education is instrumented in the two-stage estimations. Table 1.7 shows the result of validity tests of instrumental variables in the household profit equation. For the estimations with selection bias controlled, IMR and the residual from the reduced-form labor supply equation are also included as additional explanatory variables.

**Table 1.7 Validity tests of instrumental variables in the household profit equation**

| | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment |
|---|---|---|---|---|
| *Endogeneity test*[a] | | | | |
| ($H_0$: education is exogenous) | | | | |
| Using two IVs | | | | |
| Household profit | -0.125*(0.065) | 0.007(0.033) | -0.134(0.145) | -0.207**(0.094) |
| with selection bias controlled | -0.133*(0.068) | 0.030(0.030) | -0.115(0.151) | -0.203**(0.101) |
| Using one IV | | | | |
| Household profit | -0.121*(0.065) | 0.006(0.034) | -0.135(0.145) | -0.202**(0.092) |
| with selection bias controlled | -0.131*(0.068) | 0.031(0.031) | -0.117(0.152) | -0.197**(0.099) |
| *Overidentifying restriction test*[b] | | | | |
| ($H_0$: IVs are jointly valid) | | | | |
| Using two IVs | | | | |
| Household profit | 0.06 | 1.14 | 0.82 | 2.94* |
| with selection bias controlled | 0.01 | 1.26 | 1.13 | 2.16 |

*Notes:* Household profit estimation used correlated random effects model. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a] The test result shows the significance of coefficient of the residual from reduced form education equation.

[b] The test result shows Sargan-Hansen statistics from two stage least square estimation.

Similar to the result of the tests in the household hourly profit (wage) estimation, the coefficient is statistically significant in own-farming and nonfarm wage-employment. The null hypothesis of exogeneity of education is rejected in farm-wage-labor and nonfarm self-employment, which shows that there is no clear evidence that education is exogenously determined in the household profit function. The result of the overidentifying restriction test shows that instrumental variables are jointly valid in the household profit equation from any activity with selection bias controlled by IMR and residual from the reduced-from labor supply equation.

**Table 1.8 The effect of education on the household profit reduced-form and two-stage estimates (correlated random effects)**

| Dependent variable Household profit (USD/week) | Education not instrumented | | Education instrumented, 2SLS | |
|---|---|---|---|---|
| | Estimate | Standard error | Estimate | Standard error |
| Own-farming | 0.040* | (0.022) | 0.297 | (0.216) |
| with selection bias controlled | 0.043* | (0.024) | 0.265 | (0.310) |
| Farm-wage-labor | -0.022 | (0.019) | 0.153 | (0.105) |
| with selection bias controlled | -0.018 | (0.016) | 0.019 | (0.072) |
| Nonfarm self-employment | 0.132*** | (0.048) | 0.756* | (0.404) |
| with selection bias controlled | 0.127** | (0.052) | 0.708 | (0.433) |
| Nonfarm wage-employment | 0.200*** | (0.068) | 1.111*** | (0.404) |
| with selection bias controlled | 0.218** | (0.094) | 1.121** | (0.442) |

*Notes:* The full set of parameter estimates are presented in Table 1.A.3 and Table 1.A.4. Household weekly profit is computed based on the gross income from the activities and the cost of self-employed activities in a year. All estimations used the correlated random effects model. The 2SLS estimations used two instrumental variables: person-year exposure to free primary education and average distance to the nearest market in the district of birth in 1995. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 1.8 presents a summary of the reduced-form and two stage results by listing the impact of education on household profit from own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment, respectively. The full set of parameter estimates are presented in Table 1.A.3 and Table 1.A.4 in the Appendix. The results show that the two-stage estimates have higher values than the reduced-form estimates in all estimations.

The estimates of both estimations are common in that nonfarm work has a much higher return to education than does farm work. The two-stage estimates show that an additional year of the household average years of education increases profit from nonfarm self-employment and nonfarm wage-employment by 0.71 and 1.12 USD per week respectively, which are both greater than the return to education in farming activities.

**Table 1.9 The effect of education on household labor supply reduced-form and two-stage estimates**

| Dependent variable | Education not instrumented | | Education instrumented, two stage | |
|---|---|---|---|---|
| | Estimate | Standard error | Estimate | Standard error |
| *Participation, pooled probit* | | | | |
| Own-farming | 0.002 | (0.002) | 0.002 | (0.002) |
| Farm-wage-labor | -0.007*** | (0.002) | -0.006*** | (0.002) |
| Nonfarm self-employment | 0.006*** | (0.002) | 0.006*** | (0.002) |
| Nonfarm wage-employment | 0.011*** | (0.002) | 0.012*** | (0.002) |
| *Hours, lognormal CRE* | | | | |
| Own-farming | 0.005 | (0.005) | 0.014** | (0.006) |
| with selection bias controlled | 0.004 | (0.005) | 0.009 | (0.006) |
| Farm-wage-labor | 0.011 | (0.016) | 0.021 | (0.020) |
| with selection bias controlled | -0.001 | (0.017) | 0.018 | (0.020) |
| Nonfarm self-employment | 0.044*** | (0.011) | 0.056*** | (0.013) |
| with selection bias controlled | 0.041*** | (0.011) | 0.054*** | (0.013) |
| Nonfarm wage-employment | 0.073*** | (0.011) | 0.092*** | (0.014) |
| with selection bias controlled | 0.060*** | (0.012) | 0.087*** | (0.014) |

*Notes:* The full set of parameter estimates are presented in Table 1.A.5, Table 1.A.6, and Table 1.A.7. The result of pooled probit shows the average partial effect of schooling on the probability of participating in each activity. The instrumental variable estimations used an instrumental variable; person-year exposure to free primary education. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 1.9 presents the impact of education on household labor participation and hours worked by the reduced-form and two stage estimations in own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment respectively. The full set of parameter estimates are presented in Table 1.A.5, 1.A.6, and 1.A.7 in the Appendix. Both reduced-form and two-stage results show that higher levels of schooling are associated with a higher level of household labor participation and hours of labor supplied in nonfarm activities. Two-stage estimates show that an additional year of household average years of education statistically significantly increases the probability of participating in nonfarm self-employment and nonfarm wage-employment by 0.6 percent and 1.2 percent respectively at the one percent confidence level. The estimates evaluated at mean household hours worked also show that an additional year of household average years of education statistically significantly increases the hours worked in nonfarm self-employment and nonfarm wage-employment by 2.23 and 3.74 (hour/week) respectively at the one percent confidence level. The results of reduced form and two-stage estimates are similar in that increased levels of education increase nonfarm profit by a much greater amount than farm profit, and that the additional years of household education increase both the probability of participation and hours of work in nonfarm activities relative to farming, corresponding to the results from Jolliffe (2004). However, from the reduced-form or two stage results, it is not clear whether the large increases in nonfarm profit are due to more labor supply to those activities, or whether education improves the profitability of these activities.

### 1.5.B Joint Estimates: Education Does Not Significantly Increase Household Hourly Returns in Either Rural Nonfarm Activities or Farming

Table 1.10 presents the full set of parameter estimates of household hourly profit (wage) with and without IMRs and residuals from labor supply estimations. The coefficients of the residual from the $2^{nd}$ stage labor supply estimation are statistically significant in all activities at the one percent confidence level. It suggests that the selection bias of the participants of each activity exists, and it is controlled for by adding the residuals as an additional explanatory variable. The coefficient of IMR is statistically significant at the one percent confidence level in own-farming but not statistically significantly different from zero for all other activities. This is not due to the high correlations between the residual and IMR. The correlations of the residual and IMR are

**Table 1.10 Household hourly profit (wage) joint estimates**

| Dependent variable: Household hourly profit or wage (USD/hour) | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | CRE2SLS | CRE2SLS | CRE2SLS | CRE2SLS | CRE2SLS | CRE2SLS | CRE2SLS | CRE2SLS |
| Inverse mills ratio from 1st stage labor equation | | -0.151*** | | 0.033 | | -0.043 | | -0.085 |
| | | (0.046) | | (0.102) | | (0.055) | | (0.104) |
| Residuals from 2nd stage labor equation | | -0.302*** | | -0.189*** | | -0.287*** | | -0.297*** |
| | | (0.018) | | (0.030) | | (0.032) | | (0.046) |
| *Household education* | | | | | | | | |
| Average education (years) | 0.002 | -0.019 | -0.126 | -0.104 | 0.070 | 0.069 | 0.080 | 0.067 |
| | (0.042) | (0.041) | (0.088) | (0.073) | (0.057) | (0.055) | (0.055) | (0.056) |
| *Household member composition* | | | | | | | | |
| Average age | 0.002 | 0.001 | -0.019** | -0.016** | 0.001 | 0.001 | 0.007 | 0.007 |
| | (0.003) | (0.003) | (0.008) | (0.007) | (0.005) | (0.005) | (0.006) | (0.005) |
| Share of female workers | -0.083 | -0.107 | 0.006 | 0.036 | -0.024 | -0.039 | -0.007 | -0.003 |
| | (0.093) | (0.089) | (0.195) | (0.170) | (0.165) | (0.164) | (0.130) | (0.110) |
| Share of married workers | -0.021 | -0.026 | 0.252** | 0.260** | 0.009 | -0.004 | 0.196 | 0.204* |
| | (0.069) | (0.066) | (0.127) | (0.118) | (0.141) | (0.140) | (0.120) | (0.105) |
| Number of children aged 0-6 | 0.009 | 0.006 | -0.013 | -0.013 | 0.006 | 0.007 | 0.026 | 0.024 |
| | (0.010) | (0.009) | (0.024) | (0.022) | (0.023) | (0.021) | (0.023) | (0.021) |
| Number of children aged 7-12 | -0.013 | -0.015 | 0.052** | 0.052** | 0.045** | 0.047** | 0.026 | 0.029 |
| | (0.010) | (0.010) | (0.026) | (0.026) | (0.023) | (0.021) | (0.025) | (0.021) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | 0.003** | 0.003** | -0.004 | -0.003 | 0.003 | 0.003 | 0.004 | 0.004 |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.002) | (0.002) | (0.003) | (0.003) |
| Experience in own-farming (years) | -0.005* | -0.011*** | 0.010 | 0.009 | 0.015** | 0.014** | 0.002 | 0.003 |
| | (0.003) | (0.003) | (0.007) | (0.007) | (0.006) | (0.006) | (0.007) | (0.006) |
| Square of experience in own-farming (years) | 0.000 | 0.000** | -0.000 | -0.000 | -0.000 | -0.000 | 0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | -0.001 | -0.003 | -0.018* | -0.013 | -0.012 | -0.011 | -0.006 | -0.010 |
| | (0.006) | (0.006) | (0.011) | (0.018) | (0.016) | (0.016) | (0.027) | (0.027) |
| Square of experience in farm-wage-labor (years) | 0.000 | 0.000 | 0.000* | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) | (0.002) |
| Value of farm asset (100 USD) | 0.055*** | 0.057*** | -0.007 | -0.006 | 0.013 | 0.014 | 0.013 | 0.013 |
| | (0.016) | (0.017) | (0.019) | (0.019) | (0.022) | (0.023) | (0.023) | (0.019) |

Table 1.10 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | -0.002 | -0.002 | 0.001 | 0.001 | -0.002 | -0.003 | 0.008 | 0.008 |
| | (0.002) | (0.002) | (0.004) | (0.004) | (0.004) | (0.004) | (0.006) | (0.005) |
| Land rental rate (USD/acre/year) | 0.002 | 0.003 | 0.015 | 0.013 | 0.005 | 0.006 | -0.000 | -0.007 |
| | (0.007) | (0.007) | (0.012) | (0.011) | (0.012) | (0.011) | (0.014) | (0.013) |
| Regional average farming net return | 0.509*** | 0.503*** | 0.147 | 0.168 | -0.214 | -0.188 | -0.373 | -0.386 |
| (USD/hour) | (0.091) | (0.086) | (0.247) | (0.226) | (0.190) | (0.183) | (0.292) | (0.264) |
| Regional average farming wage | | | | | | | | |
| (USD/hour) | -0.018 | -0.020 | 0.516** | 0.529*** | -0.112 | -0.102 | 0.131 | 0.143 |
| | (0.070) | (0.065) | (0.207) | (0.194) | (0.160) | (0.154) | (0.230) | (0.207) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | 0.006 | 0.009* | 0.027** | 0.026** | 0.008 | 0.003 | 0.023 | 0.028* |
| (years) | (0.005) | (0.005) | (0.013) | (0.013) | (0.008) | (0.010) | (0.017) | (0.015) |
| Square of experience in nonfarm self- | 0.000 | -0.000 | -0.001 | -0.001 | -0.000 | -0.000 | -0.001 | -0.001 |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) |
| Experience in nonfarm wage- | 0.009 | 0.019 | 0.020 | 0.015 | -0.037* | -0.036 | 0.024* | 0.008 |
| employment (years) | (0.015) | (0.014) | (0.026) | (0.022) | (0.022) | (0.022) | (0.015) | (0.023) |
| Square of experience in nonfarm wage- | 0.000 | -0.000 | -0.001 | -0.001 | 0.001 | 0.001 | -0.001 | -0.000 |
| employment (years) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) | (0.000) | (0.001) |
| Nonlabor income (100 USD/year) | 0.010* | 0.010* | -0.032** | -0.030** | 0.010*** | 0.010*** | 0.008*** | 0.008*** |
| | (0.005) | (0.006) | (0.016) | (0.014) | (0.003) | (0.003) | (0.001) | (0.002) |
| Distance to nearest transport (km) | -0.002 | -0.002 | 0.011 | 0.010 | -0.002 | -0.002 | 0.004 | 0.006 |
| | (0.002) | (0.002) | (0.007) | (0.007) | (0.004) | (0.004) | (0.004) | (0.004) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm net return | -0.036 | -0.030 | -0.032 | -0.039 | 0.566*** | 0.540*** | -0.093 | -0.087 |
| (USD/hour) | (0.040) | (0.036) | (0.084) | (0.078) | (0.105) | (0.101) | (0.129) | (0.118) |
| Regional average nonfarm wage | | | | | | | | |
| (USD/hour) | 0.143 | 0.164* | 0.130 | 0.178 | 0.271 | 0.300 | 0.424 | 0.426* |
| | (0.090) | (0.084) | (0.264) | (0.245) | (0.204) | (0.195) | (0.259) | (0.248) |
| Observations (household-year pairs) | 3,981 | 3,981 | 765 | 765 | 1,546 | 1,546 | 907 | 907 |
| Number of households | 1,802 | 1,802 | 573 | 573 | 954 | 954 | 645 | 645 |
| R-squared | 0.163 | 0.250 | 0.180 | 0.266 | 0.165 | 0.254 | 0.205 | 0.352 |

*Notes:* The value of profit from self-employment activities is censored at zero. Time dummies, district dummies, time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

0.004, 0.047, -0.014, -0.004 in own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment respectively. The coefficients of the value of farm assets in own-farming and nonlabor income in nonfarm self-employment show that those variables satisfy the inclusion restriction to instrument shadow wages. The result shows that the coefficients are all statistically significant at the one percent confidence level, and the value of farm asset and nonlabor income meet the inclusion restrictions. The exclusion restriction of the instrumental variable is tested by regressing the household labor supply on the fitted value of shadow wage, fitted value of education, instrumental variable of shadow wage, and all other exogenous variables. Table 1.11 shows the estimation result. The coefficient of the value of farm asset is not statistically significant in both the 1st stage and the 2nd stage labor supply estimations of own-farming. Also, the coefficient of nonlabor income is not statistically significant in both the 1st and 2nd stage of labor supply estimations of nonfarm self-employment. The results verify that the value of farm assets and nonlabor income explains labor supply only through shadow wages. Test results show the robustness to use value of farm assets and nonlabor income as instrumental variable of shadow wage of own-farming and nonfarm self-employment respectively.

Table 1.13 shows the estimation results of the effect of education on household hourly profit (wage) and labor supply. The table is made based on the result of estimations in Table 1.10 and Table 1.12. The hourly profit (wage) functions were estimated by CRE 2SLS using two instrumental variables: person-year exposure to free primary education and average distance to the nearest market in the district of birth in 1995. The fitted value of education in both 1st stage and 2nd stage labor supply are estimated by CRE using one instrumental variable: person-year exposure to free primary education. Although the average estimates show the negative effects of

**Table 1.11 Test of instrumental variables in household self-employment labor supply**

| Dependent variable: Supply labor = 1 or Hours of labor supply (hours/week) | Own-farming | Nonfarm self-employment | Own-farming | Own-farming | Nonfarm self-employment | Nonfarm self-employment |
|---|---|---|---|---|---|---|
| Explanatory variables | Pooled probit | Pooled probit | Pooled lognormal | CRE lognormal | Pooled lognormal | CRE lognormal |
| Fitted value of log of hourly profit (USD/hour) | -0.039 | 0.090 | 1.377** | 1.238* | 0.299 | 0.177 |
| | (0.203) | (0.080) | (0.674) | (0.677) | (0.344) | (0.340) |
| *Household education* | | | | | | |
| Fitted value of education (years) | 0.001 | -0.001 | 0.043*** | 0.041*** | 0.033 | 0.043 |
| | (0.005) | (0.007) | (0.016) | (0.016) | (0.028) | (0.028) |
| *Household member composition* | | | | | | |
| Average age | -0.001 | -0.002* | -0.006*** | -0.006*** | 0.001 | -0.003 |
| | (0.001) | (0.001) | (0.002) | (0.002) | (0.004) | (0.004) |
| Share of female workers | 0.000 | 0.031 | -0.221** | -0.192* | 0.019 | 0.073 |
| | (0.031) | (0.028) | (0.109) | (0.109) | (0.136) | (0.137) |
| Share of married workers | 0.063*** | 0.086*** | 0.261*** | 0.265*** | 0.355** | 0.299** |
| | (0.023) | (0.028) | (0.081) | (0.082) | (0.150) | (0.148) |
| Number of children aged 0-6 | 0.008** | 0.006 | 0.041*** | 0.040*** | 0.030 | 0.029 |
| | (0.004) | (0.005) | (0.012) | (0.013) | (0.025) | (0.025) |
| Number of children aged 7-12 | 0.005 | 0.007 | 0.066*** | 0.063*** | 0.001 | -0.008 |
| | (0.005) | (0.006) | (0.015) | (0.016) | (0.029) | (0.029) |
| *Farming variables* | | | | | | |
| Land holdings (acres) | 0.001 | -0.001 | -0.007*** | -0.006*** | -0.006* | -0.004 |
| | (0.001) | (0.001) | (0.002) | (0.002) | (0.003) | (0.003) |
| Experience in own-farming (years) | 0.019*** | -0.007*** | 0.060*** | 0.055*** | -0.054*** | -0.048*** |
| | (0.002) | (0.002) | (0.008) | (0.008) | (0.008) | (0.008) |
| Square of experience in own-farming (years) | -0.000*** | 0.000** | -0.001*** | -0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | 0.000 | -0.012*** | -0.010 | -0.009 | -0.012 | -0.012 |
| | (0.002) | (0.002) | (0.007) | (0.006) | (0.021) | (0.021) |
| Square of experience in farm-wage-labor (years) | -0.000 | 0.000*** | -0.000 | -0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) |
| Value of farm asset (100 USD) | 0.005 | 0.006 | -0.038 | -0.026 | 0.043* | 0.041 |
| | (0.012) | (0.004) | (0.041) | (0.041) | (0.026) | (0.030) |
| *Farming prices* | | | | | | |
| Consumer Price Index of farm products | -0.001 | -0.002 | 0.011*** | 0.010*** | 0.000 | -0.000 |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.005) | (0.005) |

Table 1.11 (cont'd)

| | | | | | | |
|---|---|---|---|---|---|---|
| Land rental rate (USD/acre/year) | 0.003 | -0.002 | -0.007 | -0.006 | -0.007 | -0.010 |
| | (0.003) | (0.003) | (0.008) | (0.008) | (0.017) | (0.017) |
| Regional average farming net return (USD/hour) | 0.023 | 0.007 | -1.003*** | -0.915*** | 0.089 | 0.043 |
| | (0.107) | (0.046) | (0.350) | (0.352) | (0.211) | (0.208) |
| Regional average farming wage (USD/hour) | -0.039 | -0.071* | 0.161* | 0.140* | 0.107 | 0.104 |
| | (0.030) | (0.038) | (0.083) | (0.083) | (0.190) | (0.191) |
| *Nonfarm variables* | | | | | | |
| Experience in nonfarm self-employment (years) | -0.006*** | 0.075*** | -0.030*** | -0.028*** | 0.036*** | 0.036*** |
| | (0.002) | (0.003) | (0.008) | (0.008) | (0.010) | (0.010) |
| Square of experience in nonfarm self-employment | 0.000** | -0.002*** | 0.000 | 0.000 | -0.001** | -0.001** |
| (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in nonfarm wage-employment (years) | -0.007 | -0.007 | -0.080*** | -0.073*** | -0.053** | -0.056** |
| | (0.005) | (0.004) | (0.016) | (0.016) | (0.027) | (0.028) |
| Square of experience in nonfarm wage-employment | 0.000 | 0.000 | 0.001*** | 0.001** | 0.001 | 0.001 |
| (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.002) |
| Nonlabor income (100 USD/year) | -0.000 | -0.002 | -0.014 | -0.012 | 0.003 | 0.004 |
| | (0.002) | (0.002) | (0.008) | (0.009) | (0.006) | (0.006) |
| Distance to nearest transport (km) | -0.001 | -0.001 | 0.003 | 0.002 | -0.004 | -0.005 |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.005) | (0.005) |
| *Nonfarm prices* | | | | | | |
| Regional average nonfarm net return (USD/hour) | -0.018 | -0.017 | -0.030 | -0.025 | -0.327 | -0.271 |
| | (0.017) | (0.048) | (0.050) | (0.050) | (0.212) | (0.213) |
| Regional average nonfarm wage (USD/hour) | -0.054 | -0.004 | -0.312** | -0.279* | -0.212 | -0.195 |
| | (0.054) | (0.053) | (0.156) | (0.156) | (0.248) | (0.250) |
| Observations (household-year pairs) | 4,677 | 4,742 | 4,065 | 4,065 | 1,582 | 1,582 |
| Number of households | 1,981 | 2,006 | 1,852 | 1,852 | 962 | 962 |
| Pseudo R-squared | 0.350 | 0.413 | - | 0.210 | - | 0.286 |
| Log pseudolikelihood | -1270 | -1773 | -4591 | - | -2151 | - |

*Notes:* The estimate of pooled probit shows the average partial effect of education on the probability of participating in each activity. Time dummies, district dummies, and time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

## Table 1.12 Household participation and hours of labor supply joint estimates

| Dependent variable: Supply hours of labor = 1 or log of hours | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | Pooled probit | Pooled probit | Pooled probit | Pooled probit | CRE lognormal | CRE lognormal | CRE lognormal | CRE lognormal |
| Fitted value of log of hourly return | 0.034 | 0.142*** | 0.116* | 0.184*** | 0.830*** | 0.336 | 0.273 | 0.622* |
| (USD/hour) | (0.091) | (0.044) | (0.067) | (0.066) | (0.253) | (0.364) | (0.241) | (0.335) |
| *Household schooling* | | | | | | | | |
| Fitted value of schooling (years) | 0.003 | 0.010* | -0.002 | -0.002 | 0.032*** | 0.060 | 0.036 | 0.046 |
| | (0.003) | (0.005) | (0.006) | (0.005) | (0.008) | (0.048) | (0.023) | (0.029) |
| *Household composition* | | | | | | | | |
| Average age | -0.001* | 0.002* | -0.002* | -0.001 | -0.006*** | 0.019** | -0.003 | -0.008 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.009) | (0.004) | (0.006) |
| Share of female workers | 0.008 | -0.069*** | 0.032 | -0.049** | -0.235*** | -0.653*** | 0.078 | 0.169 |
| | (0.024) | (0.023) | (0.029) | (0.023) | (0.086) | (0.175) | (0.137) | (0.180) |
| Share of married workers | 0.065*** | -0.079*** | 0.082*** | -0.060** | 0.256*** | -0.455** | 0.303** | -0.027 |
| | (0.023) | (0.026) | (0.028) | (0.027) | (0.081) | (0.202) | (0.148) | (0.191) |
| Number of children aged 0-6 | 0.008* | 0.001 | 0.006 | -0.003 | 0.043*** | 0.086** | 0.028 | -0.066* |
| | (0.004) | (0.004) | (0.005) | (0.004) | (0.012) | (0.035) | (0.025) | (0.036) |
| Number of children aged 7-12 | 0.006 | -0.007 | 0.006 | -0.009** | 0.057*** | -0.004 | -0.013 | -0.013 |
| | (0.004) | (0.005) | (0.006) | (0.005) | (0.012) | (0.041) | (0.027) | (0.037) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | 0.001 | 0.001 | -0.001 | -0.001 | -0.005*** | -0.003 | -0.004* | -0.012*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) | (0.002) | (0.004) |
| Experience in own-farming (years) | 0.020*** | -0.003** | -0.007*** | -0.002* | 0.050*** | -0.057*** | -0.050*** | -0.029*** |
| | (0.001) | (0.001) | (0.002) | (0.001) | (0.005) | (0.009) | (0.007) | (0.008) |
| Square of experience in own-farming (years) | -0.000*** | 0.000 | 0.000** | -0.000 | -0.001*** | 0.001*** | 0.001*** | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | 0.000 | 0.049*** | -0.011*** | 0.009*** | -0.011* | 0.058*** | -0.011 | -0.003 |
| | (0.002) | (0.003) | (0.002) | (0.004) | (0.006) | (0.013) | (0.021) | (0.034) |
| Square of experience in farm-wage-labor | -0.000 | -0.001*** | 0.000*** | -0.001*** | -0.000 | -0.001*** | 0.000 | -0.002 |
| (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.003) |
| Value of farm asset (100 USD) | - | 0.007* | 0.006 | -0.005 | - | 0.054* | 0.040 | -0.042 |
| | - | (0.004) | (0.004) | (0.004) | - | (0.030) | (0.030) | (0.037) |

Table 1.12 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | -0.001 | -0.002*** | -0.001 | -0.003*** | 0.009*** | -0.009 | -0.000 | -0.004 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.006) | (0.005) | (0.006) |
| Land rental rate (USD/acre/year) | 0.003 | -0.002 | -0.003 | 0.004 | -0.005 | -0.021 | -0.011 | 0.028 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.007) | (0.021) | (0.017) | (0.018) |
| Regional average farming return | -0.014 | 0.006 | 0.010 | 0.025 | -0.710*** | -0.439 | 0.064 | 0.271 |
| (USD/hour) | (0.059) | (0.030) | (0.045) | (0.042) | (0.152) | (0.361) | (0.204) | (0.307) |
| Regional average farming wage | -0.038 | -0.104** | -0.067* | -0.059* | 0.131 | -0.397 | 0.113 | -0.030 |
| (USD/hour) | (0.030) | (0.041) | (0.038) | (0.033) | (0.081) | (0.356) | (0.189) | (0.241) |
| *Off-farm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.007*** | -0.012*** | 0.075*** | -0.012*** | -0.024*** | -0.010 | 0.036*** | -0.019 |
| (years) | (0.002) | (0.003) | (0.003) | (0.003) | (0.006) | (0.019) | (0.010) | (0.022) |
| Square of experience in nonfarm self- | 0.000** | 0.000** | -0.002*** | 0.000*** | 0.000 | -0.000 | -0.001** | 0.000 |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.000) | (0.001) |
| Experience in nonfarm wage-employment | -0.009*** | -0.008** | -0.006 | 0.075*** | -0.065*** | -0.043 | -0.053** | 0.056*** |
| (years) | (0.003) | (0.003) | (0.004) | (0.003) | (0.010) | (0.028) | (0.026) | (0.015) |
| Square of experience in nonfarm wage- | 0.000 | 0.000 | -0.000 | -0.002*** | 0.001** | 0.002** | 0.001 | -0.002*** |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.002) | (0.001) |
| Nonlabor income (100 USD/year) | -0.001 | 0.006*** | - | -0.002** | -0.008 | 0.066*** | - | -0.007* |
| | (0.001) | (0.002) | - | (0.001) | (0.006) | (0.020) | - | (0.004) |
| Distance to nearest transport (km) | -0.000 | -0.002*** | -0.001 | -0.001 | 0.002 | 0.001 | -0.005 | -0.003 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.012) | (0.004) | (0.007) |
| *Off-farm prices* | | | | | | | | |
| Regional average nonfarm return | -0.016 | 0.011 | -0.032 | -0.024 | -0.037 | -0.056 | -0.322* | 0.163 |
| (USD/hour) | (0.016) | (0.017) | (0.041) | (0.019) | (0.045) | (0.137) | (0.167) | (0.137) |
| Regional average nonfarm wage | -0.066 | 0.031 | -0.012 | -0.117** | -0.212* | -0.550 | -0.226 | -0.499 |
| (USD/hour) | (0.043) | (0.043) | (0.051) | (0.052) | (0.118) | (0.377) | (0.240) | (0.329) |
| Observations (household-year pairs) | 4,677 | 4,699 | 4,742 | 4,725 | 4,065 | 891 | 1,582 | 1,038 |
| Number of households | 1,981 | 1,976 | 2,006 | 1,999 | 1,852 | 649 | 962 | 703 |
| Log pseudolikelihood | -1270 | -1349 | -1776 | -1409 | - | - | - | - |
| (Pseudo) R-squared | 0.350 | 0.409 | 0.412 | 0.433 | 0.210 | 0.410 | 0.286 | 0.336 |

*Notes:* The estimate of pooled probit shows the average partial effect of education on the probability of participating in each activity. Time dummies, district dummies, and time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

**Table 1.13 The effect of education on household hourly returns and labor supply joint estimates**

| Dependent variable | Average years of education | | Hourly profit or wage | |
|---|---|---|---|---|
| | Estimate | Standard error | Estimate | Standard error |
| *Hourly profit or wage, CRE 2SLS* | ($\mu$) | | | |
| Own-farming | -0.019 | (0.041) | - | - |
| Farm-wage-labor | -0.104 | (0.073) | - | - |
| Nonfarm self-employment | 0.069 | (0.055) | - | - |
| Nonfarm wage-employment | 0.067 | (0.056) | - | - |
| *Participation, pooled probit* | ($\rho$) | | ($\eta$) | |
| Own-farming | 0.003 | (0.003) | 0.034 | (0.091) |
| Farm-wage-labor | 0.010* | (0.005) | 0.142*** | (0.044) |
| Nonfarm self-employment | -0.002 | (0.006) | 0.116* | (0.067) |
| Nonfarm wage-employment | -0.002 | (0.005) | 0.184*** | (0.066) |
| *Hours, CRE lognormal* | ($\rho$) | | ($\eta$) | |
| Own-farming | 0.032*** | (0.008) | 0.830*** | (0.253) |
| Farm-wage-labor | 0.060 | (0.048) | 0.336 | (0.364) |
| Nonfarm self-employment | 0.036 | (0.023) | 0.273 | (0.241) |
| Nonfarm wage-employment | 0.046 | (0.029) | 0.622* | (0.335) |

*Notes:* The full set of parameter estimates are presented in Table 1.10 and Table 1.12. The pooled probit shows the average partial effect of education on the probability of participating in each activity. The 2SLS estimations used two instrumental variables: person-year exposure to free primary education and average distance to the nearest market in district of birth in 1995. Fitted value of education in labor supply equations used one instrumental variable: person-year exposure to free primary education. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

education in farming and positive effects of education in nonfarm activities, the estimates are not statistically significantly different from zero at the ten percent confidence level in any activity.

In Table 1.14, the effect of an additional year of education on household labor supply is calculated from the results in Table 1.13. By estimating the structural model of labor supply that includes profitability, it is possible to obtain a measure of the direct effect that education has on labor supply and the indirect effect that education has on labor supply through the education-induced profitability effect. By the equations (1.12) and (1.14), the effect of education on household labor supply is divided into the direct effect of education and the indirect effect of education through the shadow wage. The effect of education on household hours of labor supply is written as:

$$\frac{\partial h}{\partial E} = \rho\bar{h} + \frac{\partial h}{\partial(logw)}\frac{\partial(logw)}{\partial E} = \rho\bar{h} + \eta\mu\bar{h} \tag{1.16}$$

where $\bar{h}$ is mean household hours worked. The mean household hours worked show 37.7, 19.1, 41.3, and 43.0 (hours/week) in own-farming, farm-wage-labor, nonfarm self-employment, and nonfarm wage-employment respectively.

**Table 1.14 An additional year of education's effect on household labor supply**

| | Effect of average years of education | | |
|---|---|---|---|
| | Direct effect | Indirect effect | Total effect |
| *Participation probability* | $(\rho)$ | $(\eta\mu)$ | $(\rho + \eta\mu)$ |
| Own-farming | 0.003 | -0.000 | 0.003 |
| Farm-wage-labor | 0.010 | -0.015 | -0.005 |
| Nonfarm self-employment | -0.002 | 0.008 | 0.006 |
| Nonfarm wage-employment | -0.002 | 0.012 | 0.010 |
| *Hours per week* | $(\rho\bar{h})$ | $(\eta\mu\bar{h})$ | $(\rho\bar{h} + \eta\mu\bar{h})$ |
| Own-farming | 1.206 | -0.594 | 0.612 |
| Farm-wage-labor | 1.149 | -0.669 | 0.480 |
| Nonfarm self-employment | 1.486 | 0.778 | 2.264 |
| Nonfarm wage-employment | 1.979 | 1.793 | 3.772 |

*Notes:* Results in this table are calculated from the results in Table 1.13, using equation (1.16) evaluated at mean household hours worked of estimation samples.

Overall, education has a greater effect and a positive effect on participation and hours worked in nonfarm activities than in farming, which corresponds to the results by reduced form and two-stage estimates. The estimated positive effect of education on participation in nonfarm activities is on average mostly from the indirect effect of education through the education-induced profitability effect. For the hours of household labor supply, education has a positive total effect on all activities, with a much larger effect on nonfarm activities. The direct effect of education on hours of labor supply is also larger than the indirect effect of education via profitability changes. The estimated total effects of education are larger than reduced form or two stage estimates. However, because the effect of education on the profitability of the activity is not statistically significant in any activity, the hypothesis that the level of education, profitability of an activity, and time allocation to that activity can be not positively correlated, and that it positively increases total household profit from the activity, cannot be rejected by the estimations. There is a case that the labor shift is induced only by the direct effect of education on the labor allocation with no indirect profitability effect.

### 1.5.C Intra-Household Decision on Labor Allocation; Negative Correlation between Hourly Return and Labor Supply in Nonfarm Activities

Throughout this chapter, the estimation results have been presented at the household and not the individual level. As illustrated in section 1.2.B and 1.2.C, however, the education qualification plays a role in determining labor allocation, and there we found negative correlations between hourly profit (wage) and labor supply at an individual level. Hence, I redo the estimations at individual level to explore whether there is any evidence to support the hypothesis that, within households, the years of education or education qualification, profitability of each activity, and labor allocation are not positively correlated.

First, I test the validity of instrumental variables of education at individual level. I use years of education, a binary variable of completing primary school, and a binary variable of completing secondary school as the measures of education. The instrumental variable is the same as in the estimations at household level, household person-years exposure to free primary school education, because the individual education attainment is determined to maximize the returns given the household budget constraint, which is a function of household members composition.

Table 1.15 presents the result of reduced form education estimations. Estimation results show that the coefficients of person-years exposure to free primary school education are statistically significant at the one percent confidence level in all estimations. Although the coefficient of distance to the nearest market in the district of birth in 1995 is not statistically

**Table 1.15 Individual schooling reduced form estimates (correlated random effects)**

| | Years of education | | Completed primary=1 | | Completed secondary=1 | |
|---|---|---|---|---|---|---|
| *Instrumental variables* | | | | | | |
| Person-year under free primary school | 0.026*** | (0.008) | 0.003*** | (0.001) | 0.003*** | (0.001) |
| Distance to nearest market in district of birth in 1995 (km) | -0.018* | (0.011) | -0.004** | (0.002) | -0.001 | (0.001) |
| $\chi^2$-statistic[a] (H$_0$: IVs violate inclusion restriction) | 13.47*** | | 12.43*** | | 17.61*** | |
| Number of observations | 8,599 | | 8,600 | | 8,600 | |
| Number of individuals | 4,433 | | 4,433 | | 4,433 | |
| R-squared | 0.299 | | 0.187 | | 0.143 | |

*Notes:* In all estimations, all other exogenous variables in the hourly profit equation are included as explanatory variables but not reported in the table. All estimations used the correlated random effects model. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a] $\chi^2$-statistics show the joint significance of all IVs in the reduced form education equation.

significant in the regression of completing secondary school dummies, the $\chi^2$-statistic shows that the combination of two instrumental variables are jointly significant at the one percent confidence level in all estimations.

Table 1.16 shows the result of endogeneity and overidentifying restriction tests in individual hourly profit (wage) and labor supply estimations. The result shows that the null hypothesis that education is exogenous is rejected in at least one estimation for both years of education and binary variables of completing primary school and completing secondary school. The results of overidentification tests do not reject the null hypothesis of joint validity of instrumental variables in more than half of the estimations of individual hourly profit (wage), labor participation, and hours of labor allocation. Hence, I use two instrumental variables, household person-years exposure to free primary education and distance to the nearest market in the district of birth in 1995, to instrument both the individual years of education and education qualification dummies.

**Table 1.16 Validity tests of instrumental variables in individual hourly profit (wage) and labor supply equations**

| | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment |
|---|---|---|---|---|
| *Endogeneity test*[a] | | | | |
| ($H_0$: education is exogenous) | | | | |
| Years of education | | | | |
| Individual hourly profit (wage) | -0.031***(0.010) | 0.002(0.032) | 0.004(0.024) | -0.074***(0.022) |
| Individual labor 1st stage | 0.11 | 0.62 | 0.56 | 0.04 |
| Individual labor 2nd stage | -0.007(0.013) | -0.017(0.045) | -0.019(0.029) | -0.007(0.028) |
| Education qualification | | | | |
| Completed primary = 1 | | | | |
| Individual hourly profit (wage) | -0.161***(0.056) | -0.068(0.173) | -0.134(0.125) | -0.205(0.192) |
| Individual labor 1st stage | 5.09* | 0.71 | 1.03 | 0.29 |
| Individual labor 2nd stage | -0.012(0.071) | -0.042(0.291) | 0.069(0.169) | -0.251(0.232) |
| Completed secondary = 1 | | | | |
| Individual hourly profit (wage) | -0.151(0.166) | 1.191**(0.564) | -0.281(0.315) | -0.697***(0.223) |
| Individual labor 1st stage | 5.09* | 0.71 | 1.03 | 0.29 |
| Individual labor 2nd stage | -0.083(0.190) | 0.274(0.765) | -0.513(0.327) | 0.087(0.205) |
| *Overidentifying restriction test*[b] | | | | |
| ($H_0$: IVs are jointly valid) | | | | |
| Years of education | | | | |
| Individual hourly profit (wage) | 0.59 | 0.01 | 1.53 | 2.28 |
| Individual labor 1st stage | 4.98** | 0.00 | 0.73 | 0.19 |
| Individual labor 2nd stage | 0.26 | 0.11 | 15.65*** | 1.01 |

*Notes:* The result of individual hourly profit (wage) and labor 2nd stage equations show correlated random effects estimates. Individual labor 1st stage estimation used pooled probit model with time means of all time-variant explanatory variables. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a] Individual hourly profit (wage) and labor 2nd stage show the significance of coefficient of the residual from reduced form education equation. Individual labor 1st stage shows chi-square statistics of Wald test of exogeneity.

[b] Individual wage and labor 2nd stage show Sargan-Hansen statistics from correlated random effects two stage least square estimations. Individual labor 1st stage shows Amemiya-Lee-Newey minimum chi-square statistics from probit two stage instrumental variable estimations.

Table 1.17 and Table 1.18 summarize the results of the joint estimates of individual hourly profit (wage), labor participation, and hours of labor supply. The full set of the estimates are reported in Table 1.A.9, Table 1.A.10, and Table 1.A.11 in the Appendix. The result is supportive of the hypothesis that there are no positive correlations which are statistically significant between education and hourly profit (wage) or hourly profit (wage) and labor supply in any activity.

## Table 1.17 The effect of years of education on individual hourly profit and labor supply joint estimates

| Dependent variable | Average years of education | | Hourly profit or wage | |
|---|---|---|---|---|
| | Estimate | Standard error | Estimate | Standard error |
| *Hourly profit or wage, CRE 2SLS* | ($\mu$) | | | |
| Own-farming | 0.012 | (0.057) | - | - |
| Farm-wage-labor | -0.004 | (0.167) | - | - |
| Nonfarm self-employment | 0.052 | (0.050) | - | - |
| Nonfarm wage-employment | -0.018 | (0.042) | - | - |
| *Participation, pooled probit* | ($\rho$) | | ($\eta$) | |
| Own-farming | -0.001 | (0.001) | -0.072*** | (0.025) |
| Farm-wage-labor | -0.006* | (0.003) | 0.127 | (0.716) |
| Nonfarm self-employment | 0.007*** | (0.002) | -0.048** | (0.023) |
| Nonfarm wage-employment | -0.001 | (0.003) | -0.336** | (0.167) |
| *Hours, lognormal CRE* | ($\rho$) | | ($\eta$) | |
| Own-farming | -0.007** | (0.004) | 0.037 | (0.069) |
| Farm-wage-labor | 0.014 | (0.045) | 9.753 | (10.054) |
| Nonfarm self-employment | 0.015 | (0.010) | -0.075 | (0.080) |
| Nonfarm wage-employment | 0.007 | (0.028) | -2.465* | (1.368) |

*Notes:* The full set of parameter estimates are presented in Table 1.A.9, Table 1.A.10, and Table 1.A.11. The pooled probit shows the average partial effect of schooling on the probability of participating in each activity. The 2SLS estimations used two instrumental variables: household person-year exposure to free primary education and distance to the nearest market in district of birth in 1995. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

## Table 1.18 The effect of education qualification on individual hourly profit and labor supply joint estimates

| | Education qualification | | |
|---|---|---|---|
| | Completed primary=1 | Completed secondary=1 | Hourly profit (wage) |
| *Hourly profit or wage, CRE 2SLS* | ($\mu$) | ($\mu$) | |
| Own-farming | -0.018(0.452) | 0.027(1.260) | - |
| Farm-wage-labor | 0.222(5.593) | -0.029(3.479) | - |
| Nonfarm self-employment | -0.367(1.178) | 2.061(2.209) | - |
| Nonfarm wage-employment | -0.233(0.555) | 0.002(0.398) | - |
| *Labor participation, pooled probit* | ($\rho$) | ($\rho$) | ($\eta$) |
| Own-farming | -0.008(0.009) | -0.030(0.020) | -0.057***(0.022) |
| Farm-wage-labor | -0.023(0.019) | -0.066***(0.022) | -0.062(0.068) |
| Nonfarm self-employment | 0.005(0.010) | 0.115***(0.045) | -0.038**(0.015) |
| Nonfarm wage-employment | 0.025(0.019) | 0.034**(0.017) | -0.022(0.067) |
| *Labor hours, lognormal CRE* | ($\rho$) | ($\rho$) | ($\eta$) |
| Own-farming | -0.025(0.027) | -0.163*(0.085) | 0.041(0.062) |
| Farm-wage-labor | 0.003(0.286) | 0.542(0.602) | -0.722(1.133) |
| Nonfarm self-employment | -0.032(0.071) | 0.391(0.249) | -0.153**(0.077) |
| Nonfarm wage-employment | 0.199(0.231) | 0.317***(0.110) | -0.829(0.799) |

*Notes:* The full set of parameter estimates are presented in Table 1.A.9, Table 1.A.10, and Table 1.A.11. The pooled probit shows the average partial effect of schooling on the probability of participating in each activity. The 2SLS estimations used two instrumental variables: household person-year exposure to free primary education and distance to the nearest market in district of birth in 1995. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Similar to the result from the household hourly profit (wage) estimations, all 12 estimates of the effect of years of education and the effect of education qualification on profitability are not statistically significantly different from zero. It suggests that there is still a very limited demand for highly educated labor in both farming and nonfarm activities due to the limited expansion of the industry in which higher levels of education increases profitability of work in rural Uganda. Because not only completing primary school but also completing secondary school do not show statistically significant effect on the profitability of any activity, it is unlikely that the deterioration of quality of education under free primary education policy due to the rapid expansion of the capacity of primary schools explains the reason of no statistically significant effect of education on the profitability.

The negative correlation between hourly profit (wage) and labor supply corresponds to the Figure 1.2 and Figure 1.3, which both illustrate the negative correlation of those variables at individual level. There are two possible explanations of the reason why profitability is not positively affecting hours. The first view is that it is because of the allocative inefficiency of labor in rural areas. Due to geographical and social disjuncture of the labor market, individuals face the constraints of job opportunities and taking job offers. It results in a gap between the predicted hourly return based on individual, household, and local characteristics and the actual hourly return expected by the individual. It could be that a person has a high predicted hourly return but is not working in the sector because of constraints.

However, the individual-level result is not consistent with the result from household estimations. There is no statistically significant evidence that profitability and labor supply are negatively correlated at the household level. It implies that those who are from relatively more educated households face less constraint in the labor market, which itself presents the potential endogeneity of household and individual education attainment. From the second point of view, if a person faces severe work opportunity constraints and is earning minimum income, the person has minimal preference for leisure instead of income. Hence, the lower the profitability is, the more of his or her time the person is likely to allocate to the work he or she has to meet the minimum income. Given the negative correlation between hourly profit (wage) and labor supply, the direct effect of education on labor supply entails the preference of the individual for working in the corresponding sector.

The estimates show the strong preference in working off-farm for those who completed secondary school. The probability of participating in nonfarm self-employment and nonfarm wage-employment for those who completed secondary school is 11.5 and 3.4 percent higher than those who have competed neither primary school nor secondary school, and 11.0 and 0.9 percent higher than those who have completed only primary school. They also provide 11.3 and 4.2 (hour/week) more hours to nonfarm wage-employment compared to those who have not completed primary education and those who completed only primary but have not completed secondary school respectively.

Table 1.19 presents the direct effect of an additional year of education and completing primary school or secondary school on household labor supply and the indirect effect through education-induced profitability effect, which are calculated from the results in Table 1.17 and Table 1.18. The total effect of education on labor participation and hours of labor supply is negative in farming and positive in nonfarm activities in all estimations except the effect of completing secondary school on the hours of labor allocation to farm-wage-labor. It is consistent with earlier studies in SSA finding that education has positive effects on nonfarm earnings and time allocation of rural farm households to nonfarm activities. The positive effect of completing

**Table 1.19 An additional year of schooling's effect on individual labor supply**

| | Effect of education, individual | | |
|---|---|---|---|
| | Direct effect | Indirect effect | Total effect |
| *Participation probability* | | | |
| *Years of schooling* | $(\rho)$ | $(\eta\mu)$ | $(\rho + \eta\mu)$ |
| Own-farming | -0.001 | -0.001 | -0.002 |
| Farm-wage-labor | -0.006 | -0.001 | -0.007 |
| Nonfarm self-employment | 0.007 | -0.002 | 0.005 |
| Nonfarm wage-employment | -0.001 | 0.006 | 0.005 |
| *Completed primary=1* | $(\rho)$ | $(\eta\mu)$ | $(\rho + \eta\mu)$ |
| Own-farming | -0.008 | 0.001 | -0.007 |
| Farm-wage-labor | -0.023 | -0.014 | -0.037 |
| Nonfarm self-employment | 0.005 | 0.014 | 0.019 |
| Nonfarm wage-employment | 0.025 | 0.005 | 0.030 |
| *Completed secondary=1* | $(\rho)$ | $(\eta\mu)$ | $(\rho + \eta\mu)$ |
| Own-farming | -0.030 | -0.002 | -0.032 |
| Farm-wage-labor | -0.066 | 0.002 | -0.064 |
| Nonfarm self-employment | 0.115 | -0.078 | 0.037 |
| Nonfarm wage-employment | 0.034 | -0.000 | 0.034 |
| *Hours per week* | | | |
| *Years of schooling* | $(\rho\bar{h})$ | $(\eta\mu\bar{h})$ | $(\rho\bar{h} + \eta\mu\bar{h})$ |
| Own-farming | -0.150 | 0.010 | -0.140 |
| Farm-wage-labor | 0.203 | -0.565 | -0.362 |
| Nonfarm self-employment | 0.485 | -0.126 | 0.359 |
| Nonfarm wage-employment | 0.249 | 1.580 | 1.829 |
| *Completed primary=1* | $(\rho\bar{h})$ | $(\eta\mu\bar{h})$ | $(\rho\bar{h} + \eta\mu\bar{h})$ |
| Own-farming | -0.537 | -0.016 | -0.553 |
| Farm-wage-labor | 0.043 | -2.319 | -2.276 |
| Nonfarm self-employment | -1.035 | 1.816 | 0.781 |
| Nonfarm wage-employment | 7.086 | 6.878 | 13.964 |
| *Completed secondary=1* | $(\rho\bar{h})$ | $(\eta\mu\bar{h})$ | $(\rho\bar{h} + \eta\mu\bar{h})$ |
| Own-farming | -3.504 | 0.024 | -3.480 |
| Farm-wage-labor | 7.843 | 0.303 | 8.146 |
| Nonfarm self-employment | 12.644 | -10.197 | 2.447 |
| Nonfarm wage-employment | 11.288 | -0.059 | 11.229 |

*Notes:* Results in this table are calculated from the results in Table 1.17 and Table 1.18, using equation (1.16) evaluated at mean household hours worked.

secondary on labor supply to farm-wage-labor is because they are engaged in wage work in the agriculture sector, but not engaged in subsistence farming.

However, the total effect veils the relations between the direct effect that education has on household profit or labor supply and the indirect effect through the re-allocation of household labor induced by profitability changes. For those who completed secondary school, the total positive effects of education on labor supply in nonfarm activities are mostly derived from the direct effect of education on labor supply. The indirect effect of education through the education-induced profitability effect is positive for workers who completed primary school. However, it is positive because of the negative correlations between profitability and labor supply. Additional education decreases the profitability in nonfarm sectors, and the profitability negatively affects both the participation and hours of labor supply in nonfarm activities.

## 1.6 Conclusion

This chapter explored the non-growing-productivity structural change from a microeconomic perspective. I test the hypothesis that the level of education, profitability of an activity, and time allocation to that activity may not be positively correlated while education positively increases total profit from the activity. Most of the human capital literature estimate the direct and indirect effects of education on profit and labor supply with the assumption that the shadow wage and labor supply are positively correlated, but the labor supply functions have not yet jointly estimated with the endogenously determined shadow wages. In this study, I jointly estimate the hourly profit (wage) and labor supply equations to incorporate the different channels through which education affects total profit: profitability of hours of labor, labor allocation across activities, and labor re-allocation through the education-induced profitability effects.

I combine multiple models to overcome the difficulties of joint estimation. First, a marginal shadow wage of own-farming and nonfarm self-employment is instrumented by the value of farm assets and nonlabor income, respectively. Second, I exploit the variation of household person-year exposure to free primary education policy implemented by the Ugandan government and use it as an instrumental variable of education. Third, the double-censored problem of hourly profit (wage) and labor supply functions is overcome by combining the Double Hurdle and the Type III structural Tobit models. The structural feature of the model allows us to decompose the effect of education on profit into the direct effect of education on profitability, labor allocation across activities, and the indirect effect on re-allocation of labor through the education-induced profitability effect.

The result of all of the reduced form, two stage, joint, and intra-household estimates could not reject the hypothesis that the level of education, profitability of an activity, and time allocation to that activity can be not positively correlated while education positively increases total household profit from the activity. All the estimates have in common that the total effect of education on labor supply shows greater and positive effect on participation and hours worked in nonfarm activities than in farming. This latter is consistent with earlier studies in SSA. The estimations using education qualification variables also reveal that for those who completed secondary school, the total positive effects of education on labor supply in nonfarm activities are mostly derived from the direct effect of education on labor supply. The indirect effect of education through the education-induced profitability effect is positive for workers who completed only primary school. However, the estimate is positive because of the negative correlations between education, profitability, and labor supply.

All of 16 estimates from joint and intra-household estimations of the effect of education on hourly profit (wage) are not statistically significantly different from zero. Education shows no statistically significant effect on the profitability of any activity. The biggest difference between the results from household and individual estimations is the relation between profitability and labor supply. There is no statistically significant evidence that profitability and labor supply are negatively correlated at household level. However, the individual-level estimations show the evidence of negative correlations. This implies that those who are from relatively more educated households face less constraints of labor market, which itself presents the potential endogeneity of household and individual education attainment.

Therefore, the hypothesis that there are not positive correlations which are statistically significant between education and hourly profit (wage) or hourly profit (wage) and labor supply in any activity cannot be rejected. And this possible negative or nonpositive relation could explain the non-growing-productivity labor shift from subsistence to non-subsistence sectors. The expansion of the industry in which higher levels of education increase the profitability of work in rural Uganda would pull labor from farming into nonfarm activities with a positive effect of education on the profitability of labor. Relaxing the labor market constraints of individuals especially from relatively less educated households would push the hours of labor allocation from less profitable activities towards more profitable activities. Also, boosting the bottom line of the household income or standard of living would increase the preference of individuals on leisure to income, and fundamentally increase the optimal marginal productivity of labor, and consequently the profitability of labor.

**APPENDIX**

**Table 1.A.1 Summary statistics of variables (household)**

| Variable | Obs. | Mean | C.v. | Min. | Max. |
|---|---|---|---|---|---|
| *Dependent Variables* | | | | | |
| Hourly profit (USD/hour) | | | | | |
| Own-farming | 4,579 | 2.0 | 10.0 | -261.5 | 952.8 |
| Farm-wage-labor | 874 | 2.2 | 2.5 | 0.0 | 113.6 |
| Nonfarm self-employment | 1,720 | 4.3 | 7.8 | -177.9 | 925.8 |
| Nonfarm wage-employment | 1,019 | 3.8 | 4.4 | 0.0 | 368.1 |
| Supply positive hour of labor = 1 | | | | | |
| Own-farming | 5,628 | 0.83 | 0.5 | 0.0 | 1.0 |
| Farm-wage-labor | 5,628 | 0.18 | 2.1 | 0.0 | 1.0 |
| Nonfarm self-employment | 5,628 | 0.31 | 1.5 | 0.0 | 1.0 |
| Nonfarm wage-employment | 5,628 | 0.21 | 2.0 | 0.0 | 1.0 |
| Labor supply (hour/week) | | | | | |
| Own-farming | 5,628 | 30.8 | 1.0 | 0.0 | 370.7 |
| Farm-wage-labor | 5,628 | 3.4 | 3.7 | 0.0 | 138.4 |
| Nonfarm self-employment | 5,628 | 12.8 | 2.3 | 0.0 | 375.1 |
| Nonfarm wage-employment | 5,628 | 8.8 | 2.9 | 0.0 | 367.7 |
| *Explanatory Variables* | | | | | |
| *Household schooling* | | | | | |
| Average education (years) | 5,616 | 5.1 | 0.6 | 0.0 | 17.0 |
| *Household composition* | | | | | |
| Age | 5,628 | 38.0 | 0.3 | 20.0 | 65.0 |
| Share of female workers | 5,628 | 0.56 | 0.5 | 0.0 | 1.0 |
| Share of married workers | 5,628 | 0.70 | 0.6 | 0.0 | 1.0 |
| Number of children aged 0-6 | 5,628 | 1.5 | 0.9 | 0.0 | 9.0 |
| Number of children aged 7-12 | 5,628 | 1.3 | 0.9 | 0.0 | 8.0 |
| *Farming variables* | | | | | |
| Land holdings (acres) | 5,502 | 4.1 | 2.7 | 0.0 | 340.0 |
| Experience in own-farming (years) | 5,325 | 18.8 | 0.7 | 0.0 | 68.0 |
| Experience in farm-wage-labor (years) | 5,325 | 1.7 | 3.0 | 0.0 | 55.0 |
| Value of farm asset (100 USD) | 5,509 | 0.5 | 2.3 | 0.0 | 19.8 |
| *Farming prices* | | | | | |
| CPI of farming products | 5,628 | 200.1 | 0.2 | 164.5 | 273.4 |
| Land rental rate (USD/acre/year) | 5,628 | 6.5 | 0.4 | 1.8 | 18.9 |
| Average profit in own-farming (ln(USD/hour)) | 5,457 | 0.4 | 0.6 | 0.0 | 2.8 |
| Average wage in farm-wage-labor (ln(USD/hour)) | 5,628 | 0.7 | 0.3 | 0.3 | 1.8 |
| *Off-farm variables* | | | | | |
| Experience in nonfarm self-employment (years) | 5,325 | 2.5 | 2.2 | 0.0 | 46.0 |
| Experience in nonfarm wage-employment (years) | 5,325 | 1.3 | 2.9 | 0.0 | 37.0 |
| Nonlabor income (100 USD/year) | 5,628 | 0.9 | 5.9 | 0.0 | 267.8 |
| Distance to nearest transport (km) | 5,621 | 3.4 | 1.9 | 0.0 | 180.0 |
| *Off-farm prices* | | | | | |
| Average net return in nonfarm self-employment (ln(USD/hour)) | 5,430 | 0.6 | 0.6 | 0.0 | 3.1 |
| Average wage in nonfarm wage-employment (ln(USD/hour)) | 5,628 | 0.8 | 0.2 | 0.2 | 1.3 |
| *Instrumental variables* | | | | | |
| Average distance to nearest market in 1995 in birth district (km) | 5,588 | 6.1 | 0.8 | 1.0 | 24.0 |
| Person-years exposure to free primary education | 5,628 | 1.8 | 1.9 | 0.0 | 40.0 |

*Notes:* Observations pooled across years. USD used in the table is 2011 PPP USD.

## Table 1.A.2 Household hourly returns and profits of non-migrants (correlated random effects)

| Dependent variable: Household hourly profit or wage (USD/hour) or profit (USD/week) | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment | Own-farming | Farm-wage-labor | Nonfarm self-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | Hourly profit | Hourly wage | Hourly profit | Hourly wage | Profit | Profit | Profit | Profit |
| Inverse mills ratio from 1st stage labor | -0.171*** | -0.121 | 0.037 | -0.158 | 0.058 | -0.206 | 0.842 | -0.206 |
| equation | (0.061) | (0.120) | (0.067) | (0.129) | (0.497) | (0.227) | (0.552) | (0.227) |
| Residuals from 2nd stage labor equation | -0.296*** | -0.184*** | -0.305*** | -0.294*** | 0.168*** | 0.275*** | 0.366*** | 0.275*** |
| | (0.023) | (0.033) | (0.039) | (0.035) | (0.055) | (0.054) | (0.128) | (0.054) |
| *Household education* | | | | | | | | |
| Average education (years) | 0.015*** | -0.001 | 0.036*** | 0.047*** | 0.043 | 0.048*** | 0.089* | 0.048*** |
| | (0.006) | (0.012) | (0.012) | (0.010) | (0.030) | (0.018) | (0.049) | (0.018) |
| *Instrumental variables* | | | | | | | | |
| Average distance to nearest market in | 0.029 | 0.001 | 0.006 | -0.040 | 0.016 | -0.004 | -0.192 | -0.004 |
| district of birth in 1995 | (0.020) | (0.044) | (0.037) | (0.044) | (0.110) | (0.128) | (0.178) | (0.128) |
| Person-years exposure to primary | -0.009 | -0.007 | 0.001 | 0.013 | -0.011 | 0.069** | 0.216** | 0.069** |
| education | (0.006) | (0.009) | (0.012) | (0.013) | (0.029) | (0.030) | (0.106) | (0.030) |
| *Household member composition* | | | | | | | | |
| Average age | 0.002 | -0.009** | -0.007 | 0.007 | 0.007 | 0.018** | 0.014 | 0.018** |
| | (0.002) | (0.004) | (0.004) | (0.005) | (0.007) | (0.009) | (0.016) | (0.009) |
| Share of female workers | -0.100 | 0.144 | 0.145 | 0.019 | -0.065 | 0.270 | 1.197** | 0.270 |
| | (0.069) | (0.125) | (0.135) | (0.141) | (0.139) | (0.231) | (0.606) | (0.231) |
| Share of married workers | -0.072 | 0.197 | 0.216 | 0.225* | 0.417* | 0.815* | 1.625** | 0.815* |
| | (0.081) | (0.129) | (0.151) | (0.135) | (0.252) | (0.495) | (0.758) | (0.495) |
| Number of children aged 0-6 | 0.005 | -0.018 | -0.026 | 0.025 | 0.109* | 0.008 | -0.093 | 0.008 |
| | (0.011) | (0.024) | (0.030) | (0.030) | (0.064) | (0.047) | (0.086) | (0.047) |
| Number of children aged 7-12 | -0.015 | 0.035 | 0.087*** | 0.034 | 0.102 | 0.056 | 0.240* | 0.056 |
| | (0.012) | (0.029) | (0.027) | (0.027) | (0.064) | (0.039) | (0.132) | (0.039) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | 0.004** | -0.005 | 0.002 | 0.018** | 0.007 | 0.034 | -0.003 | 0.034 |
| | (0.002) | (0.007) | (0.005) | (0.008) | (0.008) | (0.032) | (0.019) | (0.032) |
| Experience in own-farming (years) | -0.011*** | 0.002 | 0.017** | 0.005 | 0.022 | -0.029 | -0.034 | -0.029 |
| | (0.004) | (0.007) | (0.008) | (0.009) | (0.022) | (0.018) | (0.027) | (0.018) |
| Square of experience in own-farming | 0.000** | -0.000 | -0.000 | -0.000 | -0.001 | 0.000 | 0.000 | 0.000 |
| (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.000) |
| Experience in farm-wage-labor (years) | 0.000 | -0.021 | -0.018 | -0.038 | -0.033** | -0.068* | -0.078 | -0.068* |
| | (0.004) | (0.020) | (0.019) | (0.027) | (0.016) | (0.039) | (0.077) | (0.039) |

Table 1.A.2 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Square of experience in farm-wage-labor | 0.000 | 0.001 | 0.000 | 0.002 | 0.001* | 0.003 | 0.003 | 0.003 |
| (years) | (0.000) | (0.001) | (0.001) | (0.002) | (0.001) | (0.003) | (0.003) | (0.003) |
| Value of farm asset (100 USD) | 0.042** | -0.021 | -0.012 | 0.007 | 0.099* | -0.013 | 0.040 | -0.013 |
| | (0.017) | (0.018) | (0.019) | (0.023) | (0.051) | (0.038) | (0.055) | (0.038) |
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | -0.003 | -0.002 | -0.002 | 0.004 | -0.008 | -0.007 | 0.007 | -0.007 |
| | (0.002) | (0.004) | (0.005) | (0.005) | (0.015) | (0.019) | (0.021) | (0.019) |
| Land rental rate (USD/acre/year) | 0.006 | 0.007 | 0.009 | -0.011 | 0.018 | -0.007 | -0.033 | -0.007 |
| | (0.009) | (0.012) | (0.014) | (0.015) | (0.071) | (0.024) | (0.039) | (0.024) |
| Regional average farming net return | 0.447*** | 0.611* | 0.013 | -0.319 | -0.677 | -0.294 | 0.541 | -0.294 |
| (USD/hour) | (0.103) | (0.333) | (0.242) | (0.328) | (0.668) | (1.292) | (1.305) | (1.292) |
| Regional average farming wage | -0.053 | 0.502*** | -0.171 | 0.163 | -0.056 | 0.040 | 1.388 | 0.040 |
| (USD/hour) | (0.086) | (0.179) | (0.250) | (0.235) | (0.318) | (0.501) | (1.627) | (0.501) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | 0.010* | 0.039*** | 0.011 | 0.010 | -0.007 | 0.003 | 0.185* | 0.003 |
| (years) | (0.006) | (0.014) | (0.013) | (0.028) | (0.028) | (0.038) | (0.109) | (0.038) |
| Square of experience in nonfarm self- | -0.000 | -0.001*** | -0.000 | 0.001 | 0.000 | 0.002 | -0.004 | 0.002 |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.003) | (0.001) | (0.003) | (0.003) | (0.003) |
| Experience in nonfarm wage- | 0.008 | -0.015 | -0.043* | -0.017 | -0.046 | -0.013 | -0.187*** | -0.013 |
| employment (years) | (0.008) | (0.019) | (0.022) | (0.030) | (0.039) | (0.052) | (0.063) | (0.052) |
| Square of experience in nonfarm wage- | 0.000 | 0.000 | 0.002* | 0.001 | 0.001 | 0.001 | 0.006* | 0.001 |
| employment (years) | (0.000) | (0.001) | (0.001) | (0.001) | (0.002) | (0.001) | (0.004) | (0.001) |
| Nonlabor income (100 USD/year) | 0.001 | 0.040 | 0.048*** | 0.014 | 0.004 | -0.010 | 0.250* | -0.010 |
| | (0.005) | (0.050) | (0.010) | (0.011) | (0.023) | (0.023) | (0.143) | (0.023) |
| Distance to nearest transport (km) | -0.005* | 0.015 | -0.002 | -0.000 | -0.009 | 0.005 | 0.008 | 0.005 |
| | (0.003) | (0.010) | (0.006) | (0.007) | (0.014) | (0.013) | (0.026) | (0.013) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm net return | -0.059 | -0.094 | 0.537*** | -0.136 | -0.333 | -0.559 | 1.162* | -0.559 |
| (USD/hour) | (0.048) | (0.092) | (0.125) | (0.123) | (0.293) | (0.555) | (0.701) | (0.555) |
| Regional average nonfarm wage | 0.168 | 0.177 | 0.290 | 0.191 | -0.039 | 0.740 | -1.045 | 0.740 |
| (USD/hour) | (0.117) | (0.265) | (0.303) | (0.322) | (0.584) | (0.940) | (1.402) | (0.940) |
| Observations (household-year pairs) | 2,496 | 487 | 883 | 512 | 2,365 | 508 | 840 | 508 |
| Number of households | 1,275 | 386 | 596 | 379 | 1,225 | 376 | 566 | 376 |
| R-squared | 0.289 | 0.362 | 0.331 | 0.432 | 0.0431 | 0.293 | 0.248 | 0.293 |

*Notes:* The value of profit from self-employment activities is censored at zero. Time dummies, district dummies, time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

## Table 1.A.3 Household profit (correlated random effects)

| Dependent variable: Household profit from the activity (USD/week) | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | CRE | CRE | CRE | CRE | CRE | CRE | CRE | CRE |
| Inverse mills ratio from 1st stage labor equation | | -0.048 | | -0.311* | | -0.450 | | 0.734 |
| | | (0.719) | | (0.168) | | (0.633) | | (1.229) |
| Residuals from 2nd stage labor equation | | 0.247*** | | 0.228*** | | 0.376*** | | 0.478*** |
| | | (0.076) | | (0.046) | | (0.127) | | (0.102) |
| *Household education* | | | | | | | | |
| Average education (years) | 0.040* | 0.043* | -0.022 | -0.018 | 0.132*** | 0.127** | 0.200*** | 0.218** |
| | (0.022) | (0.024) | (0.019) | (0.016) | (0.048) | (0.052) | (0.068) | (0.094) |
| *Household member composition* | | | | | | | | |
| Average age | -0.002 | -0.001 | 0.010 | 0.010 | -0.016 | -0.012 | 0.020* | 0.016 |
| | (0.012) | (0.012) | (0.013) | (0.013) | (0.014) | (0.015) | (0.011) | (0.010) |
| Share of female workers | -0.159 | -0.163 | -0.014 | 0.061 | 0.154 | 0.080 | -0.130 | -0.276 |
| | (0.233) | (0.250) | (0.102) | (0.100) | (0.992) | (1.067) | (0.368) | (0.532) |
| Share of married workers | 0.325 | 0.325 | 0.327* | 0.380** | -0.078 | -0.441 | -0.015 | -0.112 |
| | (0.273) | (0.277) | (0.180) | (0.188) | (0.943) | (1.069) | (0.502) | (0.564) |
| Number of children aged 0-6 | 0.112** | 0.111** | -0.048 | -0.050 | -0.158 | -0.151 | 0.003 | 0.003 |
| | (0.048) | (0.048) | (0.046) | (0.044) | (0.099) | (0.104) | (0.063) | (0.057) |
| Number of children aged 7-12 | 0.056 | 0.063 | 0.076 | 0.079 | 0.113 | 0.085 | -0.000 | -0.010 |
| | (0.053) | (0.057) | (0.077) | (0.075) | (0.107) | (0.112) | (0.061) | (0.059) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | -0.005 | -0.006 | -0.005 | -0.005* | -0.009 | -0.006 | 0.004 | 0.005 |
| | (0.008) | (0.008) | (0.003) | (0.003) | (0.010) | (0.008) | (0.010) | (0.010) |
| Experience in own-farming (years) | 0.005 | 0.001 | -0.027* | -0.025* | -0.007 | -0.002 | -0.029* | -0.035* |
| | (0.009) | (0.031) | (0.016) | (0.014) | (0.020) | (0.022) | (0.016) | (0.019) |
| Square of experience in own-farming (years) | -0.000 | -0.000 | 0.000* | 0.000* | 0.000 | -0.000 | 0.000 | 0.000 |
| | (0.000) | (0.001) | (0.000) | (0.000) | (0.000) | (0.001) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | -0.019 | -0.019 | -0.003 | -0.049* | 0.034 | 0.055 | -0.028 | -0.023 |
| | (0.014) | (0.015) | (0.010) | (0.030) | (0.065) | (0.069) | (0.045) | (0.057) |
| Square of experience in farm-wage-labor (years) | 0.001 | 0.001 | -0.000 | 0.001 | -0.001 | -0.002 | 0.002 | 0.001 |
| | (0.000) | (0.001) | (0.000) | (0.001) | (0.002) | (0.003) | (0.003) | (0.004) |
| Value of farm asset (100 USD) | 0.210** | 0.231** | 0.024 | 0.018 | 0.165 | 0.195 | 0.005 | 0.006 |
| | (0.095) | (0.106) | (0.016) | (0.012) | (0.154) | (0.197) | (0.043) | (0.039) |

Table 1.A.3 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | 0.000 | -0.002 | 0.013 | 0.014 | 0.003 | 0.009 | -0.021 | -0.018 |
| | (0.010) | (0.011) | (0.014) | (0.015) | (0.021) | (0.022) | (0.018) | (0.017) |
| Land rental rate (USD/acre/year) | -0.010 | -0.010 | -0.013 | -0.011 | -0.042 | -0.048 | 0.044 | 0.050 |
| | (0.050) | (0.052) | (0.031) | (0.029) | (0.046) | (0.050) | (0.039) | (0.038) |
| Regional average farming net return | 0.140 | -0.391 | 0.250 | 0.202 | -0.477 | -0.603 | -0.535 | -0.460 |
| (USD/hour) | (0.438) | (0.561) | (0.358) | (0.346) | (1.377) | (1.373) | (1.180) | (1.170) |
| Regional average farming wage | -0.227 | -0.164 | 0.506* | 0.523* | 0.992 | 1.122 | -0.035 | -0.119 |
| (USD/hour) | (0.297) | (0.319) | (0.305) | (0.304) | (0.980) | (1.026) | (0.579) | (0.530) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.025 | -0.029 | 0.001 | 0.008 | 0.025 | -0.064 | -0.013 | -0.037 |
| (years) | (0.023) | (0.022) | (0.015) | (0.014) | (0.028) | (0.118) | (0.037) | (0.060) |
| Square of experience in nonfarm self- | 0.001 | 0.001 | -0.000 | -0.000 | -0.000 | 0.002 | -0.000 | 0.000 |
| employment (years) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) | (0.002) | (0.002) |
| Experience in nonfarm wage-employment | -0.065** | -0.068** | 0.004 | 0.012 | -0.166*** | -0.192*** | 0.093** | 0.242 |
| (years) | (0.030) | (0.031) | (0.017) | (0.016) | (0.047) | (0.062) | (0.042) | (0.282) |
| Square of experience in nonfarm wage- | 0.002* | 0.002 | -0.000 | -0.000 | 0.004** | 0.007* | -0.003** | -0.007 |
| employment (years) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.004) | (0.001) | (0.009) |
| Nonlabor income (100 USD/year) | 0.108 | 0.113 | 0.020 | 0.018 | -0.002 | 0.071 | 0.014*** | 0.014*** |
| | (0.094) | (0.098) | (0.016) | (0.016) | (0.025) | (0.051) | (0.005) | (0.004) |
| Distance to nearest transport (km) | -0.015 | -0.014 | 0.023 | 0.024 | 0.010 | 0.012 | 0.005 | 0.004 |
| | (0.013) | (0.013) | (0.023) | (0.022) | (0.016) | (0.017) | (0.012) | (0.012) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm net return | -0.478* | -0.520* | 0.044 | 0.042 | 0.525 | 0.515 | -0.110 | -0.179 |
| (USD/hour) | (0.263) | (0.271) | (0.116) | (0.110) | (0.580) | (0.597) | (0.506) | (0.554) |
| Regional average nonfarm wage | | | | | | | | |
| (USD/hour) | 0.617 | 0.677 | 0.445 | 0.342 | -0.584 | -0.659 | 0.339 | 0.341 |
| | (0.565) | (0.611) | (0.457) | (0.420) | (1.148) | (1.178) | (0.673) | (0.677) |
| Observations (household-year pairs) | 4,009 | 3,815 | 770 | 767 | 1,551 | 1,480 | 908 | 904 |
| Number of households | 1,810 | 1,761 | 577 | 575 | 955 | 919 | 645 | 643 |
| R-squared | 0.038 | 0.041 | 0.193 | 0.241 | 0.096 | 0.114 | 0.176 | 0.208 |

*Notes:* The value of profit from self-employment activities is censored at zero. Household weekly profit is computed based on the gross income from the activities and the cost of self-employed activities in a year. Time dummies, district dummies, time means of all time-variant explanatory variables are included in all estimations but not reported. All estimations used correlated random effects model. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

## Table 1.A.4 Household profit (correlated random effects instrumental variable)

| Dependent variable: Household profit from the activity (USD/week) | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS |
| Inverse mills ratio from 1st stage labor equation | | 0.206 | | -0.350* | | -0.702 | | -0.141 |
| | | (0.981) | | (0.183) | | (0.672) | | (0.700) |
| Residuals from 2nd stage labor equation | | 0.251*** | | 0.221*** | | 0.178 | | -0.253 |
| | | (0.079) | | (0.048) | | (0.177) | | (0.262) |
| *Household education* | | | | | | | | |
| Average education (years) | 0.297 | 0.265 | 0.153 | 0.019 | 0.756* | 0.708 | 1.111*** | 1.121** |
| | (0.216) | (0.310) | (0.105) | (0.072) | (0.404) | (0.433) | (0.404) | (0.442) |
| *Household member composition* | | | | | | | | |
| Average age | 0.017 | 0.016 | 0.024 | 0.013 | 0.031 | 0.036 | 0.087** | 0.089** |
| | (0.017) | (0.025) | (0.019) | (0.013) | (0.036) | (0.040) | (0.041) | (0.042) |
| Share of female workers | 0.195 | 0.142 | 0.278 | 0.137 | 1.121 | 0.828 | 0.313 | 0.354 |
| | (0.425) | (0.534) | (0.211) | (0.147) | (1.462) | (1.500) | (0.793) | (0.798) |
| Share of married workers | 0.434 | 0.432 | 0.383* | 0.394** | 0.358 | -0.283 | 0.196 | 0.207 |
| | (0.293) | (0.298) | (0.214) | (0.192) | (1.186) | (1.207) | (0.721) | (0.728) |
| Number of children aged 0-6 | 0.128*** | 0.124*** | -0.048 | -0.049 | -0.109 | -0.093 | 0.035 | 0.022 |
| | (0.045) | (0.043) | (0.050) | (0.045) | (0.107) | (0.113) | (0.123) | (0.125) |
| Number of children aged 7-12 | 0.051 | 0.059 | 0.080 | 0.081 | 0.128 | 0.084 | -0.018 | -0.009 |
| | (0.057) | (0.061) | (0.082) | (0.076) | (0.114) | (0.118) | (0.140) | (0.139) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | -0.005 | -0.006 | -0.000 | -0.004 | -0.009 | -0.005 | -0.006 | -0.006 |
| | (0.008) | (0.009) | (0.004) | (0.003) | (0.013) | (0.011) | (0.024) | (0.024) |
| Experience in own-farming (years) | 0.010 | 0.013 | -0.033* | -0.026* | -0.003 | 0.004 | -0.008 | -0.005 |
| | (0.010) | (0.041) | (0.018) | (0.014) | (0.025) | (0.027) | (0.038) | (0.039) |
| Square of experience in own-farming (years) | -0.000 | -0.000 | 0.000** | 0.000** | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.001) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) |
| Experience in farm-wage-labor (years) | 0.018 | 0.011 | 0.014 | -0.051 | 0.108 | 0.138 | 0.227 | 0.218 |
| | (0.042) | (0.054) | (0.012) | (0.034) | (0.086) | (0.092) | (0.145) | (0.156) |
| Square of experience in farm-wage-labor (years) | -0.000 | -0.000 | -0.000 | 0.001 | -0.002 | -0.004 | -0.005 | -0.004 |
| | (0.001) | (0.001) | (0.000) | (0.001) | (0.003) | (0.003) | (0.007) | (0.007) |
| Value of farm asset (100 USD) | 0.173* | 0.194* | 0.032 | 0.021* | 0.076 | 0.083 | -0.148 | -0.154 |
| | (0.097) | (0.116) | (0.020) | (0.012) | (0.167) | (0.203) | (0.125) | (0.132) |

Table 1.A.4 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | 0.002 | -0.001 | 0.011 | 0.014 | 0.001 | 0.007 | 0.013 | 0.016 |
| | (0.010) | (0.010) | (0.014) | (0.015) | (0.023) | (0.024) | (0.033) | (0.034) |
| Land rental rate (USD/acre/year) | -0.014 | -0.012 | -0.020 | -0.014 | -0.056 | -0.058 | 0.053 | 0.046 |
| | (0.051) | (0.053) | (0.034) | (0.030) | (0.051) | (0.054) | (0.063) | (0.063) |
| Regional average farming return | 0.134 | -0.473 | 0.299 | 0.213 | -0.632 | -0.696 | -1.555 | -1.660 |
| (USD/hour) | (0.440) | (0.496) | (0.391) | (0.347) | (1.375) | (1.364) | (1.754) | (1.785) |
| Regional average farming wage | -0.196 | -0.119 | 0.343 | 0.500 | 1.067 | 1.132 | 0.999 | 1.051 |
| (USD/hour) | (0.298) | (0.308) | (0.289) | (0.320) | (1.008) | (1.049) | (1.060) | (1.105) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.042* | -0.047* | -0.009 | 0.007 | 0.022 | -0.105 | -0.123 | -0.122 |
| (years) | (0.022) | (0.024) | (0.020) | (0.013) | (0.034) | (0.123) | (0.083) | (0.092) |
| Square of experience in nonfarm self- | 0.001* | 0.001** | -0.000 | -0.000 | 0.000 | 0.003 | 0.006 | 0.006 |
| employment (years) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) | (0.004) | (0.004) |
| Experience in nonfarm wage-employment | -0.153** | -0.151 | -0.038 | 0.006 | -0.358*** | -0.383** | -0.066 | -0.104 |
| (years) | (0.069) | (0.106) | (0.033) | (0.021) | (0.137) | (0.156) | (0.072) | (0.141) |
| Square of experience in nonfarm wage- | 0.004** | 0.004 | 0.001 | -0.000 | 0.007 | 0.010* | 0.001 | 0.002 |
| employment (years) | (0.002) | (0.003) | (0.001) | (0.001) | (0.004) | (0.006) | (0.002) | (0.005) |
| Nonlabor income (100 USD/year) | 0.104 | 0.110 | 0.016 | 0.015 | -0.006 | 0.065 | 0.015* | 0.014 |
| | (0.094) | (0.099) | (0.022) | (0.018) | (0.027) | (0.051) | (0.009) | (0.009) |
| Distance to nearest transport (km) | -0.014 | -0.014 | 0.020 | 0.023 | 0.010 | 0.012 | -0.012 | -0.012 |
| | (0.013) | (0.013) | (0.024) | (0.022) | (0.016) | (0.017) | (0.025) | (0.026) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm return | -0.494* | -0.542** | 0.004 | 0.036 | 0.410 | 0.377 | -0.235 | -0.210 |
| (USD/hour) | (0.266) | (0.261) | (0.127) | (0.113) | (0.619) | (0.640) | (0.627) | (0.645) |
| Regional average nonfarm wage | 0.625 | 0.692 | 0.753 | 0.395 | -0.512 | -0.535 | -0.822 | -0.861 |
| (USD/hour) | (0.577) | (0.623) | (0.557) | (0.430) | (1.188) | (1.233) | (1.340) | (1.399) |
| Observations (household-year pairs) | 3,981 | 3,790 | 765 | 762 | 1,546 | 1,475 | 907 | 903 |
| Number of households | 1,802 | 1,754 | 573 | 571 | 954 | 918 | 645 | 643 |
| R-squared | 0.025 | 0.030 | 0.103 | 0.231 | 0.055 | 0.070 | 0.097 | 0.094 |

*Notes:* The value of profit from self-employment activities is censored at zero. Household weekly profit is computed based on the gross income from the activities and the cost of self-employed activities in a year. Time dummies, district dummies, time means of all time-variant explanatory variables are included in all estimations but not reported. All estimations used the correlated random effects model. The 2SLS estimations used two instrumental variables: total years under free primary education and average distance to the nearest market in the birth district in 1995. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

**Table 1.A.5 Household average partial effect on probability of participation (pooled probit)**

| Dependent variable: Supply hours of labor = 1 | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | Reduced | Two stage | Reduced | Two stage | Reduced | Two stage | Reduced | Two stage |
| *Household education* | | | | | | | | |
| Average education (years) | 0.002 | | -0.007*** | | 0.006*** | | 0.011*** | |
| | (0.002) | | (0.002) | | (0.002) | | (0.002) | |
| Fitted value of education (years) | | 0.002 | | -0.006*** | | 0.006*** | | 0.012*** |
| | | (0.002) | | (0.002) | | (0.002) | | (0.002) |
| *Household composition* | | | | | | | | |
| Average age | -0.001* | -0.001* | -0.001 | -0.001 | -0.001* | -0.001* | 0.000 | 0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Share of female workers | 0.004 | 0.005 | -0.067*** | -0.067*** | 0.027 | 0.028 | -0.049** | -0.047** |
| | (0.021) | (0.021) | (0.023) | (0.023) | (0.028) | (0.028) | (0.023) | (0.023) |
| Share of married workers | 0.063*** | 0.064*** | -0.040* | -0.043* | 0.081*** | 0.086*** | -0.022 | -0.021 |
| | (0.022) | (0.022) | (0.022) | (0.023) | (0.028) | (0.028) | (0.023) | (0.023) |
| Number of children aged 0-6 | 0.008** | 0.008** | -0.001 | -0.001 | 0.007 | 0.007 | 0.001 | 0.001 |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.005) | (0.005) | (0.004) | (0.004) |
| Number of children aged 7-12 | 0.006 | 0.006 | 0.001 | 0.001 | 0.011** | 0.012** | -0.004 | -0.004 |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.005) | (0.005) | (0.004) | (0.004) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | 0.001 | 0.001 | 0.000 | 0.000 | -0.001 | -0.001 | 0.000 | 0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Experience in own-farming (years) | 0.019*** | 0.019*** | -0.001 | -0.001 | -0.005*** | -0.005*** | -0.002 | -0.002 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Square of experience in own-farming (years) | -0.000*** | -0.000*** | -0.000 | -0.000 | 0.000* | 0.000* | -0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | 0.000 | 0.000 | 0.047*** | 0.047*** | -0.013*** | -0.013*** | 0.007** | 0.007** |
| | (0.002) | (0.002) | (0.003) | (0.003) | (0.002) | (0.002) | (0.003) | (0.003) |
| Square of experience in farm-wage-labor (years) | -0.000 | -0.000 | -0.001*** | -0.001*** | 0.000*** | 0.000*** | -0.001*** | -0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Value of farm asset (100 USD) | 0.003 | 0.002 | 0.005 | 0.006* | 0.008* | 0.007 | -0.003 | -0.003 |
| | (0.006) | (0.006) | (0.003) | (0.003) | (0.004) | (0.004) | (0.004) | (0.004) |
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | -0.001 | -0.001 | -0.002*** | -0.002*** | -0.002* | -0.002* | -0.001 | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |

Table 1.A.5 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Land rental rate (USD/acre/year) | 0.003 | 0.003 | -0.000 | -0.000 | -0.002 | -0.002 | 0.003 | 0.003 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Regional average farming return | 0.003 | 0.003 | 0.032 | 0.030 | -0.011 | -0.009 | -0.046 | -0.045 |
| (USD/hour) | (0.037) | (0.037) | (0.030) | (0.030) | (0.043) | (0.043) | (0.035) | (0.035) |
| Regional average farming wage | -0.038 | -0.038 | -0.030 | -0.028 | -0.079** | -0.080** | -0.033 | -0.032 |
| (USD/hour) | (0.030) | (0.030) | (0.033) | (0.033) | (0.038) | (0.038) | (0.032) | (0.032) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.007*** | -0.007*** | -0.008*** | -0.008*** | 0.076*** | 0.075*** | -0.007*** | -0.007*** |
| (years) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Square of experience in nonfarm self- | 0.000** | 0.000** | 0.000 | 0.000 | -0.002*** | -0.002*** | 0.000 | 0.000 |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in nonfarm wage-employment | -0.008*** | -0.008*** | -0.005* | -0.005* | -0.010*** | -0.011*** | 0.076*** | 0.076*** |
| (years) | (0.002) | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Square of experience in nonfarm wage- | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.002*** | -0.002*** |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Nonlabor income (100 USD/year) | -0.000 | -0.000 | -0.000 | 0.001 | 0.001 | -0.001 | -0.000 | -0.001 |
| | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.001) | (0.001) |
| Distance to nearest transport (km) | -0.000 | -0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm return | -0.017 | -0.017 | 0.006 | 0.005 | 0.031 | 0.032* | -0.040** | -0.040** |
| (USD/hour) | (0.016) | (0.016) | (0.017) | (0.017) | (0.019) | (0.019) | (0.017) | (0.017) |
| Regional average nonfarm wage | -0.060 | -0.061 | 0.056 | 0.057 | 0.023 | 0.022 | -0.039 | -0.039 |
| (USD/hour) | (0.040) | (0.040) | (0.043) | (0.043) | (0.047) | (0.047) | (0.041) | (0.041) |
| Observations (household-year pairs) | 4,677 | 4,677 | 4,699 | 4,699 | 4,742 | 4,742 | 4,725 | 4,725 |
| Number of households | 1,981 | 1,981 | 1,976 | 1,976 | 2,006 | 2,006 | 1,999 | 1,999 |
| Pseudo R-squared | 0.350 | 0.350 | 0.408 | 0.407 | 0.412 | 0.413 | 0.433 | 0.432 |
| Pseudo likelihood | -1270 | -1270 | -1352 | -1354 | -1776 | -1774 | -1410 | -1413 |

*Notes:* The two stage estimations instrumented average years of schooling by an instrumental variable, total years under free primary education. Time dummies, district dummies, and time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

**Table 1.A.6 Household hours of labor supply (Lognormal correlated random effects)**

| Dependent variable: Log of hours worked (hours/week) | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | CRE | CRE | CRE | CRE | CRE | CRE | CRE | CRE |
| Inverse mills ratio from 1st stage labor equation | | -0.279* | | 0.398** | | -0.220 | | -0.451*** |
| | | (0.166) | | (0.201) | | (0.155) | | (0.166) |
| *Household education* | | | | | | | | |
| Average education (years) | 0.005 | 0.004 | 0.011 | -0.001 | 0.044*** | 0.041*** | 0.073*** | 0.060*** |
| | (0.005) | (0.005) | (0.016) | (0.017) | (0.011) | (0.011) | (0.011) | (0.012) |
| *Household composition* | | | | | | | | |
| Average age | -0.006*** | -0.005** | 0.012** | 0.010 | -0.004 | -0.003 | -0.005 | -0.003 |
| | (0.002) | (0.002) | (0.006) | (0.006) | (0.004) | (0.004) | (0.006) | (0.006) |
| Share of female workers | -0.334*** | -0.351*** | -0.667*** | -0.774*** | 0.056 | 0.038 | 0.152 | 0.232 |
| | (0.079) | (0.079) | (0.174) | (0.185) | (0.136) | (0.136) | (0.179) | (0.183) |
| Share of married workers | 0.238*** | 0.197** | -0.373** | -0.435** | 0.289* | 0.256* | 0.086 | 0.130 |
| | (0.081) | (0.083) | (0.181) | (0.184) | (0.148) | (0.147) | (0.180) | (0.183) |
| Number of children aged 0-6 | 0.048*** | 0.048*** | 0.080** | 0.079** | 0.029 | 0.028 | -0.055 | -0.057* |
| | (0.012) | (0.012) | (0.034) | (0.034) | (0.025) | (0.025) | (0.034) | (0.034) |
| Number of children aged 7-12 | 0.046*** | 0.046*** | 0.015 | 0.012 | 0.000 | -0.005 | 0.007 | 0.013 |
| | (0.012) | (0.012) | (0.036) | (0.036) | (0.024) | (0.025) | (0.035) | (0.035) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | -0.003** | -0.004*** | -0.004 | -0.004 | -0.003 | -0.003 | -0.010*** | -0.010*** |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.002) | (0.002) | (0.003) | (0.003) |
| Experience in own-farming (years) | 0.042*** | 0.032*** | -0.054*** | -0.057*** | -0.046*** | -0.043*** | -0.028*** | -0.025*** |
| | (0.004) | (0.007) | (0.008) | (0.008) | (0.007) | (0.007) | (0.008) | (0.008) |
| Square of experience in own-farming (years) | -0.001*** | -0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | -0.015** | -0.015** | 0.051*** | 0.112*** | -0.015 | -0.008 | -0.010 | -0.023 |
| | (0.006) | (0.006) | (0.011) | (0.031) | (0.021) | (0.022) | (0.034) | (0.036) |
| Square of experience in farm-wage-labor (years) | 0.000 | 0.000 | -0.001*** | -0.003*** | 0.000 | 0.000 | -0.002 | -0.001 |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) | (0.003) | (0.003) |
| Value of farm asset (100 USD) | 0.042*** | 0.038*** | 0.057* | 0.063** | 0.046 | 0.041 | -0.034 | -0.029 |
| | (0.015) | (0.015) | (0.030) | (0.030) | (0.029) | (0.029) | (0.040) | (0.039) |
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | 0.008*** | 0.008*** | -0.009 | -0.011* | -0.001 | -0.000 | 0.002 | 0.002 |
| | (0.002) | (0.002) | (0.006) | (0.006) | (0.005) | (0.005) | (0.006) | (0.006) |

Table 1.A.6 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Land rental rate (USD/acre/year) | -0.002 | -0.003 | -0.016 | -0.017 | -0.009 | -0.009 | 0.024 | 0.023 |
| | (0.007) | (0.007) | (0.021) | (0.021) | (0.018) | (0.018) | (0.018) | (0.018) |
| Regional average farming return | -0.289*** | -0.375*** | -0.368 | -0.313 | -0.006 | 0.008 | 0.042 | 0.037 |
| (USD/hour) | (0.083) | (0.107) | (0.353) | (0.355) | (0.201) | (0.202) | (0.266) | (0.262) |
| Regional average farming wage | 0.110 | 0.135 | -0.205 | -0.263 | 0.084 | 0.115 | 0.043 | 0.076 |
| (USD/hour) | (0.081) | (0.082) | (0.300) | (0.302) | (0.188) | (0.188) | (0.236) | (0.237) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.017*** | -0.014*** | -0.001 | -0.012 | 0.037*** | 0.002 | -0.000 | 0.011 |
| (years) | (0.005) | (0.005) | (0.016) | (0.017) | (0.010) | (0.026) | (0.019) | (0.020) |
| Square of experience in nonfarm self- | 0.000 | 0.000 | -0.000 | -0.000 | -0.001** | 0.000 | -0.001 | -0.001 |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) |
| Experience in nonfarm wage-employment | -0.046*** | -0.043*** | -0.034 | -0.041 | -0.058** | -0.054** | 0.066*** | -0.024 |
| (years) | (0.009) | (0.009) | (0.027) | (0.027) | (0.025) | (0.025) | (0.014) | (0.036) |
| Square of experience in nonfarm wage- | 0.001* | 0.001 | 0.002* | 0.002** | 0.001 | 0.001 | -0.002*** | 0.001 |
| employment (years) | (0.000) | (0.000) | (0.001) | (0.001) | (0.002) | (0.002) | (0.001) | (0.001) |
| Nonlabor income (100 USD/year) | -0.003 | -0.003 | 0.056*** | 0.054*** | 0.005 | 0.005 | -0.000 | -0.000 |
| | (0.004) | (0.004) | (0.014) | (0.013) | (0.005) | (0.005) | (0.003) | (0.003) |
| Distance to nearest transport (km) | -0.000 | -0.001 | 0.004 | 0.004 | -0.005 | -0.005 | -0.000 | -0.001 |
| | (0.002) | (0.002) | (0.011) | (0.011) | (0.004) | (0.004) | (0.006) | (0.006) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm return | -0.060 | -0.056 | -0.067 | -0.062 | -0.175* | -0.189* | 0.117 | 0.160 |
| (USD/hour) | (0.045) | (0.045) | (0.135) | (0.136) | (0.096) | (0.097) | (0.134) | (0.133) |
| Regional average nonfarm wage | -0.078 | -0.061 | -0.506 | -0.389 | -0.130 | -0.146 | -0.239 | -0.215 |
| (USD/hour) | (0.110) | (0.111) | (0.364) | (0.366) | (0.234) | (0.234) | (0.286) | (0.286) |
| Observations (household-year pairs) | 4,065 | 3,989 | 891 | 891 | 1,582 | 1,582 | 1,038 | 1,037 |
| Number of households | 1,852 | 1,819 | 649 | 649 | 962 | 962 | 703 | 702 |
| R-squared | 0.208 | 0.211 | 0.409 | 0.412 | 0.286 | 0.287 | 0.335 | 0.338 |

*Notes:* Time dummies, district dummies, and time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Standard errors clustered at household level are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

## Table 1.A.7 Household hours of labor supply (Lognormal correlated random effects instrumental variable)

| Dependent variable: Log of hours worked (hours/week) | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS |
| Inverse mills ratio from 1st stage labor equation | | -0.808*** | | -0.257 | | -0.510*** | | -0.820*** |
| | | (0.151) | | (0.180) | | (0.146) | | (0.155) |
| *Household education* | | | | | | | | |
| Fitted value of education (years) | 0.014** | 0.009 | 0.021 | 0.018 | 0.056*** | 0.054*** | 0.092*** | 0.087*** |
| | (0.006) | (0.006) | (0.020) | (0.020) | (0.013) | (0.013) | (0.014) | (0.014) |
| *Household member composition* | | | | | | | | |
| Average age | -0.005** | -0.003 | 0.013** | 0.013** | -0.003 | 0.001 | -0.003 | 0.002 |
| | (0.002) | (0.002) | (0.006) | (0.006) | (0.004) | (0.004) | (0.006) | (0.006) |
| Share of female workers | -0.326*** | -0.363*** | -0.649*** | -0.594*** | 0.067 | 0.041 | 0.175 | 0.292 |
| | (0.079) | (0.079) | (0.175) | (0.182) | (0.136) | (0.138) | (0.182) | (0.185) |
| Share of married workers | 0.233*** | 0.140* | -0.368** | -0.324* | 0.301** | 0.236 | 0.099 | 0.165 |
| | (0.081) | (0.081) | (0.181) | (0.185) | (0.148) | (0.149) | (0.180) | (0.185) |
| Number of children aged 0-6 | 0.048*** | 0.042*** | 0.080** | 0.079** | 0.031 | 0.030 | -0.048 | -0.043 |
| | (0.012) | (0.012) | (0.034) | (0.034) | (0.025) | (0.025) | (0.034) | (0.033) |
| Number of children aged 7-12 | 0.045*** | 0.042*** | 0.014 | 0.014 | -0.000 | -0.012 | 0.002 | 0.017 |
| | (0.012) | (0.012) | (0.036) | (0.036) | (0.024) | (0.024) | (0.036) | (0.035) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | -0.003** | -0.004*** | -0.004 | -0.004 | -0.004 | -0.003 | -0.009*** | -0.008** |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.002) | (0.002) | (0.003) | (0.003) |
| Experience in own-farming (years) | 0.041*** | 0.012* | -0.054*** | -0.053*** | -0.046*** | -0.042*** | -0.027*** | -0.022*** |
| | (0.004) | (0.006) | (0.008) | (0.008) | (0.007) | (0.007) | (0.008) | (0.008) |
| Square of experience in own-farming (years) | -0.001*** | -0.000** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | -0.014** | -0.014** | 0.052*** | 0.012 | -0.013 | 0.001 | -0.011 | -0.028 |
| | (0.006) | (0.006) | (0.011) | (0.028) | (0.021) | (0.022) | (0.034) | (0.037) |
| Square of experience in farm-wage-labor (years) | -0.000 | 0.000 | -0.001*** | -0.000 | 0.000 | -0.000 | -0.002 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) | (0.003) | (0.003) |
| Value of farm asset (100 USD) | 0.044*** | 0.037** | 0.055* | 0.052* | 0.043 | 0.031 | -0.030 | -0.028 |
| | (0.015) | (0.015) | (0.030) | (0.029) | (0.030) | (0.028) | (0.034) | (0.031) |
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | 0.008*** | 0.008*** | -0.009 | -0.008 | -0.001 | 0.001 | 0.001 | 0.002 |
| | (0.002) | (0.002) | (0.006) | (0.006) | (0.005) | (0.004) | (0.006) | (0.006) |

Table 1.A.7 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Land rental rate (USD/acre/year) | -0.003 | -0.004 | -0.016 | -0.017 | -0.009 | -0.009 | 0.024 | 0.021 |
| | (0.007) | (0.007) | (0.021) | (0.021) | (0.017) | (0.017) | (0.018) | (0.019) |
| Regional average farming return | -0.293*** | -0.385*** | -0.371 | -0.423 | 0.016 | 0.082 | 0.026 | 0.015 |
| (USD/hour) | (0.082) | (0.107) | (0.354) | (0.354) | (0.201) | (0.202) | (0.271) | (0.266) |
| Regional average farming wage | 0.111 | 0.158* | -0.212 | -0.158 | 0.086 | 0.164 | 0.065 | 0.123 |
| (USD/hour) | (0.081) | (0.082) | (0.300) | (0.300) | (0.188) | (0.187) | (0.239) | (0.238) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.017*** | -0.008 | -0.001 | 0.006 | 0.036*** | -0.043* | -0.001 | 0.020 |
| (years) | (0.005) | (0.005) | (0.016) | (0.017) | (0.010) | (0.024) | (0.019) | (0.020) |
| Square of experience in nonfarm self- | 0.000 | -0.000 | -0.000 | -0.001 | -0.001** | 0.001* | -0.001 | -0.001 |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) |
| Experience in nonfarm wage-employment | -0.049*** | -0.039*** | -0.037 | -0.028 | -0.063** | -0.058** | 0.057*** | -0.109*** |
| (years) | (0.009) | (0.009) | (0.027) | (0.028) | (0.025) | (0.025) | (0.015) | (0.035) |
| Square of experience in nonfarm wage- | 0.001* | 0.001 | 0.002** | 0.002* | 0.001 | 0.001 | -0.002*** | 0.003*** |
| employment (years) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Nonlabor income (100 USD/year) | 0.001 | -0.000 | 0.056*** | 0.057*** | 0.005 | 0.003 | -0.003 | -0.003 |
| | (0.005) | (0.005) | (0.018) | (0.018) | (0.005) | (0.005) | (0.003) | (0.003) |
| Distance to nearest transport (km) | -0.000 | -0.001 | 0.004 | 0.005 | -0.005 | -0.005 | 0.000 | -0.002 |
| | (0.002) | (0.002) | (0.011) | (0.011) | (0.004) | (0.004) | (0.006) | (0.006) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm return | -0.061 | -0.057 | -0.070 | -0.087 | -0.175* | -0.208** | 0.097 | 0.185 |
| (USD/hour) | (0.045) | (0.045) | (0.135) | (0.136) | (0.095) | (0.098) | (0.131) | (0.130) |
| Regional average nonfarm wage | -0.075 | -0.031 | -0.492 | -0.579 | -0.146 | -0.190 | -0.212 | -0.115 |
| (USD/hour) | (0.110) | (0.111) | (0.364) | (0.368) | (0.234) | (0.234) | (0.286) | (0.283) |
| Observations (household-year pairs) | 4,065 | 3,964 | 891 | 885 | 1,582 | 1,576 | 1,038 | 1,036 |
| Number of households | 1,852 | 1,814 | 649 | 644 | 962 | 960 | 703 | 702 |
| R-squared | 0.209 | 0.221 | 0.410 | 0.411 | 0.286 | 0.294 | 0.334 | 0.356 |

*Notes:* Time dummies, district dummies, and time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Standard errors clustered at household level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

**Table 1.A.8 Summary statistics of variables (individual)**

| Variable | Obs. | Mean | C.v. | Min. | Max. |
|---|---|---|---|---|---|
| *Dependent Variables* | | | | | |
| Hourly profit (USD/hour) | | | | | |
| Own-farming | 10,382 | 4.2 | 27.4 | -261.5 | 6598.8 |
| Farm-wage-labor | 1,293 | 1.7 | 2.7 | 0.0 | 113.6 |
| Nonfarm self-employment | 4,229 | 10.9 | 14.7 | -177.9 | 3863.6 |
| Nonfarm wage-employment | 1,398 | 3.2 | 4.5 | 0.0 | 368.1 |
| Supply positive hours of labor = 1 | | | | | |
| Own-farming | 12,180 | 0.67 | 0.7 | 0.0 | 1.0 |
| Farm-wage-labor | 12,180 | 0.11 | 2.9 | 0.0 | 1.0 |
| Nonfarm self-employment | 12,180 | 0.18 | 2.1 | 0.0 | 1.0 |
| Nonfarm wage-employment | 12,180 | 0.11 | 2.8 | 0.0 | 1.0 |
| Labor supply (hours/week) | | | | | |
| Own-farming | 12,180 | 14.2 | 1.1 | 0.0 | 145.0 |
| Farm-wage-labor | 12,180 | 1.6 | 5.1 | 0.0 | 125.4 |
| Nonfarm self-employment | 12,180 | 5.9 | 3.0 | 0.0 | 219.4 |
| Nonfarm wage-employment | 12,180 | 4.0 | 3.7 | 0.0 | 148.4 |
| *Explanatory Variables* | | | | | |
| *Individual schooling* | | | | | |
| Education (years) | 11,994 | 5.5 | 0.7 | 0.0 | 17.0 |
| *Individual characteristics* | | | | | |
| Age | 12,180 | 37.0 | 0.3 | 20.0 | 65.0 |
| Female = 1 | 12,180 | 0.53 | 0.9 | 0.0 | 1.0 |
| Married = 1 | 12,166 | 0.70 | 0.6 | 0.0 | 1.0 |
| Number of children aged 0-6 | 12,180 | 1.6 | 0.8 | 0.0 | 9.0 |
| Number of children aged 7-12 | 12,180 | 1.3 | 0.9 | 0.0 | 8.0 |
| *Farming variables* | | | | | |
| Land holdings (acres) | 11,871 | 4.8 | 2.7 | 0.0 | 340.0 |
| Experience in own-farming (years) | 10,447 | 18.4 | 0.8 | 0.0 | 114.0 |
| Experience in farm-wage-labor (years) | 10,447 | 1.5 | 3.6 | 0.0 | 55.0 |
| Value of farm assets (100 USD) | 11,545 | 0.6 | 2.3 | 0.0 | 27.1 |
| *Farming prices* | | | | | |
| CPI of farming products | 12,180 | 202.3 | 0.2 | 164.5 | 273.4 |
| Land rental rate (USD/acre/year) | 12,180 | 6.6 | 0.4 | 1.8 | 18.9 |
| Average profit in own-farming (ln(USD/hour)) | 12,180 | 0.4 | 0.6 | 0.0 | 2.8 |
| Average wage in farm-wage-labor (ln(USD/hour)) | 12,180 | 0.7 | 0.3 | 0.3 | 1.8 |
| *Nonfarm variables* | | | | | |
| Experience in nonfarm self-employment (years) | 10,447 | 2.4 | 2.6 | 0.0 | 59.0 |
| Experience in nonfarm wage-employment (years) | 10,447 | 1.2 | 3.6 | 0.0 | 47.0 |
| Nonlabor income (100 USD/year) | 12,180 | 1.0 | 5.5 | 0.0 | 267.8 |
| Distance to nearest transport (km) | 12,166 | 3.4 | 1.9 | 0.0 | 180.0 |
| *Nonfarm prices* | | | | | |
| Average net return in nonfarm self-employment (ln(USD/hour)) | 12,180 | 0.6 | 0.6 | 0.0 | 3.1 |
| Average wage in nonfarm wage-employment (ln(USD/hour)) | 12,180 | 0.8 | 0.2 | 0.2 | 1.3 |
| *Instrumental variables* | | | | | |
| Distance to nearest market in 1995 in birth district (km) | 11,975 | 6.3 | 0.8 | 1.0 | 26.3 |
| Person-years under free primary education | 12,180 | 3.2 | 1.6 | 0.0 | 40.0 |

*Notes:* Observations pooled across years. USD used in the table is 2011 PPP USD.

**Table 1.A.9 Individual hourly profit or wage (correlated random effects instrumental variable)**

| Dependent variable: Hourly profit or wage (USD/week) | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS | CRE 2SLS |
| *Individual education* | | | | | | | | |
| Education (years) | 0.012 | | -0.004 | | 0.052 | | -0.018 | |
| | (0.057) | | (0.167) | | (0.050) | | (0.042) | |
| Completed primary school = 1 | | -0.018 | | 0.222 | | -0.367 | | -0.233 |
| | | (0.452) | | (5.593) | | (1.178) | | (0.555) |
| Completed secondary school = 1 | | 0.027 | | -0.029 | | 2.061 | | 0.002 |
| | | (1.260) | | (3.479) | | (2.209) | | (0.398) |
| *Individual characteristics* | | | | | | | | |
| Age | 0.005 | 0.003 | -0.006 | -0.005 | 0.003 | -0.002 | 0.004 | 0.004 |
| | (0.003) | (0.002) | (0.012) | (0.018) | (0.004) | (0.005) | (0.004) | (0.005) |
| Married = 1 | 0.011 | -0.018 | 0.117 | 0.116 | 0.121 | 0.109 | 0.173** | 0.181** |
| | (0.031) | (0.064) | (0.080) | (0.106) | (0.087) | (0.145) | (0.077) | (0.086) |
| Female = 1 | 0.014 | -0.031 | 0.097 | 0.152 | -0.023 | -0.109 | -0.028 | -0.033 |
| | (0.073) | (0.046) | (0.279) | (1.047) | (0.118) | (0.168) | (0.080) | (0.078) |
| Number of children aged 0-6 | 0.017 | 0.014 | -0.009 | -0.007 | -0.000 | 0.001 | 0.021 | 0.020 |
| | (0.012) | (0.012) | (0.023) | (0.029) | (0.021) | (0.029) | (0.022) | (0.024) |
| Number of children aged 7-12 | -0.015 | -0.014 | 0.043 | 0.040 | 0.031 | 0.048* | -0.021 | -0.021 |
| | (0.010) | (0.011) | (0.030) | (0.030) | (0.021) | (0.025) | (0.021) | (0.022) |
| *Farming variables* | | | | | | | | |
| Land holdings (acres) | 0.004** | 0.003** | 0.006 | 0.005 | 0.002 | 0.003 | 0.001 | 0.001 |
| | (0.002) | (0.001) | (0.005) | (0.029) | (0.002) | (0.002) | (0.003) | (0.003) |
| Experience in own-farming (years) | -0.004 | -0.005** | 0.012*** | 0.013** | 0.017*** | 0.008* | 0.010* | 0.009 |
| | (0.007) | (0.003) | (0.005) | (0.006) | (0.005) | (0.005) | (0.005) | (0.006) |
| Square of experience in own-farming (years) | 0.000 | 0.000 | -0.000** | -0.000 | -0.000*** | -0.000 | -0.000* | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | -0.001 | -0.000 | -0.006 | -0.009 | 0.023 | 0.007 | 0.022 | 0.018 |
| | (0.007) | (0.009) | (0.020) | (0.052) | (0.015) | (0.018) | (0.029) | (0.031) |
| Square of experience in farm-wage-labor (years) | 0.000 | -0.000 | 0.000 | 0.000 | -0.001* | -0.000 | -0.001 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.000) | (0.000) | (0.001) | (0.001) |
| Value of farm asset (100 USD) | 0.039** | 0.059*** | 0.007 | 0.009 | 0.020 | 0.049* | 0.044*** | 0.044*** |
| | (0.017) | (0.016) | (0.019) | (0.036) | (0.024) | (0.027) | (0.016) | (0.016) |

Table 1.A.9 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | -0.005*** | -0.004** | 0.002 | 0.001 | 0.002 | -0.002 | -0.002 | -0.001 |
| | (0.002) | (0.002) | (0.005) | (0.008) | (0.003) | (0.005) | (0.004) | (0.004) |
| Land rental rate (USD/acre/year) | 0.004 | 0.002 | 0.005 | 0.004 | -0.001 | 0.006 | -0.002 | -0.000 |
| | (0.007) | (0.007) | (0.014) | (0.048) | (0.012) | (0.017) | (0.013) | (0.014) |
| Regional average farming return | 0.490*** | 0.446*** | -0.045 | -0.026 | 0.012 | -0.042 | 0.119 | 0.141 |
| (USD/hour) | (0.089) | (0.090) | (0.297) | (0.600) | (0.163) | (0.209) | (0.218) | (0.226) |
| Regional average farming wage | -0.060 | -0.050 | 0.495** | 0.474 | 0.099 | -0.083 | 0.024 | 0.006 |
| (USD/hour) | (0.058) | (0.061) | (0.250) | (0.730) | (0.171) | (0.221) | (0.209) | (0.227) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | 0.004 | 0.007* | 0.014 | 0.017 | -0.022 | -0.000 | 0.080*** | 0.082*** |
| (years) | (0.005) | (0.004) | (0.015) | (0.069) | (0.014) | (0.009) | (0.024) | (0.026) |
| Square of experience in nonfarm self- | -0.000 | -0.000 | -0.000 | -0.000 | 0.001 | 0.000 | -0.002* | -0.002* |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.002) | (0.000) | (0.000) | (0.001) | (0.001) |
| Experience in nonfarm wage-employment | 0.018 | 0.019 | 0.017 | 0.010 | 0.013 | -0.034 | -0.006 | -0.005 |
| (years) | (0.021) | (0.023) | (0.052) | (0.220) | (0.022) | (0.027) | (0.022) | (0.021) |
| Square of experience in nonfarm wage- | -0.000 | -0.001 | -0.001 | -0.001 | -0.001 | 0.000 | 0.000 | 0.000 |
| employment (years) | (0.000) | (0.000) | (0.001) | (0.006) | (0.001) | (0.001) | (0.001) | (0.001) |
| Nonlabor income (100 USD/year) | 0.015* | 0.013 | -0.016 | -0.021 | 0.007 | 0.009 | 0.010** | 0.010** |
| | (0.008) | (0.010) | (0.027) | (0.102) | (0.009) | (0.014) | (0.004) | (0.005) |
| Distance to nearest transport (km) | -0.002 | -0.002 | 0.011 | 0.011 | -0.002 | -0.004 | 0.007* | 0.007* |
| | (0.002) | (0.002) | (0.008) | (0.012) | (0.004) | (0.005) | (0.004) | (0.004) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm return | -0.051 | -0.058* | -0.009 | -0.019 | 0.393*** | 0.453*** | -0.074 | -0.069 |
| (USD/hour) | (0.032) | (0.033) | (0.067) | (0.136) | (0.076) | (0.093) | (0.078) | (0.082) |
| Regional average nonfarm wage | 0.142* | 0.162* | 0.089 | 0.149 | 0.033 | 0.056 | 0.725*** | 0.736*** |
| (USD/hour) | (0.075) | (0.089) | (0.402) | (1.324) | (0.178) | (0.277) | (0.244) | (0.253) |
| Observations (individual-year pairs) | 6,870 | 7,679 | 1,048 | 1,054 | 1,942 | 3,158 | 1,185 | 1,190 |
| Number of individuals | 3,719 | 4,002 | 833 | 837 | 1,338 | 2,108 | 872 | 876 |
| R-squared | 0.274 | 0.273 | 0.305 | 0.284 | 0.258 | 0.118 | 0.226 | 0.221 |

*Notes:* The value of profit from self-employment activities is censored at zero. Time dummies, district dummies, dummies of negative net return, IMR and residuals from reduced form labor supply estimation, and time means of all time-variant explanatory variables are included in all estimations but not reported. All estimations used correlated random effects model. The 2SLS estimations used an instrumental variable: total years under free primary education. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

**Table 1.A.10 Individual average partial effect on probability of participation (pooled probit)**

| Dependent variable: Supply hours of labor = 1 | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | Probit | Probit | Probit | Probit | Probit | Probit | Probit | Probit |
| Fitted value of log of hourly return | -0.072*** | -0.057*** | 0.127 | -0.062 | -0.048** | -0.038** | -0.336** | -0.022 |
| (USD/hour) | (0.025) | (0.022) | (0.716) | (0.068) | (0.023) | (0.015) | (0.167) | (0.067) |
| *Individual education* | | | | | | | | |
| Fitted value of education (years) | -0.001 | - | -0.006* | - | 0.007*** | - | -0.001 | - |
| | (0.001) | - | (0.003) | - | (0.002) | - | (0.003) | - |
| Fitted value of completed primary = 1 | - | -0.008 | - | -0.023 | - | 0.005 | - | 0.025 |
| | - | (0.009) | - | (0.019) | - | (0.010) | - | (0.019) |
| Fitted value of completed secondary = 1 | - | -0.030 | - | -0.066*** | - | 0.115*** | - | 0.034** |
| | - | (0.020) | - | (0.022) | - | (0.045) | - | (0.017) |
| *Individual characteristics* | | | | | | | | |
| Age | -0.002*** | -0.002*** | 0.001 | 0.000 | 0.001 | 0.000 | 0.001* | -0.000 |
| | (0.001) | (0.001) | (0.004) | (0.000) | (0.000) | (0.000) | (0.001) | (0.000) |
| Female = 1 | 0.040*** | 0.038*** | -0.025 | -0.022*** | -0.002 | -0.007 | -0.029*** | -0.031*** |
| | (0.007) | (0.007) | (0.017) | (0.006) | (0.006) | (0.006) | (0.005) | (0.006) |
| Married = 1 | 0.032*** | 0.030*** | -0.025 | -0.018** | 0.031*** | 0.030*** | 0.055* | -0.001 |
| | (0.009) | (0.009) | (0.032) | (0.007) | (0.008) | (0.008) | (0.029) | (0.015) |
| Number of children aged 0-6 | 0.007** | 0.006** | -0.002 | -0.004 | -0.001 | -0.000 | 0.005 | -0.002 |
| | (0.003) | (0.003) | (0.007) | (0.003) | (0.003) | (0.003) | (0.004) | (0.003) |
| Number of children aged 7-12 | -0.000 | -0.000 | -0.006 | 0.002 | 0.001 | 0.002 | -0.010** | -0.003 |
| | (0.003) | (0.003) | (0.031) | (0.004) | (0.003) | (0.003) | (0.004) | (0.003) |
| *Farming variables* | | | | | | | | |
| Household land holdings (acres) | -0.000 | -0.000 | -0.000 | 0.001 | 0.000 | 0.000 | 0.001*** | 0.001** |
| | (0.000) | (0.000) | (0.004) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in own-farming (years) | 0.017*** | 0.017*** | -0.005 | -0.002** | -0.005*** | -0.006*** | -0.001 | -0.004*** |
| | (0.001) | (0.001) | (0.009) | (0.001) | (0.001) | (0.001) | (0.002) | (0.001) |
| Square of experience in own-farming | -0.000*** | -0.000*** | 0.000 | 0.000 | 0.000*** | 0.000*** | -0.000 | 0.000*** |
| (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | -0.007*** | -0.007*** | 0.030*** | 0.029*** | -0.011*** | -0.012*** | 0.001 | -0.006*** |
| | (0.001) | (0.001) | (0.004) | (0.002) | (0.002) | (0.002) | (0.004) | (0.002) |
| Square of experience in farm-wage-labor | 0.000*** | 0.000*** | -0.001*** | -0.001*** | 0.000*** | 0.000*** | -0.000 | 0.000** |
| (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |

Table 1.A.10 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Value of farm asset (100 USD) | - | - | -0.001 | 0.001 | 0.003 | 0.004* | 0.008 | -0.006 |
| | - | - | (0.005) | (0.002) | (0.002) | (0.002) | (0.008) | (0.005) |
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | 0.000 | 0.000 | -0.002 | -0.002*** | -0.001 | -0.001* | -0.001** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.000) |
| Land rental rate (USD/acre/year) | 0.005** | 0.005** | -0.001 | 0.000 | -0.002 | -0.002 | 0.002 | 0.002 |
| | (0.002) | (0.002) | (0.004) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Regional average farming return | 0.040 | 0.030 | 0.011 | 0.005 | -0.029 | -0.030 | 0.033 | -0.004 |
| (USD/hour) | (0.030) | (0.029) | (0.037) | (0.018) | (0.025) | (0.025) | (0.027) | (0.021) |
| Regional average farming wage | 0.002 | 0.003 | -0.120 | -0.031 | -0.047** | -0.054** | -0.002 | -0.010 |
| (USD/hour) | (0.023) | (0.023) | (0.353) | (0.039) | (0.023) | (0.023) | (0.020) | (0.020) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.013*** | -0.013*** | -0.009 | -0.006*** | 0.048*** | 0.049*** | 0.014 | -0.011** |
| (years) | (0.001) | (0.001) | (0.010) | (0.002) | (0.002) | (0.001) | (0.013) | (0.006) |
| Square of experience in nonfarm self- | 0.000*** | 0.000*** | 0.000 | 0.000*** | -0.001*** | -0.001*** | -0.000 | 0.000 |
| employment (years) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in nonfarm wage-employment | -0.016*** | -0.016*** | -0.011 | -0.008*** | -0.017*** | -0.019*** | 0.037*** | 0.039*** |
| (years) | (0.002) | (0.002) | (0.012) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Square of experience in nonfarm wage- | 0.000*** | 0.000*** | 0.000 | 0.000** | 0.000*** | 0.000*** | -0.001*** | -0.001*** |
| employment (years) | (0.000) | (0.000) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Nonlabor income (100 USD/year) | 0.001 | 0.000 | 0.001 | -0.002 | - | - | 0.004** | 0.000 |
| | (0.001) | (0.001) | (0.012) | (0.002) | - | - | (0.002) | (0.001) |
| Distance to nearest transport (km) | -0.000 | -0.000 | -0.001 | 0.001 | -0.001 | -0.001 | 0.003*** | 0.001* |
| | (0.001) | (0.001) | (0.008) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm return | -0.019* | -0.018* | -0.009 | -0.011 | 0.018 | 0.016 | -0.024 | -0.001 |
| (USD/hour) | (0.010) | (0.010) | (0.012) | (0.010) | (0.014) | (0.013) | (0.015) | (0.009) |
| Regional average nonfarm wage | 0.005 | 0.004 | 0.057 | 0.078*** | 0.027 | 0.028 | 0.203* | -0.024 |
| (USD/hour) | (0.033) | (0.033) | (0.071) | (0.029) | (0.031) | (0.031) | (0.123) | (0.054) |
| Observations (individual-year pairs) | 8,595 | 8,596 | 8,482 | 8,483 | 8,576 | 8,577 | 8,550 | 8,551 |
| Number of individuals | 4,429 | 4,429 | 4,367 | 4,367 | 4,412 | 4,412 | 4,405 | 4,405 |
| Pseudo R-squared | 0.427 | 0.427 | 0.476 | 0.475 | 0.509 | 0.508 | 0.551 | 0.548 |
| Log pseudolikelihood | -2339 | -2339 | -1662 | -1664 | -2260 | -2262 | -1545 | -1557 |

*Notes:* The estimate of pooled probit shows the average partial effect of schooling on the probability of participating in each activity. Time dummies, district dummies, and time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

**Table 1.A.11 Individual hours of labor supply (lognormal correlated random effects)**

| Dependent variable:<br>Log of hours worked (hours/week) | Own-farming | Own-farming | Farm-wage-labor | Farm-wage-labor | Nonfarm self-employment | Nonfarm self-employment | Nonfarm wage-employment | Nonfarm wage-employment |
|---|---|---|---|---|---|---|---|---|
| Explanatory variables | LN CRE | LN CRE | LN CRE | LN CRE | LN CRE | LN CRE | LN CRE | LN CRE |
| Fitted value of log of hourly return | 0.037 | 0.041 | 9.753 | -0.722 | -0.075 | -0.153** | -2.465* | -0.829 |
| (USD/hour) | (0.069) | (0.062) | (10.054) | (1.133) | (0.080) | (0.077) | (1.368) | (0.799) |
| *Individual education* | | | | | | | | |
| Fitted value of education (years) | -0.007** | - | 0.014 | - | 0.015 | - | 0.007 | - |
| | (0.004) | - | (0.045) | - | (0.010) | - | (0.028) | - |
| Fitted value of completed primary = 1 | - | -0.025 | - | 0.003 | - | -0.032 | - | 0.199 |
| | - | (0.027) | - | (0.286) | - | (0.071) | - | (0.231) |
| Fitted value of completed secondary = 1 | - | -0.163* | - | 0.542 | - | 0.391 | - | 0.317*** |
| | - | (0.085) | - | (0.602) | - | (0.249) | - | (0.110) |
| *Individual characteristics* | | | | | | | | |
| Age | -0.002 | -0.002 | 0.064 | 0.007 | -0.005 | -0.006** | 0.004 | -0.003 |
| | (0.001) | (0.001) | (0.057) | (0.006) | (0.003) | (0.003) | (0.007) | (0.005) |
| Female = 1 | 0.146*** | 0.144*** | -1.366 | -0.133 | 0.220** | 0.229** | 0.652** | 0.378** |
| | (0.040) | (0.040) | (1.199) | (0.158) | (0.101) | (0.103) | (0.260) | (0.185) |
| Married = 1 | -0.020 | -0.015 | -1.574 | -0.498** | -0.113 | -0.136 | 0.084 | 0.130 |
| | (0.046) | (0.046) | (1.001) | (0.198) | (0.110) | (0.110) | (0.122) | (0.119) |
| Number of children aged 0-6 | 0.010 | 0.010 | 0.114 | 0.021 | 0.005 | 0.005 | 0.008 | -0.026 |
| | (0.009) | (0.009) | (0.095) | (0.029) | (0.021) | (0.021) | (0.040) | (0.032) |
| Number of children aged 7-12 | 0.012 | 0.012 | -0.411 | 0.034 | 0.002 | 0.008 | -0.049 | -0.017 |
| | (0.009) | (0.009) | (0.431) | (0.056) | (0.021) | (0.021) | (0.043) | (0.035) |
| *Farming variables* | | | | | | | | |
| Household land holdings (acres) | -0.001 | -0.001 | -0.057 | 0.005 | -0.003 | -0.003 | -0.008 | -0.011* |
| | (0.001) | (0.001) | (0.059) | (0.009) | (0.003) | (0.003) | (0.006) | (0.006) |
| Experience in own-farming (years) | 0.022*** | 0.022*** | -0.174 | -0.045*** | -0.048*** | -0.048*** | -0.021 | -0.037*** |
| | (0.003) | (0.003) | (0.123) | (0.016) | (0.005) | (0.005) | (0.015) | (0.009) |
| Square of experience in own-farming | -0.000*** | -0.000*** | 0.003 | 0.001* | 0.001*** | 0.001*** | 0.000 | 0.001** |
| (years) | (0.000) | (0.000) | (0.002) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Experience in farm-wage-labor (years) | -0.018*** | -0.018*** | 0.083 | 0.023** | -0.019 | -0.020 | -0.049 | -0.083** |
| | (0.004) | (0.004) | (0.059) | (0.012) | (0.014) | (0.014) | (0.044) | (0.037) |
| Square of experience in farm-wage-labor | 0.000* | 0.000* | -0.002 | -0.000 | 0.000 | 0.000 | 0.001 | 0.002 |
| (years) | (0.000) | (0.000) | (0.002) | (0.000) | (0.000) | (0.000) | (0.002) | (0.001) |

Table 1.A.11 (cont'd)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Value of farm asset (100 USD) | - | - | -0.034 | 0.039** | 0.015 | 0.022 | 0.059 | -0.010 |
| | - | - | (0.070) | (0.020) | (0.019) | (0.019) | (0.065) | (0.042) |
| *Farming prices* | | | | | | | | |
| Consumer Price Index of farm products | 0.009*** | 0.009*** | -0.021 | -0.005 | -0.002 | -0.002 | -0.002 | 0.001 |
| | (0.002) | (0.002) | (0.017) | (0.006) | (0.004) | (0.004) | (0.005) | (0.005) |
| Land rental rate (USD/acre/year) | 0.003 | 0.003 | -0.053 | -0.004 | -0.005 | -0.003 | 0.020 | 0.022 |
| | (0.006) | (0.006) | (0.051) | (0.020) | (0.014) | (0.014) | (0.016) | (0.016) |
| Regional average farming return | -0.330*** | -0.327*** | 0.479 | 0.059 | 0.172 | 0.159 | 0.282 | 0.097 |
| (USD/hour) | (0.083) | (0.080) | (0.511) | (0.311) | (0.174) | (0.175) | (0.272) | (0.249) |
| Regional average farming wage | 0.139** | 0.136** | -4.744 | 0.432 | -0.106 | -0.131 | -0.078 | -0.126 |
| (USD/hour) | (0.065) | (0.065) | (5.018) | (0.598) | (0.165) | (0.166) | (0.236) | (0.238) |
| *Nonfarm variables* | | | | | | | | |
| Experience in nonfarm self-employment | -0.023*** | -0.024*** | -0.166 | -0.012 | 0.036*** | 0.038*** | 0.103 | -0.030 |
| (years) | (0.004) | (0.004) | (0.145) | (0.025) | (0.007) | (0.007) | (0.111) | (0.069) |
| Square of experience in nonfarm self- | 0.000** | 0.000** | 0.003 | 0.000 | -0.001*** | -0.001*** | -0.003 | 0.001 |
| employment (years) | (0.000) | (0.000) | (0.002) | (0.001) | (0.000) | (0.000) | (0.003) | (0.002) |
| Experience in nonfarm wage-employment | -0.062*** | -0.060*** | -0.203 | -0.039 | -0.055** | -0.060*** | 0.046*** | 0.054*** |
| (years) | (0.007) | (0.008) | (0.178) | (0.038) | (0.023) | (0.023) | (0.012) | (0.010) |
| Square of experience in nonfarm wage- | 0.001*** | 0.001*** | 0.011 | 0.001 | 0.001 | 0.001 | -0.001 | -0.001*** |
| employment (years) | (0.000) | (0.000) | (0.010) | (0.001) | (0.001) | (0.001) | (0.001) | (0.000) |
| Nonlabor income (100 USD/year) | -0.001 | -0.001 | 0.208 | 0.036 | - | - | 0.028* | 0.012 |
| | (0.004) | (0.004) | (0.169) | (0.035) | - | - | (0.016) | (0.010) |
| Distance to nearest transport (km) | -0.002 | -0.002 | -0.106 | 0.007 | 0.004 | 0.003 | 0.018* | 0.007 |
| | (0.002) | (0.002) | (0.110) | (0.017) | (0.006) | (0.006) | (0.010) | (0.007) |
| *Nonfarm prices* | | | | | | | | |
| Regional average nonfarm return | -0.065** | -0.066** | -0.001 | -0.105 | -0.078 | -0.037 | -0.146 | -0.027 |
| (USD/hour) | (0.033) | (0.033) | (0.147) | (0.108) | (0.089) | (0.092) | (0.136) | (0.107) |
| Regional average nonfarm wage | -0.142 | -0.140 | -1.577 | -0.597 | -0.324 | -0.315 | 1.591 | 0.414 |
| (USD/hour) | (0.090) | (0.090) | (0.968) | (0.382) | (0.197) | (0.197) | (1.059) | (0.649) |
| Observations (individual-year pairs) | 7,031 | 7,032 | 1,048 | 1,048 | 1,952 | 1,952 | 1,187 | 1,187 |
| Number of individuals | 3,822 | 3,822 | 833 | 833 | 1,347 | 1,347 | 874 | 874 |
| R-squared | 0.154 | 0.154 | 0.443 | 0.441 | 0.299 | 0.299 | 0.403 | 0.404 |

*Notes:* The estimate of pooled probit shows the average partial effect of schooling on the probability of participating in each activity. Time dummies, district dummies, and time means of all time-variant explanatory variables are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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# CHAPTER 2

## Land and Labor Bias of Farm Technology and the Household's Labor Allocation Decisions

### 2.1 Introduction

For over 250 years, since the first industrialization, the growth path and the preconditions of economic growth have been of great interest for many scholars. The early scholars tried to understand the process of economic development by isolating the factors that trigger structural transformation. The early studies include the observations of a process of structural transformation: the fall of the share of agriculture in employment (Petty, 1690; Clark, 1951; Lewis, 1954; Kuznets, 1957); agricultural productivity growth as the precondition of structural transformation (Rosenstein-Rodan, 1943; Schultz, 1953; Rostow, 1959; Nurkse, 1966); and the bi-sectoral economic model to describe the labor shift from rural agriculture to urban industries (Lewis, 1954; Ranis & Fei, 1961; Jorgenson, 1961; Johnston & Mellor, 1961). In the 2010s some countries in Sub-Saharan Africa (SSA) achieved structural transformation and economic growth. In spite of the stagnation of agricultural land productivity growth, the share of employment in agriculture has constantly decreased since the 2000s, from 82.5 percent in 2000 to 66.4 percent in 2018 (World Bank, 2019). Whether agriculture productivity growth advances the labor shift from the agriculture sector to the non-agriculture sector is still an open question and of great interest for efficient investment in agriculture development and economic growth of the countries in SSA.

From a macroeconomic view, on the one hand, the growth in agricultural productivity raises income per capita, which generates demand for manufacturing goods, and the higher demand for manufactures generates a reallocation of labor away from agriculture (Baumol, 1967;

Murphy et al., 1989; Kongsamut et al., 2001; Gollin et al., 2002; Ngai & Pissarides, 2007; Gollin et al., 2007). Also, productivity growth in agriculture allows labor that was otherwise used to produce food to be released to other activities if productivity growth in agriculture is faster than in manufacturing and these goods are complements in consumption (Baumol, 1967; Ngai & Pissarides, 2007). On the other hand, the increase in agricultural output leads to an increase in agricultural labor demand, resulting in the crowding-out of non-agricultural employment (Field, 1978; Wright, 1979; Corden & Neary, 1982; Krugman, 1987; Matsuyama, 1992; Mokyr, 1977, 2013). Bustos et. al. (2016) show that the effects of agricultural productivity growth on the labor shift depend on the factor-bias of farm technology and whether land productivity or labor productivity increases. While the adoption of land-augmenting technology and land productivity growth in agriculture leads to a higher share of agriculture employment at the expense of the manufacturing sector, the adoption of labor-augmenting technology and increase in labor productivity in agriculture lead to a higher share of the manufacturing sector. McGowan and Vasilakis (2019) find that improving land productivity in agriculture causes a relocation of the workforce not only from manufacturing but from tradable services as well.

From a microeconomic view, as new technologies develop, the farm household's marginal product of labor in farm and non-farm work changes, which determines the household allocation of an increment in human capital services between farm production and off-farm work (Huffman, 2001). The experience of the Philippines during the Green Revolution showed that because the adoption of modern varieties in rice farming increases the demand for labor in cropping but does not increase the return to human capital as much as in nonfarm earnings, educated farm households tend to allocate more time away from farming to nonfarm employment (Estudillo & Otsuka, 1999). How technology develops in farming is the essential determinant of farm household's labor decisions due to agricultural productivity growth. To explore the relations of farm technology, farm productivity, and the household's labor allocation, I borrow the concept of biased technology, labor-augmenting and land-augmenting technologies, from Bustos et. al. (2016), and construct a model which explains how a farm household's labor allocation decisions are affected by labor- and land-augmenting technological change.

This chapter consists of a theoretical part and an empirical part. In the theoretical part, I present a model to describe the household labor allocation responses to land- and labor-augmenting technical change in farming. The model is based on the agricultural household model developed by Singh et. al. (1986). I derive the propositions of the effects of the land- and labor-augmenting technical change from the household's decisions on labor allocations. The model is then calibrated using microdata from the Tanzania National Panel Survey (TNPS) in 2012/2013. The results of the calibrations satisfy all the propositions derived in the theoretical model.

In the empirical part, I apply the theoretical model to empirically test the relations between land and labor augmenting technical change in farming and Tanzanian maize farmers' decisions on labor allocation between on-farm and off-farm labor supply, and the demand for on-farm labor. The empirical study provides micro evidence of the effect of land- and labor-augmenting technology change on the household's decisions on labor allocations using microeconomic data from Tanzania. I exploit the variation of the adoption of land- and labor-augmenting technologies among Tanzanian maize farmers during the input voucher program from 2008 to 2013 and the gap of the potential yield before and after the adoption of technologies for the estimation of the effect of land- and labor-biased farm technology on the household's labor allocation between on-farm and off-farm activities as well as the demand of on-farm labor.

The remainder of the paper is organized as follows. In the theoretical part, section 2.2.1 illustrates the theoretical model and derives propositions of the relations of the land- and labor-augmenting technical changes and the household's labor allocation. Section 2.2.2 explains the data and strategy of the model calibration to compute the relations of the household variables and the optimal on-farm family and hired labor derived from the theoretical model. Section 2.2.3 presents the results of the model calibrations. Section 2.2.4 summarizes the key findings of the theoretical study and discussions. The empirical part begins with an explanation of the background of farming technology and labor shift in Tanzania in section 2.3.1. Section 2.3.2 describes a conceptual model and estimation strategy. Section 2.3.3 illustrates the data and descriptive statistics. Section 2.3.4 presents the conceptual and empirical model as a robustness check, followed by the results of the estimations in section 2.3.5. Section 2.3.6 concludes with the summary of the key findings of the empirical study and discussions.

## 2.2 Theoretical Study

### 2.2.1 Theoretical Model

#### 2.2.1.A Basic Model

Suppose that a unitary household maximizes the utility of all family members over consumption and leisure, subject to budget and time constraints. Consumption is considered only as consumption of money, and the household's preferences are defined over income ($Y$) and leisure ($l$); $U(Y,l;Z^u)$ where $Z^u$ are the exogenous factors which affect household preferences such as the number of adults and children. The utility function satisfies the standard assumptions: twice continuously differentiable and strictly quasi-concave.

Farm production is assumed to have a CES form with two inputs, labor ($L$) and land ($A$). Apart from the two inputs, a vector of regional and the household exogenous factors ($Z^q$) such as rainfall, crop disease, and the household head's age determine the level of farm production. The production function is specified as:

$$Q(L, A; Z^q) = e^{Z^q} T^N \left[\delta (T^L L)^{\frac{\sigma-1}{\sigma}} + (1-\delta)(T^A A)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{2.17}$$

where $T^N$ represents the Hicks-neutral technical change, and $T^L$ and $T^A$ indicate labor-augmenting and land-augmenting technical change respectively; $\sigma$ is elasticity of substitution between labor and land; $\delta$ is a parameter taking between 0 and 1. This function is not very restrictive because the usual Cobb-Douglas form is included as the limit case; $\sigma \rightarrow 1$. Farm production satisfies the diminishing marginal product of each input and the complementarity of labor and land; $Q_L > 0, Q_A > 0, Q_{LL} < 0, Q_{AA} < 0, Q_{LA} > 0$ and $Q_{LL} Q_{AA} - {Q_{LA}}^2 > 0$ where the first partial derivative of the production function with respect to labor is written as:

$$Q_L = \frac{\partial Q}{\partial L} = e^{Z^q} T^N T^L \delta \left[\delta + (1-\delta)\left(\frac{T^A A}{T^L L}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}} \tag{2.18}$$

Now assume that the off-farm labor market is flexible enough to set no constraint on household's decisions on labor. Also, suppose that the farm labor market and land market are not functioning in remote areas. These conditions are relaxed in section B and C below. The household is endowed with time $\bar{T}$ and land $\bar{A}$ and allocates endowed time $\bar{T}$ to on-farm labor ($L$), off-farm work ($O$), and leisure ($l$); $\bar{T} = L + O + l$. Hence, the household income ($Y$) comes from three sources: farm production, off-farm work, and non-labor income as:

$$Y = pQ(L, \bar{A}; Z^q) + w_o(\bar{T} - L - l) + R \tag{2.19}$$

where $p$ is the competitive price of the farm product; $w_o$ is wage rate of off-farm work; $R$ is non-labor income. Substituting equation (2.3) into the utility function yields:

$$U = \mathrm{U}\ (pQ(L, \bar{A}; Z^q) + w_o(\bar{T} - L - l) + R, l) \tag{2.20}$$

The household maximizes its utility by choosing $L$ and $l$. The optimal choices, $L*$ and $l*$ solve the following first order conditions (FOC):

$$pQ_L(L, \bar{A}) = w_o \tag{2.21}$$

$$\frac{U_l(Y, l)}{U_Y(Y, l)} = w_o \tag{2.22}$$

The interpretation of these conditions is intuitive. By equation (2.5), the household determines the amount of on-farm labor ($L*$) so that the value of the marginal product of labor ($pQ_L$) equals the market off-farm wage ($w_o$). By equation (2.6), the household chooses time allocated to leisure so that the marginal rate of substitution of leisure for income ($\frac{U_l}{U_Y}$) equals the competitive price of leisure, which is represented by the off-farm wage rate ($w_o$).

Given the form of the marginal product of labor ($Q_L$) in equation (2.2) and FOC of equation (2.5), we have the interior solution of on-farm labor as:

$$L^i = \frac{T^A \bar{A}}{T^L}\left[\left(\frac{\delta}{1-\delta}\right)\left\{\delta^{-\sigma}\left(\frac{e^{Z^q} T^N T^L}{w_o/p}\right)^{1-\sigma} - 1\right\}\right]^{\frac{\sigma}{1-\sigma}} \tag{2.23}$$

Figure 2.1 shows the interior and corner solutions of farm labor supply. If the interior solution of farm labor ($L^i$) is smaller than the endowed time deducting the optimal time on leisure ($\bar{T} - l^*$), the optimal farm labor ($L^*$) satisfies the interior solution. In this case, the household provides positive hours of labor ($\bar{T} - l^* - L^*$) to off-farm work (*O*). If the interior solution ($L^i$) is larger than the endowed time deducting the optimal time on leisure ($\bar{T} - l^*$), the optimal farm labor ($L^*$) takes a corner solution, which equals $\bar{T} - l^*$. In this case, the household does not provide labor

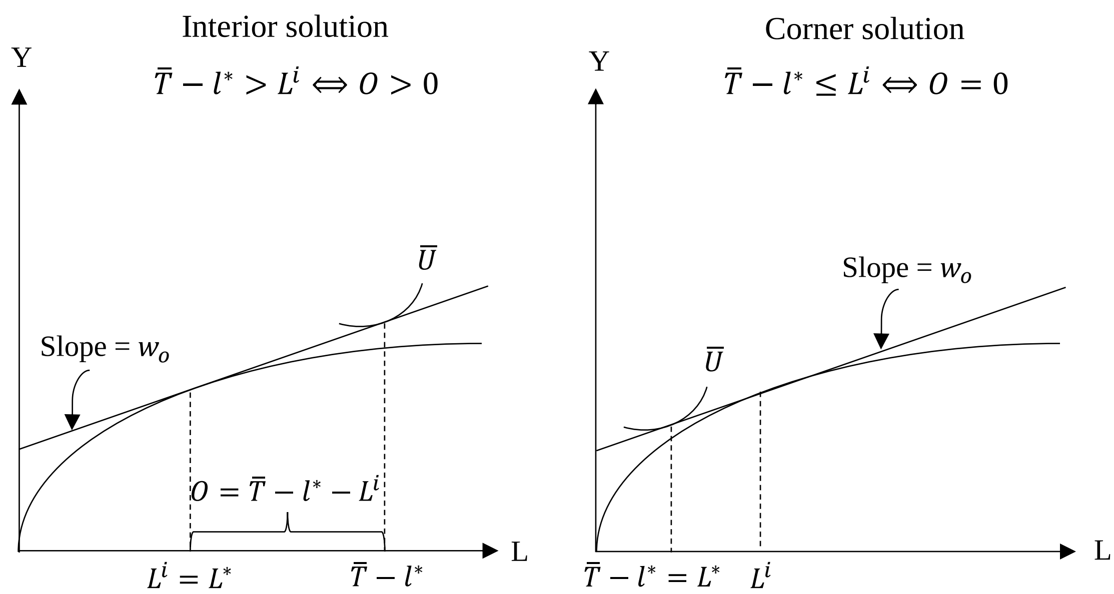


**Figure 2.1 Interior and corner solution of the basic model**

to off-farm work. The optimal farm labor takes a corner solution when the endowed time, that is, the number of adults of working age is small, the preference for leisure to income is high, or the off-farm wage rate is low. The optimal farm labor is summarized as:

$$L^* = \begin{cases} L^i & if\ \bar{T} - l^* > L^i \Leftrightarrow O > 0 \\ \bar{T} - l^* & if\ \bar{T} - l^* \le L^i \Leftrightarrow O = 0 \end{cases} \tag{2.24}$$

By equation (2.7) and equation (2.8), under flexible off-farm work opportunities and non-functioning farm labor or land market, if the household provides positive hours to off-farm work, the optimal farm labor ($L^*$) increases as the endowed land ($\bar{A}$) increases while it decreases as the real off-farm wage ($w_o/p$) increases. As for technical change, both Hicks-neutral technical change ($T^N$) and land-augmenting technical change ($T^A$) increase the optimal level of farm labor. Labor-augmenting technical change ($T^L$), on the other hand, decreases the optimal on-farm labor unless the elasticity of substitution between labor and land ($\sigma$) is sufficiently small.

If the household does not provide time to off-farm work, optimal farm labor ($L^*$) increases as endowed time ($\bar{T}$), that is, the number of adults of working age, increases. It also depends on household characteristics which determine the household preference for income and leisure. These relations are summarized in the proposition 2.1.

Proposition 2.1 *Under flexible off-farm work opportunities and non-functioning farm labor or land market,*

*(a). if the household provides positive hours to off-farm work,*

- *(i). the optimal farm labor increases as the land endowment increases while it decreases as the real off-farm wage increases;*
- *(ii). land-augmenting technical change increases optimal farm labor;*
- *(iii). labor-augmenting technical change increases or decreases optimal on-farm labor depending on the elasticity of substitution between labor and land.*

*(b). If the household does not provide time to off-farm work,*

- *(i). optimal farm labor increases as the number of adults of working age increases;*
- *(ii). optimal farm labor depends on household characteristics which determine the household's preference for income and leisure.*

### 2.2.1.B Model with On-Farm Labor Market

In this section, I relax the assumption of a non-functioning farm labor market. Assume that there is no constraint on hiring in on-farm labor or supplying labor to off-farm work. Also, assume that family labor and hired labor are perfect substitutes but have different levels of efficiency so that the off-farm wage rate is different from the wage rate of on-farm hired labor. I adopt the concept of the effective labor input, introduced by Deolalikar and Vijverberg (1987), in which effective farm labor ($L$) is given as an increasing linear function of family labor ($F$) and hired labor ($H$); $L_F > 0$ and $L_H > 0$ where $L_F$ and $L_H$ are the first partial derivatives of effective farm labor with respect to family labor and hired labor, respectively.

Same as the basic model, the household income ($Y$) comes from three sources: farm production, off-farm work, and non-labor income:

$$Y = [pQ(L, \bar{A}; Z^q) - w_h H] + w_o(\bar{T} - F - l) + R \tag{2.25}$$

where $w_h$ is wage rate of on-farm hired labor. In equation (2.9), the net income from farm production equals the gross income from farm production ($pQ$) deducting the payment to the hired labor ($w_h H$). Substituting equation (2.9) into the utility function yields:

$$U = \mathrm{U}\ (pQ(L, \bar{A}; Z^q) - w_h H + w_o(\bar{T} - F - l) + R, l) \tag{2.26}$$

The household maximizes its utility by choosing $F$, $H$, and $l$. The optimal choices, $F$*, $H$*, and $l$*, solve the following FOCs:

$$pQ_F(L, A) = pQ_L(L, A)L_F = w_o \tag{2.27}$$

$$pQ_H(L, A) = pQ_L(L, A)L_H = w_h \tag{2.28}$$

$$\frac{U_l(Y, l)}{U_Y(Y, l)} = w_o \tag{2.29}$$

Equation (2.11) and (2.12) indicate that the household determines the amount of effective farm labor ($L$*) for farm production so that the value of the marginal product of family labor ($pQ_F$) and hired labor ($pQ_H$) equal the market off-farm wage ($w_o$) and hired-in wage ($w_h$) respectively. By equation (2.13), the household allocates optimal time to leisure so that the marginal rate of substitution of leisure for income ($\frac{U_l}{U_Y}$) equals the off-farm wage ($w_o$). Given the form of the marginal product of labor ($Q_L$) in equation (2.2) and FOCs of equations (2.11) and (2.12), we have the interior solutions of on-farm labor as:

$$L^{i1} = \frac{T^A \bar{A}}{T^L}\left[\left(\frac{\delta}{1-\delta}\right)\left\{\delta^{-\sigma}\left(\frac{e^{Z^q}T^N T^L L_F}{(w_o/p)}\right)^{1-\sigma} - 1\right\}\right]^{\frac{\sigma}{1-\sigma}} \tag{2.30}$$

$$L^{i2} = \frac{T^A \bar{A}}{T^L}\left[\left(\frac{\delta}{1-\delta}\right)\left\{\delta^{-\sigma}\left(\frac{e^{Z^q}T^N T^L L_H}{(w_h/p)}\right)^{1-\sigma} - 1\right\}\right]^{\frac{\sigma}{1-\sigma}} \tag{2.31}$$

Figure 2.2 shows the possible cases of optimal on-farm family and hired labor. When $w_o > w_h$, the optimal on-farm hired labor ($H^*$) satisfies the second interior solution ($L^{i2}$), and the household does not provide on-farm family labor because the hired labor is cheaper than family labor. In this case, the household provides the endowed time deducting the optimal time on leisure ($\bar{T} - l^*$) to off-farm work.

When $w_o \leq w_h$, there are three subcases. If the second interior solution ($L^{i2}$) is larger than the endowed time deducting the optimal time on leisure ($\bar{T} - l^*$), the optimal on-farm family labor ($F^*$) takes the corner solution, which equals $\bar{T} - l^*$ while the optimal on-farm hired labor ($H^*$) takes the second interior solution deducting the optimal on-farm family labor ($L^{i2} - (\bar{T} - l^*)$). In this case, the household does not provide labor to off-farm work. If the endowed time deducting the optimal time on leisure ($\bar{T} - l^*$) is between the second and first interior solutions, the optimal on-farm family labor ($F^*$) again takes the corner solution, which equals $\bar{T} - l^*$. In this case, the household does not hire on-farm labor because family labor is cheaper than hired-in labor. Also, because the endowed time is constrained, the household does not provide labor to off-farm work. If the endowed time deducting the optimal time on leisure ($\bar{T} - l^*$) is larger than the first interior solution ($L^{i1}$), the optimal on-farm family labor ($F^*$) takes the first interior solution ($L^{i1}$), and the household does not hire on-farm labor because family labor is cheaper than hired-in labor. In this case, the household provides positive hours of labor ($\bar{T} - l^* - L^{i1}$) to

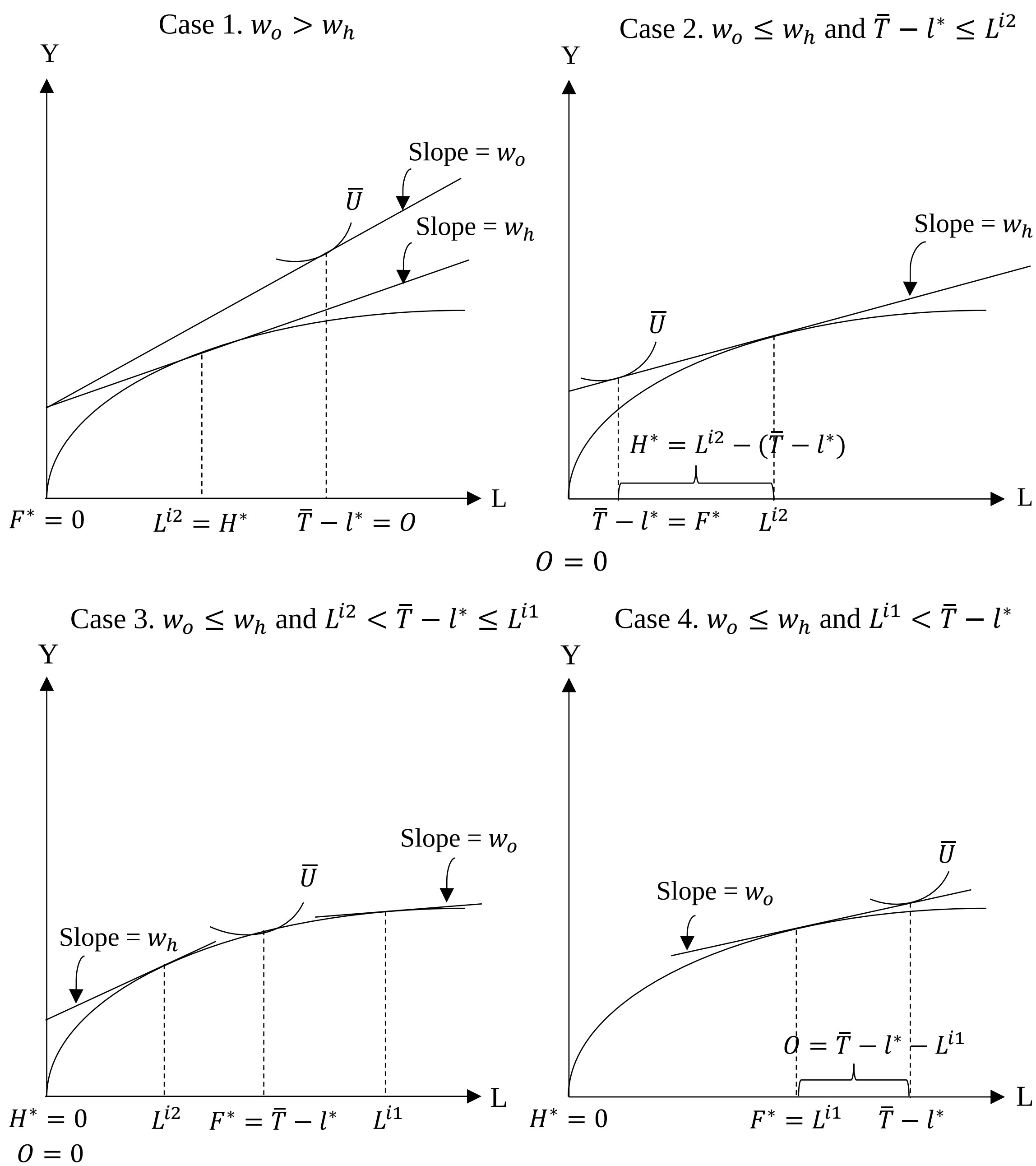


**Figure 2.2 Cases of solution with on-farm labor market**

off-farm work. The optimal on-farm family labor ($F^*$) and hired labor ($H^*$) are summarized as:

$$F^* = \begin{cases} 0 & if\ w_o > w_h \\ \bar{T} - l^* & if\ w_o \leq w_h\ and\ \bar{T} - l^* \leq L^{i1} \\ L^{i1} & if\ w_o \leq w_h\ and\ \bar{T} - l^* > L^{i1} \end{cases} \tag{2.32}$$

$$H^* = \begin{cases} L^{i2} & if\ w_o > w_h \\ L^{i2} - (\bar{T} - l^*) & if\ w_o \le w_h\ and\ \bar{T} - l^* \le L^{i2} \\ 0 & if\ w_o \le w_h\ and\ \bar{T} - l^* > L^{i2} \end{cases} \tag{2.33}$$

By equation (2.14) and (2.16), under flexible off-farm work opportunities with on-farm labor market and no land market, if the household provides positive hours of labor to both on-farm and off-farm work, the optimal family labor ($F^*$) increases as the endowed land ($\bar{A}$) increases while it decreases as the real off-farm wage ($w_o/p$) increases. Both Hicks-neutral technical change ($T^N$) and land-augmenting technical change ($T^A$) increase the optimal level of family labor ($F^*$). Labor-augmenting technical change ($T^L$), on the other hand, decreases the optimal family labor unless the elasticity of substitution between labor and land ($\sigma$) is sufficiently small. If the household does not provide labor to off-farm work, the optimal family labor ($F^*$) increases as the endowed time ($\bar{T}$), that is, the number of adults of working age, increases. It also depends on household characteristics which determines the household preference for income and leisure.

By equation (2.15), and (2.17), under flexible off-farm work opportunities with on-farm labor market and no land market, if the household provides positive hours of labor to off-farm work and hires in on-farm labor, the optimal on-farm hired labor ($H^*$) increases as the endowed land ($\bar{A}$) increases while it decreases as the real on-farm hired-in wage ($w_h/p$) increases. Both Hicks-neutral technical change ($T^N$) and land-augmenting technical change ($T^A$) increase the optimal on-farm hired labor ($H^*$). Labor-augmenting technical change ($T^L$), on the other hand, decreases the optimal hired labor unless the elasticity of substitution between labor and land ($\sigma$) is sufficiently small. If the household does not provide labor to off-farm work, the optimal on-farm hired labor ($H^*$) decreases as the endowed time ($\bar{T}$), that is, the number of adults of working age, increases. It also depends on household characteristics which determines the household preference for income and leisure. These relations are summarized in the propositions 2.2 and 2.3.

Proposition 2.2. *Under flexible off-farm work opportunities with on-farm labor market and non-functioning land market,*

*(a). if the household provides positive hours of labor to both on-farm and off-farm work,*

*(i). the optimal on-farm family labor increases as the endowed land increases; it decreases as the real off-farm wage increases;*

*(ii). land-augmenting technical change increases the optimal on-farm family labor;*

*(iii). labor-augmenting technical change increases or decreases the optimal on-farm family labor depending on the elasticity of substitution between labor and land.*

*(b). If the household does not provide labor to off-farm work,*

*(i). the optimal on-farm family labor increases as the number of adults of working age increases;*

*(ii). the optimal on-farm family labor depends on household characteristics which determine the preference for income and leisure.*

Proposition 2.3. *Under flexible off-farm work opportunities with on-farm labor market and non-functioning land market,*

*(a). if the household provides positive hours of labor to off-farm work and hires in on-farm labor,*

*(i). the optimal on-farm hired labor increases as the endowed land increases; it decreases as the real on-farm hired-in wage increases;*

*(ii). land-augmenting technical change increases the optimal on-farm hired labor;*

*(iii).* *labor-augmenting technical change increases or decreases the optimal on-farm hired labor depending on the elasticity of substitution between labor and land.*

*(b). If the household does not provide labor to off-farm work,*

*(i).* *the optimal on-farm hired labor decreases as the number of adults of working age increases;*

*(ii).* *the optimal on-farm hired labor depends on household characteristics which determine the preference for income and leisure.*

### 2.2.1.C Model with Binding Constraint on Off-Farm Job Opportunities

Heterogeneous households choose the optimal time allocation by maximizing their utilities with or without facing a binding constraint on the off-farm work opportunities. In this section, assume that the off-farm work opportunities are limited and binding at $\bar{O} > 0$. Then, the time spent on leisure is given as $l = \bar{T} - \bar{O} - F$. The corresponding household income and utility function are written as:

$$Y = [pQ(L, \bar{A}; Z^q) - w_h H] + w_o \bar{O} + R \tag{2.34}$$

$$U = \mathrm{U}\,(pQ(L, \bar{A}; Z^q) - w_h H + w_o \bar{O} + R, \bar{T} - \bar{O} - F) \tag{2.35}$$

The household maximizes its utility ($U$) with respect to family labor ($F$) and hired labor ($H$). The optimal level of family labor ($F^*$) and hired labor ($H^*$) satisfy the following FOCs:

$$pQ_F(L, A) = pQ_L(L, A)L_F = \frac{U_l(Y, l)}{U_Y(Y, l)} \tag{2.36}$$

$$pQ_H(L, A) = pQ_L(L, A)L_H = w_h \tag{2.37}$$

Equation (2.20) and (2.21) show that the household determines effective farm labor ($L$*) for farm production so that the value of the marginal product of family labor ($pQ_F$) and hired labor ($pQ_H$)

equal the marginal rate of substitution of leisure for income ($\frac{U_l}{U_Y}$) and on-farm hired-in wage ($w_h$) respectively. Given the form of the marginal product of labor ($Q_L$) in equation (2.2) and FOCs of equations (2.20) and (2.21), we have the interior solutions of on-farm labor as:

$$L^{i3} = \frac{T^A \bar{A}}{T^L}\left[\left(\frac{\delta}{1-\delta}\right)\left\{\delta^{-\sigma}\left(\frac{e^{Z^q}T^N T^L L_F}{(\frac{U_l}{U_Y}/p)}\right)^{1-\sigma} - 1\right\}\right]^{\frac{\sigma}{1-\sigma}} \tag{2.38}$$

$$L^{i2} = \frac{T^A \bar{A}}{T^L}\left[\left(\frac{\delta}{1-\delta}\right)\left\{\delta^{-\sigma}\left(\frac{e^{Z^q}T^N T^L L_H}{(w_h/p)}\right)^{1-\sigma} - 1\right\}\right]^{\frac{\sigma}{1-\sigma}} \tag{2.39}$$

Figure 2.3 shows the cases of solution of optimal on-farm family and hired labor. When $w_o > w_h$, the household does not provide on-farm family labor because hired labor is cheaper than family labor. In this case, the optimal on-farm family labor ($F^*$) takes the second interior solution ($L^{i2}$). When $w_o \leq w_h$, the household does not hire on-farm labor because family labor is cheaper than hired labor. In this case, the optimal on-farm family labor ($F^*$) takes the third interior solution ($L^{i3}$). The optimal on-farm family labor ($F^*$) and hired-in labor ($H^*$) are summarized as:

$$F^* = \begin{cases} 0 & if\ w_o > w_h \\ L^{i3} & if\ w_o \leq w_h \end{cases} \tag{2.40}$$

$$H^* = \begin{cases} L^{i2} & if\ w_o > w_h \\ 0 & if\ w_o \leq w_h \end{cases} \tag{2.41}$$

By equation (2.22) and (2.24), under binding constraints on off-farm work opportunities, if the household provides positive hours to on-farm family labor, the optimal family labor ($F^*$) depends on the household characteristics which determine the preference for income and leisure. If the household hires on-farm labor, the optimal on-farm hired labor ($H^*$) increases as the

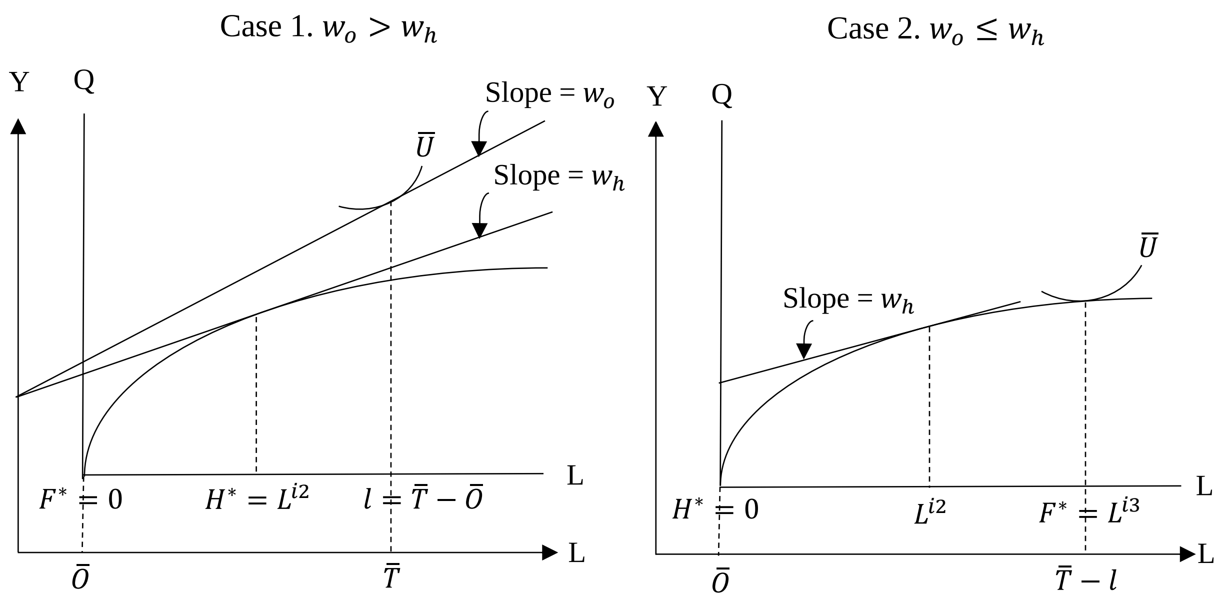


**Figure 2.3 Cases of solution with binding constraint on off-farm work opportunities**

endowed land ($\bar{A}$) increases while it decreases as the real on-farm hired-in wage ($w_h/p$) increases. Both Hicks-neutral technical change ($T^N$) and land-augmenting technical change ($T^A$) increase the optimal on-farm hired labor ($H^*$). Labor-augmenting technical change ($T^L$), on the other hand, decreases the optimal hired labor unless the elasticity of substitution between labor and land ($\sigma$) is sufficiently small. These relations are summarized in the propositions 2.4. and 2.5.

Proposition 2.4. *Under binding constraints on off-farm work opportunities and a non-functioning land market, if the household provides positive hours to on-farm labor,*

*(i). the optimal on-farm family labor depends on household's characteristics which determine the household's preference for income and leisure.*

Proposition 2.5. *Under binding constraints on off-farm work opportunities and a non-functioning land market, if the household hires on-farm labor,* *(i).* *the optimal on-farm hired labor increases as the endowed land increases; it decreases as the real on-farm hired-in wage increases;*

*(ii).* *land-augmenting technical change increases the optimal on-farm hired labor;*

*(iii).* *labor-augmenting technical change increases or decreases the optimal on-farm hired labor depending on the elasticity of substitution between labor and land.*

### 2.2.2 Data and Strategy of Model Calibration

#### 2.2.2.A Identification of the Household Regime and Summary of Propositions

Heterogeneous households choose optimal time allocations by maximizing their utilities. Each household chooses the interior or corner solutions of the on-farm family labor supply and hired labor demand given the exogenous household and regional variables. With the existence of the on-farm labor market, the interior and corner solutions of the optimal on-farm family labor supply and hired labor demand present six cases. According to the six solution cases, the households are classified into six regimes, which are interpreted according to the two observable and one unobservable criteria: whether the household spends positive hours on off-farm work, whether the household hires in positive hours of on-farm labor, and whether the constraints on off-farm work opportunities are binding. Table 2.1. shows the classification of the household regimes. Each regime corresponds to a case in Figure 2.2 or Figure 2.3. The corresponding case to each regime is presented in the table. The optimal choices of on-farm family labor ($F^*$) and hired labor ($H^*$) in each regime are given by the functions of the different set of variables. Those relations correspond to the propositions 2.2, 2.3, 2.4, and 2.5. Table 2.2. summarizes the relations.

**Table 2.1 Classification of household regime**

| | The household regime | | | | | |
|---|---|---|---|---|---|---|
| | Regime I | | Regime II | | Regime III | Regime IV |
| | Regime (i) | Regime (ii) | Regime (iii) | Regime (iv) | Regime (v) | Regime (vi) |
| **Observable criteria** | | | | | | |
| Spend positive hours on off-farm work | Yes | Yes | Yes | Yes | No | No |
| Hire in positive hours of on-farm labor | Yes | Yes | No | No | No | Yes |
| **Unobservable criteria** | | | | | | |
| Off-farm job constraint is binding | No | Yes | No | Yes | No | No |
| Case no. in Figure 2.2 | Case 1 | - | Case 4 | - | Case 3 | Case 2 |
| Case no. in Figure 2.3 | - | Case 1 | - | Case 2 | - | - |

**Table 2.2 Household regime and optimal on-farm labor**

| The household regime | Optimal on-farm family labor ($F^*$) | Proposition | Optimal on-farm hired labor ($H^*$) | Proposition |
|---|---|---|---|---|
| Regime (i) | 0 | - | $L^{i2}(\bar{A}, w_h, \sigma, T^A, T^L)$ | Proposition 2.3.(a) |
| Regime (ii) | 0 | - | $L^{i2}(\bar{A}, w_h, \sigma, T^A, T^L)$ | Proposition 2.5 |
| Regime (iii) | $L^{i1}(\bar{A}, w_o, \sigma, T^A, T^L)$ | Proposition 3.2.(a) | 0 | - |
| Regime (iv) | $L^{i3}(Z^u)$ | Proposition 3.4 | 0 | - |
| Regime (v) | $\bar{T} - l^*(Z^u)$ | Proposition 3.2.(b) | 0 | - |
| Regime (vi) | $\bar{T} - l^*(Z^u)$ | Proposition 3.2.(b) | $L^{i2} - (\bar{T} - l^*(Z^u))$ | Proposition 2.3.(b) |

*Notes:* The specifications of $L^{i1}$, $L^{i2}$, and $L^{i3}$ are given in equations (2.14), (2.15), and (2.22) respectively. $Z^u$ is the set of variables which determine the household's utility level including household's preference parameters, non-labor income, and meso-variables.

#### 2.2.2.B Data

I calibrate the model using data from the Tanzania National Panel Survey (TNPS[4]) and show the relations of the household variables and the optimal on-farm family labor supply and hired labor demand. The relations correspond to the propositions in section 2.2.1. I use data from household, agriculture, and community questionnaires in mainland for the households who cultivate maize. Among 3,021 households in the mainland, 2,892 households cultivate maize.

**Table 2.3 Number of households in each regime by year**

| | 2008/2009 | | 2010/2011 | | 2012/2013 | |
|---|---|---|---|---|---|---|
| Regime | Obs. | Share | Obs. | Share | Obs. | Share |
| Regime I[a] | 189 | 0.11 | 296 | 0.15 | 434 | 0.18 |
| Regime II[b] | 297 | 0.18 | 547 | 0.28 | 709 | 0.29 |
| Regime III[c] | 723 | 0.43 | 726 | 0.38 | 759 | 0.31 |
| Regime IV[d] | 471 | 0.28 | 359 | 0.19 | 525 | 0.22 |
| Total | 1680 | 1.00 | 1928 | 1.00 | 2427 | 1.00 |

*Notes:*
[a] The household spends time on off-farm work and hires in on-farm labor.
[b] The household spends time on off-farm work and does not hire in on-farm labor.
[c] The household does not spend time on off-farm work or hire in on-farm labor.
[d] The household does not spend time on off-farm work but hires in on-farm labor.

Table 2.3 displays the number of households in each regime by year. Because we cannot identify whether the household faces a binding constraint on off-farm work opportunities by the observable variables, in Table 2.3 the households are classified into 4 regimes by two observable criteria. Table 2.3 shows that the number of households who spend time on off-farm work, that is the number of households in regime I and II, constantly increases from 2008/2009 to 2012/2013. Although just 29 percent of households spend time on off-farm work in 2008/2009, 47 percent of households spend time on off-farm work in 2012/2013. Also, the share of households who hire in on-farm labor, that is the number of households in regime I and IV, increases from 39 percent in

[4] TNPS was implemented by the Tanzania National Bureau of Statistics.

2008/2009 to 40 percent in 2012/ 2013. For the balancing of the number of households in each regime, I use the data from 2012/2013 for the model calibrations.

Table 2.4 shows summary statistics of the household and district variables in 2012/2013 by household regime. Although in the theoretical model the households in the first (I) regime do not do on-farm work (Figure 2.2, Case 1), in practice (beyond the theoretical model) they spend time on on-farm work. This would be because the expected off-farm wage varies across the household members, and for some members the expected off-farm wage could be lower than the on-farm wage even if the household average expected off-farm wage among all members is higher than the household average expected on-farm wage. For those who face a lower expected off-farm wage than the on-farm wage, there exists the incentive to spend time on on-farm work. In terms of the solutions of the optimal on-farm family labor, the households in regime II take the interior solution of the optimal on-farm family labor while the households in regime III and IV take the corner solution of the optimal on-farm family labor (Figure 2.2, Cases 2, 3, and 4). The households in regime II, as described by the theoretical model, have more adults of working age, that is, a larger time endowment. The households in regime II also have more children aged from 0 to 3 than the households in regime III and IV. This corresponds to the theoretical model if the household with more infants and toddlers has a higher preference for money to leisure. The off-farm wage and on-farm hired-in wage at the household level also coincide with the model. The average off-farm wage of the households in regime I is higher than that of the households in regime II (Figure 2.2, Cases 1 and 4) while the average on-farm hired-in wage is higher for the households in regime IV than for the household in regime I (Figure 2.2, Cases 1 and 2). In case the household is facing a binding constraint on the off-farm work opportunities (Figure 2.3), the level of the constraint is likely to be tighter for the households in regime II than for the

### Table 2.4 Household and district variables in 2012/2013 by household regime

| | Regime I [a] | | | Regime II[b] | | | Regime III[c] | | | Regime IV[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | P50 | Sd | Mean | P50 | Sd | Mean | P50 | Sd | Mean | P50 | Sd |
| **Household variable** | | | | | | | | | | | | |
| *Labor allocation* | | | | | | | | | | | | |
| On-farm family labor (day) | 123.5 | 82.5 | 139.1 | 117.8 | 82.0 | 112.7 | 127.7 | 94.0 | 135.0 | 116.0 | 82.0 | 127.2 |
| On-farm hired labor (day) | 32.9 | 14.0 | 60.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 31.5 | 16.0 | 43.8 |
| Off-farm labor (day) | 193.3 | 84.0 | 258.5 | 131.9 | 55.8 | 171.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Household characteristics* | | | | | | | | | | | | |
| Land holdings (acres) | 10.8 | 4.4 | 35.4 | 5.6 | 2.9 | 11.7 | 6.9 | 4.0 | 9.8 | 10.6 | 5.2 | 23.6 |
| Number of adults aged 15-65 | 3.3 | 3.0 | 1.9 | 3.1 | 3.0 | 1.6 | 2.9 | 2.0 | 1.9 | 2.6 | 2.0 | 1.8 |
| Number of children aged 0-3 | 0.8 | 1.0 | 0.9 | 0.8 | 1.0 | 0.9 | 0.7 | 1.0 | 1.1 | 0.7 | 0.0 | 1.0 |
| Number of children aged 3-6 | 0.5 | 0.0 | 0.7 | 0.5 | 0.0 | 0.7 | 0.5 | 0.0 | 0.7 | 0.5 | 0.0 | 0.7 |
| Number of children aged 7-14 | 1.3 | 1.0 | 1.3 | 1.3 | 1.0 | 1.3 | 1.3 | 1.0 | 1.3 | 1.2 | 1.0 | 1.3 |
| 1=HH is female | 0.20 | 0.00 | 0.40 | 0.23 | 0.00 | 0.42 | 0.24 | 0.00 | 0.42 | 0.26 | 0.00 | 0.44 |
| HH's education (years) | 6.0 | 7.0 | 4.3 | 5.2 | 7.0 | 3.3 | 4.4 | 6.0 | 3.2 | 4.7 | 6.0 | 3.5 |
| 1=member belongs to SACCO | 0.14 | 0.00 | 0.34 | 0.04 | 0.00 | 0.18 | 0.02 | 0.00 | 0.14 | 0.04 | 0.00 | 0.20 |
| *Wage at household level* | | | | | | | | | | | | |
| Off-farm wage (USD/hour) | 4.0 | 1.4 | 19.4 | 3.7 | 1.5 | 8.0 | - | - | - | - | - | - |
| On-farm wage (USD/hour) | 1.3 | 0.9 | 1.9 | - | - | - | - | - | - | 1.4 | 0.9 | 1.8 |
| **District variable** | | | | | | | | | | | | |
| Off-farm wage (USD/hour) | 1.3 | 1.1 | 0.5 | 1.2 | 1.1 | 0.5 | 1.3 | 1.2 | 0.6 | 1.3 | 1.2 | 0.6 |
| On-farm wage (USD/day) | 5.2 | 4.8 | 1.4 | 5.2 | 4.9 | 1.4 | 5.2 | 4.9 | 1.2 | 5.3 | 4.9 | 1.3 |
| Local price of maize (USD/kg) | 1.0 | 1.0 | 0.2 | 0.9 | 1.0 | 0.2 | 0.9 | 1.0 | 0.2 | 0.9 | 1.0 | 0.2 |
| Observations | | 434 | | | 709 | | | 759 | | | 525 | |

*Notes:* USD used in the table is 2011 PPP USD. The mean and median of wages at household level are computed by using only positive values of wages. SACCO refers to Savings and Credit Co-Operative.

[a] The household spends time on off-farm work and hires in on-farm labor.

[b] The household spends time on off-farm work and does not hire in on-farm labor.

[c] The household does not spend time on off-farm work or hire in on-farm labor.

[d] The household does not spend time on off-farm work but hires in on-farm labor.

households in regime I. The share of households who have a female household head is larger, the household head's education level is lower, and the share of households who have a member who belongs to Savings and Credit Co-Operative (SACCO) is lower in regime II than in regime I. In fact, the households in regime I provide 193.3 days to off-farm work, which is greater than 131.9 days provided by those in regime II.

### 2.2.2.C Parameter Values

Table 2.5 presents the values of the calibration parameters and a brief explanation of how the value of each parameter is selected. The weighted mean of each variable among the households in each regime is selected as the parameter value if the variable is available in TNPS 2012/2013. The values of share parameter ($\delta$) and EOS (elasticity of substitution) between land and labor ($\sigma$) are taken from my estimates of the CES production function. The detail of the estimation of the CES production function is in section 2.3.2.B. The land- and labor-augmenting technical change ($T^A$ and $T^L$), Hicks-neutral technical change ($T^N$), and the efficiency of hired labor ($L_H$) are normalized at one unless the variable is used as the indefinite number in the model calibration. The value of efficiency of family labor ($L_F$), 2.54, is collected from the estimate by Deolalikar and Vijverberg (1987), who introduced the concept of effective farm labor that I applied in the theoretical model.

The strategy of the calibration exercise is to restrict the values of the farm production variables ($e^{Z^q}$) to match the observations of on-farm family and hired labor (*F* and *H*) variables from TNPS 2012/2013. The model is then calibrated to show the relations of the optimal on-farm family and hired labor and other variables to correspond to the propositions in section 2.2.1. For the households in regime I, I used equation (2.14) to set the farm production variables ($e^{Z^q}$) by

**Table 2.5 Calibration parameters**

| Parameter | | Value | | | | Explanations |
|---|---|---|---|---|---|---|
| | | Regime I [a] | Regime II[b] | Regime III[c] | Regime IV[d] | |
| **Household parameters** | | | | | | |
| $\bar{A}$ | Land holdings (acres) | 8.04 | 4.94 | 5.87 | 9.07 | Weighted mean from TNPS 2012/2013 |
| $M$ | Number of adults aged 15-65 | 3.09 | 2.94 | 2.71 | 2.37 | Weighted mean from TNPS 2012/2013 |
| $\bar{T}$ | Time endowment (day) | 1127.85 | 1073.1 | 989.15 | 865.05 | Number of adults multiplied by 365 |
| $O$ | Off-farm labor (day) | 172.54 | 127.63 | 0.00 | 0.00 | Weighted mean from TNPS 2012/2013 |
| **Farming parameters** | | | | | | |
| $F$ | On-farm family labor (day) | 119.17 | 110.27 | 124.82 | 108.58 | Weighted mean from TNPS 2012/2013 |
| $H$ | On-farm hired labor (day) | 28.52 | 0.00 | 0.00 | 32.91 | Weighted mean from TNPS 2012/2013 |
| $\delta$ | Share parameter | 0.82 | 0.80 | 0.82 | 0.85 | Weighted mean of author's estimates[e] |
| $\sigma$ | EOS between land and labor | 0.67 | 0.70 | 0.69 | 0.65 | Weighted mean of author's estimates[e] |
| $e^{Z^q}$ | Farm production variables | 10.30 | 2.61 | - | 21.18 | Set to equalize right and left-hand sides[f] |
| $L_F$ | Efficiency of family labor | - | 2.54 | - | - | From Deolalikar and Vijverberg (1987) |
| $L_H$ | Efficiency of hired labor | 1.00 | - | - | 1.00 | Normalization |
| $T^A$ | Land-augmenting technical change | 1.00 | 1.00 | 1.00 | 1.00 | Normalization |
| $T^L$ | Labor-augmenting technical change | 1.00 | 1.00 | 1.00 | 1.00 | Normalization |
| $T^N$ | Hicks-neutral technical change | 1.00 | 1.00 | 1.00 | 1.00 | Normalization |
| **District parameters** | | | | | | |
| $w_o$ | Off-farm wage (USD/hour) | 1.24 | 1.15 | 1.28 | 1.27 | Weighted mean from TNPS 2012/2013 |
| $w_h$ | On-farm wage (USD/day) | 5.23 | 5.25 | 5.29 | 5.34 | Weighted mean from TNPS 2012/2013 |
| $p$ | Local market price of maize (USD/kg) | 0.96 | 0.95 | 0.91 | 0.96 | Weighted mean from TNPS 2012/2013 |
| Observations | | 434 | 709 | 759 | 525 | Number of households |

*Notes:* USD used in the table is 2011 PPP USD.
[a] The household spends time on off-farm work and hires in on-farm labor.
[b] The household spends time on off-farm work and does not hire in on-farm labor.
[c] The household does not spend time on off-farm work or hire in on-farm labor.
[d] The household does not spend time on off-farm work but hires in on-farm labor.
[e] The detail of the estimation of share parameters ($\delta$) and EOS ($\sigma$) is in section 2.3.2.B.
[f] The detail of setting production variables is explained in section 2.2.2.C.

equalizing the right and left-hand sides of the equation. For the households in regime II and IV, equation (2.23) is used to set the farm production variables ($e^{Z^q}$) while the observed on-farm family labor (*F*) is used as the value of the endowed time deducting the optimal time on leisure ($\bar{T} - l^*$) for the households in regime IV because the households in regime IV does not spend time on off-farm work. By using set values of the farm production variables ($e^{Z^q}$), the model is calibrated by changing endowed land, off-farm or on-farm wage, land-augmenting technical change, labor-augmenting technical change, and EOS between land and labor respectively to derive the relations of those variables and the optimal on-farm family and hired labor. Those relations correspond to the propositions in section 2.2.1.

### 2.2.3 Result of Model Calibration

#### 2.2.3.A Bias of Farm Technology and On-Farm Family Labor

Figure 2.4 shows the relations of optimal on-farm family labor and the household variables. Panel A, B, C, and D of Figure 2.4 correspond to propositions 2.2.a.(i), (i), (ii), and (iii) respectively. The calibration was done by using the weighted mean of the variables of the households in regime II. The figures show that the relations of the household variables and optimal on-farm family labor all satisfy the propositions. In panel A and C, the land holdings and the land-augmenting technical change both show positive correlations with the optimal on-farm family labor regardless of the value of the EOS between land and labor. In panel B, the off-farm wage is negatively correlated with the optimal on-farm family labor at any value of the EOS. In panel D, on the other side, labor-augmenting technical change displays both positive and negative correlations with the optimal on-farm family labor depending on the value of the EOS between land and labor.

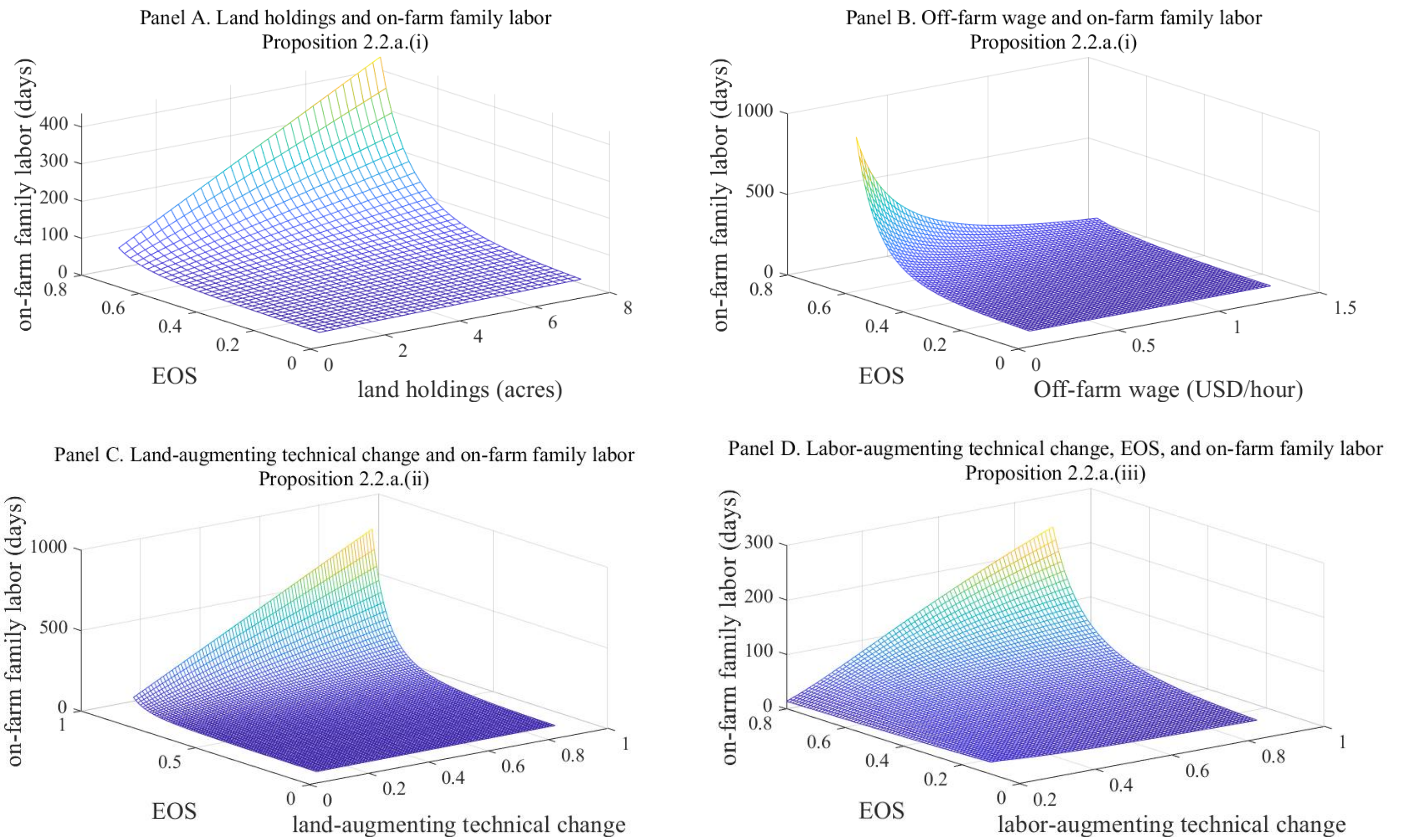


**Figure 2.4 Relations of optimal on-farm family labor and other variables**

The calibration results show that an additional one acre of landholdings increases the optimal on-farm family labor by 22.3 person-days from 110.3 person-days to 132.6 person-days at the weighted mean of landholdings, 4.94 acres, and EOS between land and labor, 0.70. The effect of additional land holdings increases as the EOS increases. The increase in one dollar per hour off-farm wage is accompanied by the decrease in the optimal on-farm family labor by 70.2 person-days when off-farm wage and EOS take the weighted means, 1.15 USD per hour and 0.70 respectively. The effect of off-farm wage increases as the EOS between land and labor increases or off-farm wage decreases. Since the optimal on-farm family labor is the multiplication of the land-augmenting technical change and other variables, one percent increase in land-augmenting technical change is associated with one percent increase in the optimal on-farm family labor. Hence, when EOS takes the weighted mean, 0.70, 10 percent land-augmenting technical change from 1.0 to 1.1 increases the optimal on-farm family labor by 10 percent from 110.3 person-days to 121.3 person-days. The effect of the land-augmenting technical change increases as the EOS between land and labor increases. The labor-augmenting technical change, on the other side, increases and decreases the optimal on-farm family labor depending on the values of the EOS between land and labor. When the EOS is greater than 0.56, labor-augmenting technical change is positively correlated with the optimal on-farm family labor at any value of labor-augmenting technical change between 0 and 1. When labor-augmenting technical change is smaller than 0.23, the EOS is negatively correlated with the optimal on-farm family labor at any value of the EOS between 0 and 1. When EOS takes the weighted mean, 0.70, the increase in labor-augmenting technical change from 1.0 to 1.1 results in the increase in the optimal on-farm family labor by 4.5 person-days from 110.3 person-days to 114.8 person-days. The effect of labor-augmenting technical change is positive because EOS takes 0.70, which is greater than 0.23.

### 2.2.3.B Bias of Farm Technology and On-Farm Hired Labor

Figure 2.5 shows the relations of optimal on-farm hired labor and the household variables. Panel A, B, C, and D of Figure 2.5 correspond to propositions 2.3.a.(i) and 2.5.(i), 2.3.a.(i) and 2.5.(i), 2.3.a.(ii) and 2.5.(ii), and 2.3.a.(iii) and 2.5.(iii) respectively. The calibration was done by using the weighted mean of the variables of the households in regime I. The figure shows that the propositions are all satisfied by the relations of the household variables and the optimal on-farm hired labor. In panel A and C, the land holdings and the land-augmenting technical change both show the positive correlations with the optimal on-farm hired labor regardless of the value of the EOS between land and labor. In panel B, the off-farm wage is negatively correlated with the optimal on-farm hired labor at any value of the EOS. In panel D, on the other side, labor-augmenting technical change displays both positive and negative correlations with the optimal on-farm hired labor depending on the value of the EOS between land and labor.

The calibration results show that an additional one acre of landholdings increases the optimal on-farm hired labor by 3.5 person-days from 28.5 person-days to 32.1 person-days at the weighted mean of landholdings, 8.04 acres, and EOS between land and labor, 0.67. The effect of additional land holdings increases as the EOS increases. Additional one dollar per hour on-farm hired-in wage decreases the optimal on-farm family labor by 10.1 person-days when on-farm hired-in wage and EOS take the weighted means, 5.23 USD per day and 0.67 respectively. The effect of on-farm hired-in wage increases as the EOS between land and labor increases or on-farm wage decreases. Similar to the optimal on-farm family labor, one percent increase in land-augmenting technical growth is accompanied by one percent increase in the optimal on-farm

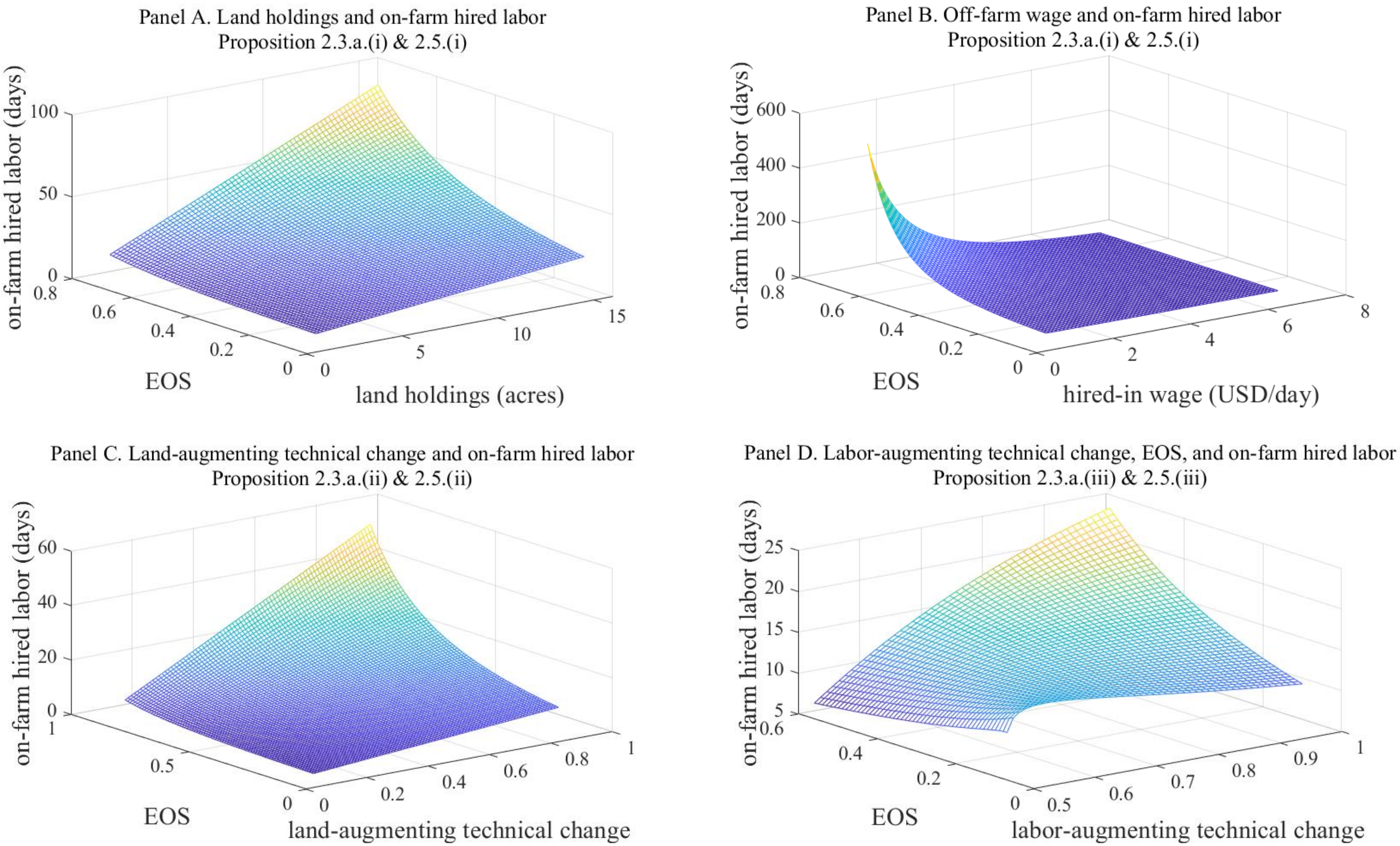


**Figure 2.5 Relations of optimal on-farm hired labor and other variables**

hired labor. Hence, when EOS takes the weighted mean, 0.67, 10 percent land-augmenting technical growth from 1.0 to 1.1 increases the optimal on-farm hired labor by 10 percent from 28.5 person-days to 31.4 person-days. The effect of the land-augmenting technical change increases as the EOS between land and labor increases. The labor-augmenting technical change, on the other side, increases and decreases the optimal on-farm hired labor depending on the values of the EOS between land and labor. When the EOS is greater than 0.39, labor-augmenting technical change is positively correlated with the optimal on-farm hired labor at any value of labor-augmenting technical change between zero and one. When labor-augmenting technical change is smaller than 0.65, the EOS is negatively correlated with the optimal on-farm family labor at any value of the EOS between zero and one. When the EOS takes the weighted mean, 0.67, the increase in labor-augmenting technical change from 1.0 to 1.1 results in the increase in the optimal on-farm hired labor by 3.5 person-days from 28.5 person-days to 32.0 person-days. The effect of labor-augmenting technical change is positive because EOS takes 0.67, which is greater than 0.39.

### 2.2.4 Conclusion

This study provides a theoretical model to explain how land and labor-augmenting technical changes determine the household's optimal on-farm family and hired labor. The model is based on the agricultural household model, which was developed by Singh et. al. (1986). I derive the propositions of the effects of land and labor-augmenting technical change on the household's decisions on labor. The model calibration results satisfy all the propositions derived in the theoretical model. The calibrations are done by using microdata from Tanzania National Panel Survey (TNPS) in 2012/2013. The households are, as described in the theoretical model, classified into regimes by whether they face a binding constraint on the off-farm work opportunities and whether they are in off-farm or on-farm labor markets.

The results show that labor- and land-augmenting technical changes could have the opposite effects on the household's decisions on labor. When the EOS takes the weighted mean, the land-augmenting technical change from 1.0 to 1.1 increases the optimal on-farm family labor from 110.3 person-days to 121.3 person-days and the optimal on-farm hired labor from 28.5 person-days to 31.4 person-days. Labor-augmenting technical change, on the other side, increases and decreases the optimal on-farm family labor depending on the values of the EOS between land and labor. Labor-augmenting technical change is negatively correlated with the optimal on-farm family labor and on-farm hired labor for at least some value of labor-augmenting technical change between 0 and 1 when EOS is smaller than 0.56 and 0.39 respectively. When the EOS takes the weighted mean, the increase in labor-augmenting technical change from 1.0 to 1.1 results in the increase in the optimal on-farm family labor by 4.5 person-days from 110.3 person-days to 114.8 person-days and the optimal on-farm hired labor by 3.5 person-days from 28.5 person-days to 32.0 person-days.

The results suggest that depending on the conditions of a country such as the level of EOS between land and labor and the constraints on off-farm work opportunities, labor-augmenting farm technologies have a good potential for accelerating structural transformation in SSA countries.

## 2.3 Empirical Study

### 2.3.1 Farm Technology and Labor Shift in Tanzania

In Tanzania, the agriculture sector has long been identified as the key driver for economic development. Since the Tanzania Development Vision 2025[5] raised the priority of agricultural sector development for the acceleration of the economic growth and poverty reduction in 1999, the government has allocated a lot of resources into agricultural programs. In 2003, the government of Tanzania agreed to allocate a minimum of 10 percent of its budget to the agricultural and rural sector, which was reaffirmed through the Comprehensive Africa Agricultural Development Program (CAADP) in 2010. From 2008 to 2013, the government invested approximately 300 million USD including a concessional loan of 160 million USD from the World Bank to provide small-scale maize and rice farmers with input vouchers of fertilizer and improved seeds (World Bank, 2014).

In spite of the government's consistent effort for agricultural productivity growth, aggregate productivity has shown little growth in the last 20 years, which remains only 20 to 30 percent of potential yields (World Bank, 2009). Yet, in terms of the labor reallocation in the development process, the share of employment (measuring in terms of share of number of persons doing some farming) in agriculture has constantly decreased since 2000, from 82.5 percent in 2000 to 66.4 percent in 2018, in Tanzania (World Bank, 2019). Whether agriculture productivity growth advances the labor shift from agriculture sector to the non-agriculture sector is still an open question and of great interest for efficient investment in agriculture development and economic growth of the country.

Following the success of high-yielding varieties (MVs) of rice and wheat in Latin American and Asian countries in the mid-1960s, large numbers of MVs were released in Sub-

[5] Tanzania Development Vision 2025 was first adopted in 2000 with the goal of transforming the country into a strong and competitive middle income economy by 2015. During the first five year plan, the government worked to address infrastructure needs within the country's energy and transport sectors, improve productivity in the agriculture sector, increase the number of skilled laborers, and enhanced the business environment within the country (Tanzania Invest, 2019).

Saharan African countries in the 1960s and 1970s (Evenson & Gollin, 2003). In spite of the release of the MVs, few farmers adopted MVs in the 1960s and 1970s in Sub-Saharan Africa. Because MVs respond to fertilizer better than traditional varieties, the diffusion of MVs has been always considered jointly with the application of the fertilizer.

In Tanzania, the government operated the input subsidy program in the 1970s and early 1980s to promote the adoption of fertilizer and improved seeds. The program was, however, criticized for being costly, inefficient, overwhelmingly beneficial to large farmers, and detrimental to the private sector (Carter et al., 2013). Because of the critiques, input subsidies were phased out during agricultural market liberalization in 1990s (Putterman, 1995). Ten years later, the government instituted a transport subsidy for fertilizer, which was replaced with a voucher-based subsidy called the national agricultural input voucher scheme (NAIVS) in 2008. In 2008, the adoption rate of improved seeds and fertilizer was still low; improved seeds were adopted by eight percent of maize farmers, and only three percent of farmers applied fertilizer (National Breau of Statistics, 2012). NAIVS was started in 56 pilot districts in 2008 and extended to 65 districts in 2009 as part of a three-year program until 2013. Learning from the inefficiency of the past universal price subsidy programs, NAIVS was targeted to the high-potential small-scale farms (Druilhe & Barreiro-Hurlé, 2012). The eligible households are those who (1) are able to top up the price of inputs purchased with the voucher; (2) are literate; (3) do not cultivate more than 1 ha of maize or rice; with priority to be given to female headed households who have used little or no modern inputs on maize or rice in the prior five years (Pan & Christiaensen, 2012).

The program resulted in an increase in maize yields by an average of 433 kg per acre among farmers receiving subsidized maize seed and fertilizer. 47 percent of the farmers who had never tried improved inputs prior to the NAIVS continued to purchase seed on their own, and 19 percent continued to purchase fertilizer (World Bank, 2014). However, because of the targeting structure of the program and the reported operational problems and fraud, the number of farmers who were benefitted by the program was limited. Aggregate productivity of maize displayed almost no growth from 1990 to 2012 in Tanzania (World Bank, 2014). The productivity remains only 20 to 30 percent of potential yield (World Bank, 2009).

Compared to improved seeds and fertilizer, the government has put little effort into promoting other farming technologies such as irrigation, sprayer, pesticide, herbicide, animal traction, or tractor uses. Given the fact that the average size of the land holdings remains small, ranging from 0.2 to 2.0 hectares, and only 26 percent of potentially arable land is currently farmed in Tanzania (World Bank, 2014), there is much potential for increasing labor productivity by increasing farm size and the adoption of labor-augmenting technologies.

Also, in terms of structural transformation, that is the labor shift from the farming sector to the non-farm sector, labor productivity growth in agriculture sector contributes to the labor shift more than land productivity growth (Bustos et al., 2016). Because the share of employment in agriculture has constantly decreased since the 2000s, from 82.5 percent in 2000 to 66.4 percent in 2018 (World Bank, 2019) in spite of the stagnation of the agricultural land productivity growth, the relation between the adoption of land or labor-augmenting technology, agricultural productivity, and the labor shift from farming sector to non-farm sector is still an open question. In the following sections I estimate the effect of land- and labor-augmenting technologies on the household decisions on labor allocation by exploiting the variation in the potential yield increase by the adoption of farm technologies.

### 2.3.2 Conceptual Model and Estimation Strategy

#### 2.3.2.A A Model of Biased Farm Technology and Labor Allocation

I assume that a unitary household maximizes income (*Y*) given the endowment of labor ($\bar{M}$) and cultivated land ($\bar{A}$). The household allocates the endowed labor between on-farm family labor (*F*) and off-farm labor (*O*). Suppose that land market is not functioning in rural areas but the household faces a perfect farm labor market where the household hires in farm labor at a given wage without restrictions. The household's income comes from farm production and off-farm activity. It is written as:

$$Y = [pQ(L, \bar{A}; Z^q) - w^h H] + w^o(\bar{M} - F) \tag{2.42}$$

where $p$ is the competitive price of the farm product; $Q$ is farm production which is determined by two inputs, labor (*L*) and land (*A*), and the vector of exogenous variables ($Z^q$) such as rainfall, crop disease, and the household head's age; $H$ is on-farm hired labor; $w^h$ is wage rate of on-farm hired labor; $w^o$ is wage rate of off-farm labor. Farm production is assumed to have CES form which is specified as:

$$Q(L, A; Z^q) = e^{Z^q} T^N \left[\delta (T^L L)^{\frac{\sigma-1}{\sigma}} + (1-\delta)(T^A A)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{2.43}$$

where $T^N$ represents Hicks-neutral technical change, and $T^L$ and $T^A$ indicate labor-augmenting and land-augmenting technical changes respectively; $\sigma$ is the elasticity of substitution between labor and land; $\delta$ is a parameter taking between 0 and 1. This function is not very restrictive because the usual Cobb-Douglas form is included as the limit case; $\sigma \to 1$. Farm production satisfies the diminishing marginal product of each input and the complement feature of labor and land; $Q_L > 0, Q_A > 0, Q_{LL} < 0, Q_{AA} < 0, Q_{LA} > 0$ and $Q_{LL}Q_{AA} - {Q_{LA}}^2 > 0$ where the first derivative of the production function with respect to labor is written as:

$$Q_L = \frac{\partial Q}{\partial L} = e^{Z^q} T^N T^L \delta \left[ \delta + (1-\delta) \left( \frac{T^A A}{T^L L} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} \quad (2.44)$$

Assume that family labor and hired labor are perfect substitutes but have different efficiencies. The off-farm wage rate is, therefore, different from the wage rate of on-farm hired labor. I adopt the concept of effective labor input introduced by Deolalikar and Vijverberg (1987), in which effective farm labor ($L$) is given as an increasing linear function of family labor and hired labor; $L_F > 0$ and $L_H > 0$ where $L_F$ and $L_H$ are the first partial derivatives of effective farm labor with respect to family labor and hired labor respectively.

The optimal on-farm family labor ($F^*$) and on-farm hired labor ($H^*$) solve the following FOCs:

$$pQ_F(L^*, \bar{A}) = pQ_L(L^*, \bar{A})L_F = w^o \quad (2.45)$$

$$pQ_H(L^*, \bar{A}) = pQ_L(L^*, \bar{A})L_H = w^h \quad (2.46)$$

Equation (2.29) and (2.30) indicate that the household determines the amount of effective farm labor for farm production so that the value of the marginal product of family labor ($pQ_F$) and hired labor ($pQ_H$) equal the market off-farm wage ($w^o$) and hired-in wage ($w^h$) respectively. Given the form of the marginal product of labor ($Q_L$) in equation (2.28) and FOCs of equation (2.29) and equation (2.30), we have the interior solutions of on-farm family and hired labor as:

$$F^* = \frac{T^A \bar{A}}{T^L} \left[ \left( \frac{\delta}{1-\delta} \right) \left\{ \delta^{-\sigma} \left( \frac{e^{Z^q} T^N T^L L_F}{(w^o/p)} \right)^{1-\sigma} - 1 \right\} \right]^{\frac{\sigma}{1-\sigma}} \quad (2.47)$$

$$H^* = \frac{T^A \bar{A}}{T^L} \left[ \left( \frac{\delta}{1-\delta} \right) \left\{ \delta^{-\sigma} \left( \frac{e^{Z^q} T^N T^L L_H}{(w^h/p)} \right)^{1-\sigma} - 1 \right\} \right]^{\frac{\sigma}{1-\sigma}} \quad (2.48)$$

By equation (2.31) and (2.32), when interior solutions exist, the optimal on-farm family labor ($F^*$) increases as the endowed cultivated land ($\bar{A}$) increases. It decreases as the off-farm wage relative to the price of farm production ($w^o/p$) increases. As for technical changes, both Hicks-neutral technical change ($T^N$) and land-augmenting technical change ($T^A$) increase the optimal family labor. Labor-augmenting technical change ($T^L$), on the other hand, decreases the optimal on-farm family labor unless the elasticity of substitution between labor and land ($\sigma$) is sufficiently small. Similarly, the optimal on-farm hired labor ($H^*$) increases as the endowed land ($\bar{A}$) increases. It decreases as the hired-in wage relative to the price of farm production ($w^h/p$) increases. Hicks-neutral technical change and land-augmenting technical change increase the optimal on-farm hired labor. Labor-augmenting technical change decreases the optimal hired-in labor unless the elasticity of substitution between labor and land is sufficiently small. These relations are summarized in the proposition 2.6.

Proposition 2.6. *Under an unrestricted labor market with a non-functioning land market,*

*a) the optimal on-farm family labor increases as the endowed cultivated land increases; it decreases as off-farm wage relative to production price increases;*

*b) land-augmenting technical change increases the optimal on-farm family labor;*

*c) labor-augmenting technical change decreases the optimal on-farm family labor unless the elasticity of substitution between labor and land is sufficiently small;*

*d) the optimal on-farm hired labor increases as the endowed land increases; it decreases as on-farm hired-in wage relative to production price increases;*

*e) land-augmenting technical change increases the optimal on-farm hired labor;*

*f) labor-augmenting technical change decreases the optimal on-farm hired labor unless the elasticity of substitution between labor and land is sufficiently small.*

#### 2.3.2.B Estimating the Elasticity of Substitution between Labor and Land

Proposition 2.6 presents that the effect of labor augmenting technical change on optimal on-farm family and hired labor depends on the elasticity of substitution (EOS) between labor and land ($\sigma$). In this section I estimate the EOS between labor and land by estimating the CES farm production function. I present the estimations by climate zone using plot level data. Figure 2.6 shows the climate zones in Tanzania from the Global Yield Gap Atlas (GYGA, 2019). The climate zone consists of three categorical values: growing degree days (GDD), annual aridity

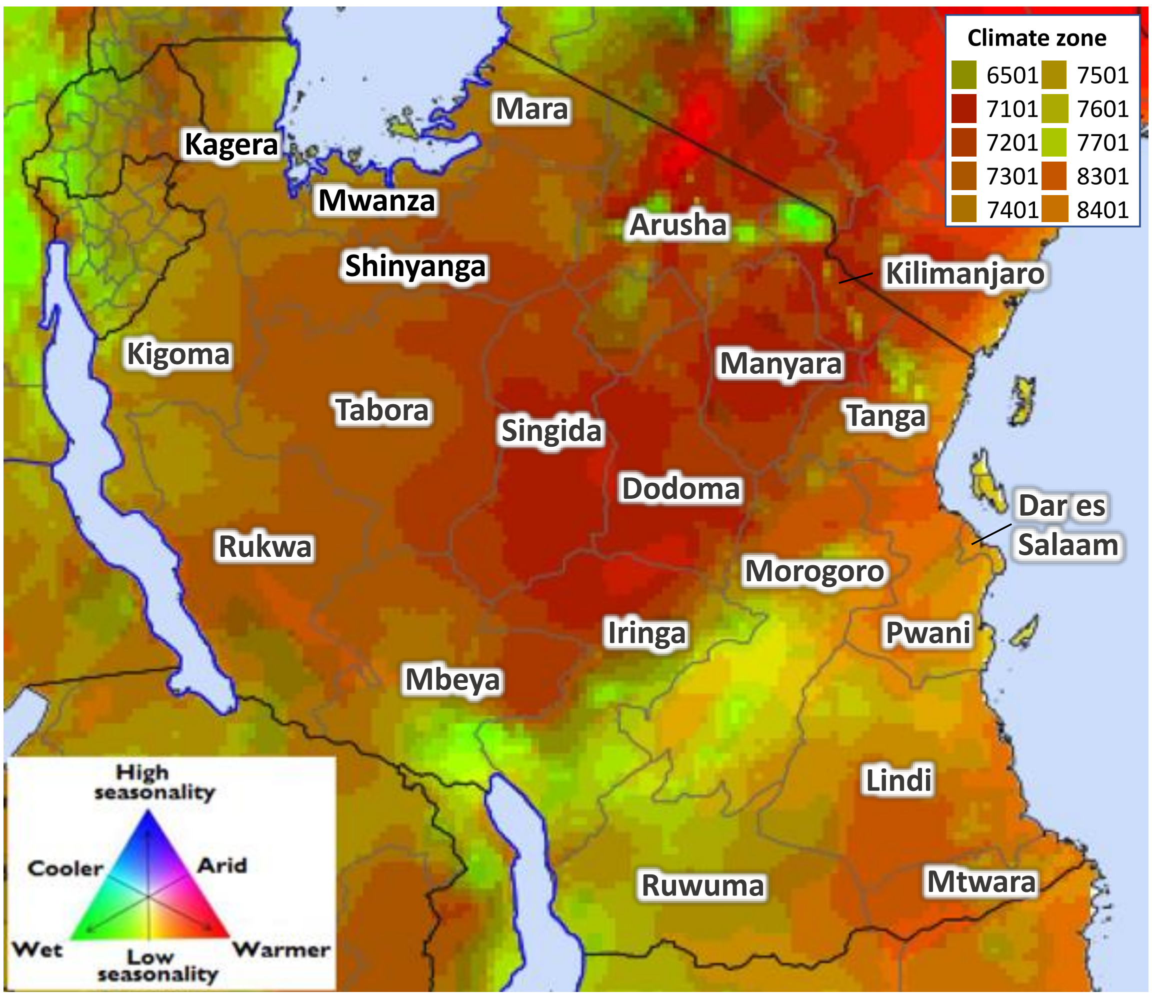


**Figure 2.6 Climate zones in Tanzania**

*Notes:* The zoning map is sourced from GYGA (2019).

**Table 2.6 Classification of categorical values and climate zones**

| (1) | | (2) | | (3) | |
|---|---|---|---|---|---|
| GDD | Climate zone | AI | Climate zone | TS | Climate zone |
| 5950-7111 | 6000 | 2696-3893 | 100 | 0-3832 | 01 |
| 7112-8564 | 7000 | 3894-4791 | 200 | 3833-8355 | 02 |
| 8565-9311 | 8000 | 4792-5689 | 300 | >8356 | 03 |
| | | 5690-6588 | 400 | | |
| | | 6589-7785 | 500 | | |
| | | 7786-8685 | 600 | | |
| | | 8686-10181 | 700 | | |

*Notes:* Classifications are cited from GYGA (2019).

index (AI), and temperature seasonality (TS). GDD and AI are calculated as:

$$GDD = \sum_{i=1}^{365} \max(0, T_i) \tag{2.49}$$

$$AI = \frac{MAP}{MAE} \tag{2.50}$$

where $T_i$ is temperature (℃) for each time period, MAP is mean annual precipitation (100 mm), and MAE is mean annual potential evapotranspiration (100 mm). TS is calculated as the standard deviation of the 12 mean monthly temperatures (10 ℃). The data of temperature, precipitation, and temperature seasonality are taken from University of East Anglia Climate Research Unit (CRU, 2019), CGIAR Consortium for Spatial Information (CGIAR, 2019), and World Clim Global Climate Data (World Clim, 2019) respectively. The classification of three categorical values and the climate zones are summarized in Table 2.6. To estimate the production function by climate zone, for each estimation I include all the observations in the regions which have the climate zone in the region. I assume the EOS does not change over time. By taking the log of equation (2.27), we have the CES production function as:

$$lnQ = Z^q - \frac{1}{\rho} ln[\delta L^{-\rho} + (1-\delta)A^{-\rho}] \tag{2.51}$$

where $\rho$ is parameter formed by EOS ($\sigma$): $\rho = \frac{1-\sigma}{\sigma}$. I estimate Kumar and Gapinski's (Kumar & Gapinski, 1974) nonlinear least square (NLLS) estimator using pooled data. The specification of the estimation is:

$$\min \sum_{i=1}^{N} \sum_{t=1}^{T} \varepsilon_{iht}^{2}$$
$$s.t.\;\; ln\, Q_{iht} = Z_{iht}^{q}\alpha - \frac{1}{\rho} ln[\delta L_{iht}{}^{-\rho} + (1-\delta) A_{iht}{}^{-\rho}] + c_i + c_h + \varepsilon_{iht} \tag{2.52}$$

where subscripts $i$, $h$, and $t$ represent plot, household, and time respectively; $Q_{iht}$ is total kg of harvested maize; $L_{iht}$ is total days of on-farm labor; $A_{iht}$ is total acres of the plot; $Z_{iht}^{q}$ is the vector of exogenous household and plot characteristics which affect the level of production as well as the total value of farm assets and total expenses on inputs; $c_i$ and $c_h$ are plot and household unobserved heterogeneities. The vector of exogenous variables ($Z_{iht}^{q}$) include household head's age, whether the household experienced drought or flood, crop disease, price decrease of the crop, price rise of the input, water shortage in a year, whether the plot is with title or not, and the years since the household acquired the plot. Unobserved heterogeneities are controlled by the observed time-invariant variables such as household head's education, whether household head is female, type and quality of the soil, and slope of the plot.

Table 2.7 presents the result of the estimations of production function and the EOS by climate zone. The estimates of the EOS range from 0.303 to 1.258. All the estimates are statistically significant at from one to ten percent confidence levels.

**Table 2.7 Estimation of the production function and the elasticity of substitution between labor and land by climate zone (NLLS)**

| Dependent variable: | Climate zone | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ln(harvested maize (kg)) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Explanatory variables | 7101 | 7201 | 7301 | 6501 | 8301 | 8401 | 7601 | 7501 | 7701 | 7401 |
| **Household variables** | | | | | | | | | | |
| HH education (years) | 0.067*** | 0.005 | 0.014 | 0.062*** | 0.018 | 0.042* | 0.027 | 0.085*** | 0.039* | 0.032** |
| | (0.024) | (0.017) | (0.016) | (0.023) | (0.018) | (0.023) | (0.027) | (0.024) | (0.023) | (0.016) |
| HH age (years) | -0.018*** | -0.012*** | -0.000 | -0.003 | -0.018*** | -0.014*** | -0.021*** | 0.011* | -0.005 | -0.002 |
| | (0.006) | (0.003) | (0.003) | (0.005) | (0.004) | (0.005) | (0.005) | (0.005) | (0.006) | (0.003) |
| 1 = HH is female | -0.007 | -0.109 | -0.082 | 0.038 | -0.101 | 0.233 | -0.059 | -0.127 | -0.007 | -0.141 |
| | (0.184) | (0.137) | (0.123) | (0.162) | (0.145) | (0.157) | (0.180) | (0.191) | (0.173) | (0.119) |
| 1 = experienced draught or flood | -0.365** | -0.412*** | -0.434*** | -0.356** | -0.339** | -0.282 | -0.149 | -0.350** | -0.519*** | -0.515*** |
| | (0.163) | (0.104) | (0.115) | (0.154) | (0.136) | (0.172) | (0.206) | (0.167) | (0.171) | (0.112) |
| 1 = experienced crop disease | 0.105 | -0.002 | -0.147 | 0.099 | -0.136 | -0.032 | 0.044 | -0.539*** | 0.113 | -0.646*** |
| | (0.157) | (0.113) | (0.128) | (0.168) | (0.160) | (0.180) | (0.153) | (0.156) | (0.170) | (0.097) |
| 1 = experienced price decrease of crop | 0.306* | 0.320** | 0.290** | 0.101 | -0.155 | -0.021 | -0.169 | 0.262 | 0.049 | 0.199* |
| | (0.179) | (0.124) | (0.114) | (0.152) | (0.132) | (0.200) | (0.154) | (0.208) | (0.166) | (0.106) |
| 1 = experienced price rise input | 0.0642 | -0.103 | -0.194 | 0.195 | 0.075 | -0.222 | 0.304** | 0.205 | 0.178 | -0.035 |
| | (0.211) | (0.138) | (0.132) | (0.135) | (0.153) | (0.185) | (0.142) | (0.175) | (0.137) | (0.096) |
| 1 = experienced water shortage | 0.066 | -0.046 | -0.025 | -0.108 | -0.037 | 0.387** | -0.266* | -0.546*** | 0.022 | -0.014 |
| | (0.193) | (0.116) | (0.131) | (0.173) | (0.146) | (0.156) | (0.147) | (0.178) | (0.153) | (0.114) |
| 1 = rural | -0.019 | 0.082 | -0.629*** | -0.440*** | 0.098 | -0.209 | -0.101 | -0.538*** | -0.381*** | 0.052 |
| | (0.226) | (0.206) | (0.177) | (0.128) | (0.171) | (0.182) | (0.175) | (0.162) | (0.142) | (0.150) |
| **Plot variables** | | | | | | | | | | |
| 1 = soil is sandy | 0.368** | 0.023 | -0.106 | -0.169 | -0.428*** | -0.076 | -0.310** | -0.126 | -0.339** | -0.166 |
| | (0.155) | (0.126) | (0.125) | (0.153) | (0.147) | (0.133) | (0.129) | (0.157) | (0.171) | (0.110) |
| 1 = soil is clay | -0.072 | -0.138 | -0.294* | -0.253 | -0.311** | 0.231 | 0.014 | -0.556*** | -0.237 | -0.230** |
| | (0.248) | (0.126) | (0.159) | (0.165) | (0.143) | (0.221) | (0.178) | (0.155) | (0.168) | (0.108) |
| 1 = soil is good quality | 0.292* | 0.321*** | 0.324*** | 0.329*** | 0.202* | 0.0150 | 0.098 | 0.458*** | 0.062 | 0.395*** |
| | (0.155) | (0.103) | (0.104) | (0.116) | (0.111) | (0.130) | (0.123) | (0.142) | (0.108) | (0.081) |

Table 2.7 (cont'd)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 = soil is bad quality | -0.081 | 0.095 | 0.163 | -0.321 | -0.135 | 0.005 | -0.311 | -0.233 | -0.570** | -0.244* |
| | (0.277) | (0.172) | (0.132) | (0.257) | (0.331) | (0.190) | (0.245) | (0.237) | (0.265) | (0.139) |
| 1 = plot is sloped | 0.169 | 0.079 | -0.025 | 0.101 | -0.053 | -0.645*** | 0.243** | -0.119 | 0.159 | -0.211*** |
| | (0.150) | (0.099) | (0.099) | (0.111) | (0.123) | (0.185) | (0.111) | (0.121) | (0.102) | (0.079) |
| 1 = plot is steep | 1.001*** | -0.026 | -0.259 | -0.130 | 0.226 | -0.339 | 0.266 | 0.141 | -0.182 | -0.312 |
| | (0.331) | (0.185) | (0.634) | (0.246) | (0.180) | (0.603) | (0.310) | (0.262) | (0.248) | (0.218) |
| 1 = have problem of | 0.271 | 0.104 | -0.133 | 0.018 | 0.178 | 0.157 | -0.091 | -0.331* | -0.162 | -0.183* |
| erosion | (0.166) | (0.106) | (0.131) | (0.160) | (0.186) | (0.311) | (0.178) | (0.179) | (0.170) | (0.107) |
| 1 = plot with title | -0.106 | 0.160 | 0.025 | -0.281 | -0.166 | -0.065 | 0.359 | -0.358 | 0.054 | -0.099 |
| | (0.189) | (0.134) | (0.149) | (0.199) | (0.183) | (0.306) | (0.230) | (0.273) | (0.260) | (0.118) |
| Year since acquired land | -0.001 | 0.001 | 0.001 | -0.002 | 0.006*** | -0.000 | 0.001 | -0.002 | -0.003 | -0.001 |
| | (0.003) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.003) | (0.002) | (0.001) |
| **Parameters** | | | | | | | | | | |
| Rho ($\rho$) | 0.368 | 1.033* | 0.642* | 0.108 | -0.125 | -0.205 | -0.185 | 2.303 | -0.196 | 0.976*** |
| | (0.465) | (0.553) | (0.378) | (0.291) | (0.214) | (0.308) | (0.353) | (1.737) | (0.303) | (0.359) |
| Delta ($\delta$) | 0.782*** | 0.972*** | 0.932*** | 0.583** | 0.422* | 0.385 | 0.415 | 0.999*** | 0.249 | 0.967*** |
| | (0.293) | (0.051) | (0.083) | (0.290) | (0.220) | (0.314) | (0.300) | (0.004) | (0.229) | (0.044) |
| EOS ($\sigma$) | 0.731*** | 0.492*** | 0.609*** | 0.903*** | 1.143*** | 1.258** | 1.227** | 0.303* | 1.244*** | 0.506*** |
| | (0.249) | (0.134) | (0.140) | (0.237) | (0.280) | (0.488) | (0.532) | (.159) | (0.469) | (0.092) |
| Observations | 767 | 2301 | 1642 | 879 | 1038 | 670 | 580 | 1098 | 651 | 2667 |
| Adjusted R-squared | 0.197 | 0.145 | 0.186 | 0.197 | 0.149 | 0.038 | 0.313 | 0.203 | 0.267 | 0.180 |

*Notes:* Time dummies are included in all estimations but not reported. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

### 2.3.2.C Test of Propositions

To empirically test the proposition 2.6, I specify the reduced form empirical model as:

$$F_{hjt} = Z^q_{hjt}\beta_1 + A_{hjt}\beta_2 + T^A_{hjt}\beta_3 + T^L_{hjt}\beta_4 + \left(T^L_{hjt} \cdot \sigma_j\right)\beta_5 + w^o_{jt}\beta_6 + w^h_{jt}\beta_7 + c_h + c_j + u_{hjt} \tag{2.53}$$

where the subscripts *h, j,* and *t* represent household, region, and time respectively; $F_{hjt}$ is total days of on-farm family labor; $Z^q_{hjt}$ is the vector of household characteristics which affect the household's production; $A_{hjt}$ is total area of plots; $T^A_{hjt}$ and $T^L_{hjt}$ are dummy variables of technological growth which takes $T^A_{hjt}$ =1 if the household applies land-augmenting technology, $T^L_{hjt} = 1$ if the household applies labor-augmenting technology, and takes $T^k_{hjt} = 0$ otherwise; $\sigma_j$ is the estimated EOS between labor and land from equation (2.36); $w^o_{jt}$ and $w^h_{jt}$ are wage rate of off-farm labor and on-farm hired labor relative to the producer price of maize, respectively; $c_h$ and $c_j$ are household and regional unobserved heterogeneities. The vector of exogenous production variables ($Z^q_{hjt}$) include whether the household experienced drought or flood, crop disease, price decrease of the crop, price rise of the input, and water shortage in a year and whether the household has a plot with title. Because on-farm hired labor is zero for 3,742 among 5,967 observations, I apply the Tobit model for the on-farm hired labor. The reduced form empirical model is specified as:

$$H_{hjt} = \max\left(0, Z^q_{hjt}\gamma_1 + A_{hjt}\gamma_2 + T^A_{hjt}\gamma_3 + T^L_{hjt}\gamma_4 + \left(T^L_{hjt} \cdot \sigma_j\right)\gamma_5 + w^o_{jt}\gamma_6 + w^h_{jt}\gamma_7 + c_h + c_j + v_{hjt}\right) \tag{2.54}$$

where $H_{hjt}$ is total days of on-farm hired labor.

The hypotheses I test from the proposition 2.6 are as follows. Under the existence of the interior solutions, the optimal on-farm family and hired labor increase as total farm area increases ($\beta_2 > 0$ and $\gamma_2 > 0$). Both optimal on-farm labor and hired labor increase as land-augmenting technological change increases ($\beta_3 > 0$ and $\gamma_3 > 0$). They both decrease as land-augmenting technological change increases unless the EOS between land and labor is sufficiently small ($\beta_5 < 0$ and $\gamma_5 < 0$). The optimal on-farm family labor decreases as the off-farm wage relative to the producer price of maize increases ($\beta_6 < 0$). The optimal on-farm hired labor decreases as the on-farm hired-in wage relative to the producer price of maize increases ($\gamma_7 < 0$).

The decision on whether to apply farm technology is normally dependent on the various characteristics of the plot and the household. Those characteristics include water availability and land quality (Caswell & Zilberman, 1985; Caswell & Zilberman, 1986; Green et al., 1996; Moreno & Sunding, 2005), the network in which the household is involved (Foster & Rosenzweig, 1995; Munshi, 2004; Conley & Udry, 2010), and the resource endowment and scarcity in the location (Hayami & Ruttan, 1971; Matsuyama, 1992). I, therefore, present the fixed effect estimation to eliminate the effect of unobserved household and regional heterogeneities as well as two stage estimations to test and control for the endogeneity of the adoption of farming technologies. For the two stage estimations, the first stage estimations of the adoption of farming technologies are specified as:

$$T_{hjt}^{k} = 1\left[Z_{hjt}^{q}\delta_1 + A_{ijt}\delta_2 + w_{jt}^{o}\delta_3 + w_{jt}^{h}\delta_4 + IV\delta_5 + c_h + c_j + e_{hjt} > 0\right] \tag{2.55}$$

where $IV$ is the vector of instrumental variables which include dummy variables of the receipt of input voucher and the potential yield gain from the adoption of farming technology. For the two step estimations of on-farm hired labor, I apply the Type II Tobit, that is the Heckman selection model (Heckman 1976), to control for the selection bias as well as the endogeneity of the adoption of farming technology. The household heterogeneities $c_h$ are controlled by the time-invariant household variables such as household head's education, whether household head is female or not, and whether household member belongs to Savings and Credit Co-Operative (SACCO) or not. Similarly, $c_j$ is controlled by the EOS in all estimations.

### 2.3.3 Data and Descriptive Statistics

I use data from the Tanzania National Panel Survey (TNPS) wave 1 to 3; 2008/2009, 2010/2011, and 2012/2013. It is a part of World Bank Living Standards Measurement Study (LSMS) dataset. I use data from household, agriculture, and community questionnaires in the mainland for the households who cultivate maize. Among 3,021 households and 6,561 plots in the mainland, 2,892 households cultivate maize in 5,598 plots. Among 9,266 plot observations, 3,171 plots form a 3-year panel, 1,186 plots form a 2-year panel, and 1,241 plots are a 1-year panel. Table 2.8 and Table 2.9 report the summary statistics of variables at plot level and at household level respectively.

#### 2.3.3.A Farming Technology, Gross Productivity, and Labor Shift

Figure 2.7 shows the change in the labor to land ratio and area of land to yield one ton of maize by applying each farming technology. A technology is called a land-augmenting technology when it reduces relatively more land than labor to yield one ton of maize because farmers gain area to cultivate additional maize by applying that technology. For example, by applying inorganic fertilizer, the farmer saves 10 acres to yield one ton of maize, so inorganic fertilizer augments land by 10 acres. Similarly, a technology is called labor-augmenting technology when it reduces relatively more labor than land to yield one ton of maize because farmers gain labor to cultivate additional maize by applying that technology. In Figure 2.7, I use the labor to land ratio rather than labor to examine the labor bias of technology because the simple labor productivity,

**Table 2.8 Summary statistics of variables at plot level**

| Variable | Obs | Mean | Sd | Min | Max |
|---|---|---|---|---|---|
| *Panel A. TNPS - Agriculture Questionnaire* | | | | | |
| Total area under maize (acres) | 8477 | 2.01 | 4.00 | 0.00 | 150.00 |
| Total cultivated area (acres) | 8477 | 3.34 | 9.58 | 0.00 | 600.00 |
| Harvested maize (kg) | 8477 | 460.93 | 1195.12 | 0.00 | 50000.00 |
| Total on-farm labor (person*day) | 8477 | 88.28 | 92.85 | 0.00 | 1170.00 |
| 1 = apply organic fertilizer | 8477 | 0.14 | 0.35 | 0.00 | 1.00 |
| 1 = apply inorganic fertilizer | 8477 | 0.15 | 0.36 | 0.00 | 1.00 |
| 1 = apply improved seed | 8477 | 0.23 | 0.42 | 0.00 | 1.00 |
| 1 = apply irrigation | 8477 | 0.02 | 0.13 | 0.00 | 1.00 |
| 1 = apply pesticide or herbicide | 8477 | 0.09 | 0.29 | 0.00 | 1.00 |
| 1 = apply sprayer | 8477 | 0.07 | 0.26 | 0.00 | 1.00 |
| 1 = apply animal traction | 8477 | 0.13 | 0.34 | 0.00 | 1.00 |
| 1 = apply tractor use | 8477 | 0.03 | 0.18 | 0.00 | 1.00 |
| 1 = receive input voucher | 8477 | 0.09 | 0.28 | 0.00 | 1.00 |
| Year since acquired plot (years) | 8477 | 20.88 | 26.13 | 0.00 | 113.00 |
| 1 = plot with title | 8477 | 0.11 | 0.31 | 0.00 | 1.00 |
| 1 = soil is sandy | 8477 | 0.17 | 0.38 | 0.00 | 1.00 |
| 1 = soil is clay | 8477 | 0.17 | 0.37 | 0.00 | 1.00 |
| 1 = soil is good quality | 8477 | 0.48 | 0.50 | 0.00 | 1.00 |
| 1 = soil is bad quality | 8477 | 0.06 | 0.24 | 0.00 | 1.00 |
| 1 = plot is sloped | 8477 | 0.33 | 0.47 | 0.00 | 1.00 |
| 1 = plot is steep | 8477 | 0.04 | 0.19 | 0.00 | 1.00 |
| 1 = have problem of erosion | 8477 | 0.14 | 0.34 | 0.00 | 1.00 |
| *Panel B. TNPS - Household Questionnaire* | | | | | |
| 1 = experienced drought or flood | 8477 | 0.32 | 0.46 | 0.00 | 1.00 |
| 1 = experienced crop disease | 8477 | 0.28 | 0.45 | 0.00 | 1.00 |
| 1 = experienced price decrease of crop | 8477 | 0.32 | 0.47 | 0.00 | 1.00 |
| 1 = experienced price rise of input | 8477 | 0.32 | 0.47 | 0.00 | 1.00 |
| 1 = experienced water shortage | 8477 | 0.27 | 0.45 | 0.00 | 1.00 |
| 1 = rural | 8477 | 0.87 | 0.34 | 0.00 | 1.00 |
| *Panel C. GYGA and FAO-Agromaps* | | | | | |
| Potential yield gain from input (ton/acre) | 8477 | 5.01 | 1.24 | 1.54 | 7.41 |

*Notes:* Observations pooled across years.

**Table 2.9 Summary statistics of variables at household level**

| Variable | Obs | Mean | Sd | Min | Max |
|---|---|---|---|---|---|
| *Panel A. TNPS - Agriculture Questionnaire* | | | | | |
| On-farm family labor (person*day) | 5967 | 123.02 | 132.60 | 2.00 | 1400.00 |
| On-farm hired labor (person*day) | 5967 | 11.02 | 32.40 | 0.00 | 661.00 |
| Off-farm labor (person*day) | 5967 | 55.12 | 132.34 | 0.00 | 2064.00 |
| Total cultivated area (acres) | 5967 | 4.86 | 8.03 | 0.01 | 150.00 |
| On-farm hired in wage (USD/day) | 5967 | 4.90 | 1.47 | 1.87 | 10.24 |
| 1 = apply land augmenting technology | 5967 | 0.31 | 0.46 | 0.00 | 1.00 |
| 1 = apply labor augmenting technology | 5967 | 0.24 | 0.43 | 0.00 | 1.00 |
| 1 = have plot title | 5966 | 0.12 | 0.33 | 0.00 | 1.00 |
| 1 = receive input voucher | 5967 | 0.07 | 0.25 | 0.00 | 1.00 |
| *Panel B. TNPS - Household Questionnaire* | | | | | |
| HH education (years) | 5927 | 4.79 | 3.51 | 0.00 | 19.00 |
| 1= HH is female | 5967 | 0.24 | 0.42 | 0.00 | 1.00 |
| 1 = household member belongs to SACCO | 5967 | 0.05 | 0.22 | 0.00 | 1.00 |
| Off-farm wage (USD/hour) | 5967 | 1.60 | 1.18 | 0.31 | 11.56 |
| Number of adults aged 15-65 | 5967 | 2.87 | 1.73 | 0.00 | 25.00 |
| Number of children aged 0-3 | 5967 | 0.74 | 0.91 | 0.00 | 14.00 |
| Number of children aged 4-6 | 5967 | 0.53 | 0.70 | 0.00 | 6.00 |
| Number of children aged 7-14 | 5967 | 1.28 | 1.28 | 0.00 | 10.00 |
| 1 = experienced drought or flood | 5967 | 0.32 | 0.47 | 0.00 | 1.00 |
| 1 = experienced crop disease | 5967 | 0.27 | 0.45 | 0.00 | 1.00 |
| 1 = experienced price decrease of crop | 5967 | 0.30 | 0.46 | 0.00 | 1.00 |
| 1 = experienced price rise of input | 5967 | 0.30 | 0.46 | 0.00 | 1.00 |
| 1 = experienced water shortage | 5967 | 0.28 | 0.45 | 0.00 | 1.00 |
| 1 = rural | 5967 | 0.87 | 0.34 | 0.00 | 1.00 |
| *Panel C. TNPS - Community Questionnaire* | | | | | |
| Local market price of maize (USD/kg) | 5967 | 0.84 | 0.20 | 0.44 | 1.62 |
| *Panel D. GYGA and FAO-Agromaps* | | | | | |
| Potential yield gain by input (ton/acre) | 5967 | 5.02 | 1.29 | 1.54 | 7.41 |

*Notes:* Observations pooled across years. USD used in the table is 2011 PPP USD.

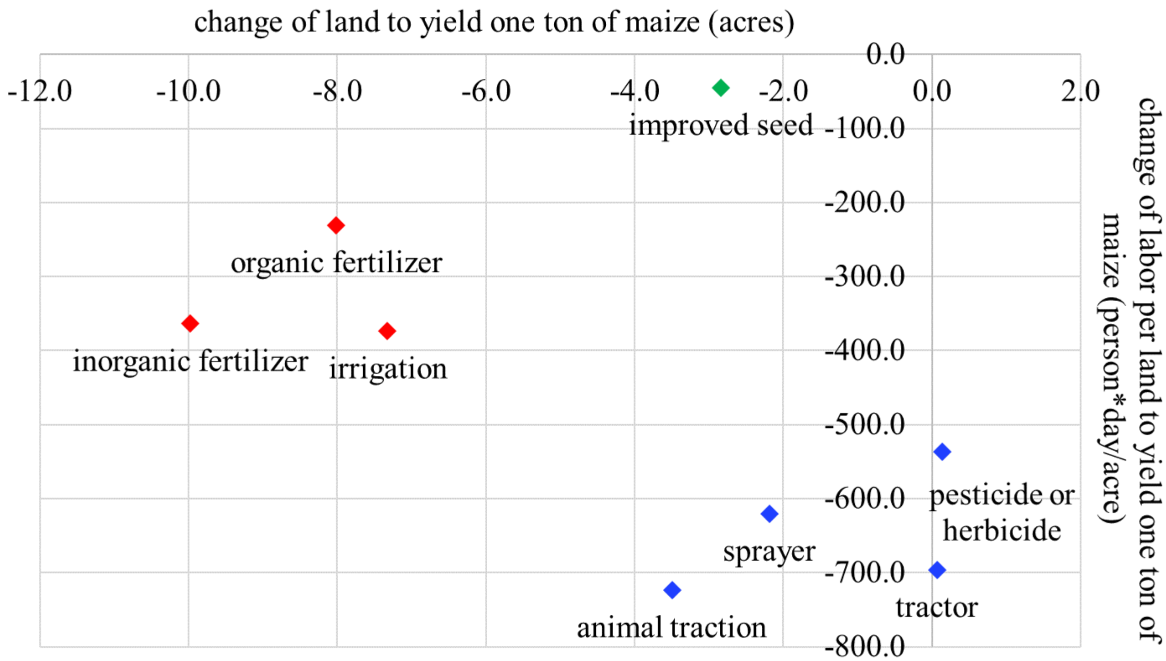


**Figure 2.7 Bias of farm technology**

the labor used to yield one ton of maize, entails the change in the area of land to yield one ton of maize. Hence, by using the labor to land ratio rather than labor, I determined the net labor bias of the technology. The values in the figure are computed by taking the difference of the means of each variable of the plots to which the household applied the technology and the plots to which the household did not apply the technology. Based on the result of the calculations, I classified organic fertilizer, inorganic fertilizer, and irrigation into land-augmenting technology, and sprayer, pesticide, herbicide, animal traction, and tractor use into labor-augmenting technology. This classification is used for the empirical test of propositions.

Table 2.10 shows the change of adoption of farming technologies, gross productivity of maize, and the labor shift from farming sector to off-farm sector from 2008 to 2013. The table shows that the adoption of technology, change in land and labor productivity, and the labor shift from farming sector to off-farm sector are not exactly corresponding to each other. The adoption

**Table 2.10 Technology adoption, gross productivity, and labor shift from farm to off-farm sectors**

| | 2008/2009 | | 2010/2011 | | 2012/2013 | |
|---|---|---|---|---|---|---|
| | Mean | Sd | Mean | Sd | Mean | Sd |
| **Plot variables** | | | | | | |
| ***Land-augmenting technology*** | | | | | | |
| Organic fertilizer | 0.14 | 0.35 | 0.13 | 0.34 | 0.15 | 0.36 |
| Inorganic fertilizer | 0.13 | 0.33 | 0.15 | 0.36 | 0.14 | 0.34 |
| Irrigation | 0.02 | 0.14 | 0.02 | 0.13 | 0.01 | 0.12 |
| ***Neutral technology*** | | | | | | |
| Improved seed | 0.15 | 0.36 | 0.11 | 0.31 | 0.39 | 0.49 |
| ***Labor-augmenting technology*** | | | | | | |
| Pesticide or herbicide | 0.10 | 0.30 | 0.08 | 0.28 | 0.08 | 0.28 |
| Sprayer | 0.08 | 0.28 | 0.06 | 0.24 | 0.08 | 0.26 |
| Animal traction | 0.13 | 0.33 | 0.13 | 0.34 | 0.16 | 0.37 |
| Tractor | 0.00 | 0.06 | 0.04 | 0.20 | 0.05 | 0.22 |
| ***Gross productivity of maize*** | | | | | | |
| Land productivity (kg/acre) | 227.06 | 375.42 | 280.71 | 407.07 | 261.76 | 443.02 |
| Land labor ratio (person*day/acre) | 78.90 | 163.73 | 64.12 | 111.13 | 68.70 | 107.43 |
| Labor productivity (kg/person*day) | 6.36 | 10.26 | 7.52 | 10.10 | 6.60 | 10.24 |
| **Household variables** | | | | | | |
| On-farm labor (person*day) | 140.36 | 162.63 | 128.41 | 127.62 | 134.17 | 130.51 |
| 1 = supply off-farm labor | 0.29 | 0.45 | 0.44 | 0.50 | 0.47 | 0.50 |
| Off-farm labor (person*day) | 33.16 | 72.59 | 53.34 | 131.22 | 71.67 | 159.97 |

*Notes:* On-farm labor is sum of on-farm family labor and hired labor.

rate of the most land biased technology, that is inorganic fertilizer, increased from 0.13 to 0.14 from 2008/2009 to 2012/2013 having the highest adoption rate, 0.15, in 2010/2011. It is corresponding to the increase in the gross land productivity, which increased from 227.06 kg per acre in 2008/2009 to 261.76 kg per acre in 2012/2013, and has the highest land productivity, 280.71 kg per acre, in 2010/2011. While the adoption rate of labor augmenting technologies all increased from 2010/2011 to 2012/2013, gross labor productivity hit the highest value, 7.52 kg per person-day, in 2010/2011, and the land labor ratio shows the smallest value, 64.12 person-days per acre, in 2010/2011. In terms of the labor shift from farm sector to non-farm sector, the rate of households who supply off-farm labor and the days supplied to the off-farm activities both constantly increased from 2008/2009 to 2012/2013. The rate of households who supply off-farm labor increased from 0.29 in 2008/2009 to 0.47 in 2012/2013, and the supply of off-farm labor increased from 33.16 person-days in 2008/2009 to 71.67 person-days in 2012/2013. To further examine the effect of the adoption of biased farming technologies on the labor allocation of the households, we need to estimate empirical models.

#### 2.3.3.B Adoption Decision with Input Voucher and Yield Potential

Table 2.11 shows the comparison of household characteristics by the receipt of the input voucher. Except from whether household head is female or not, all other variables correspond to the targeting criteria explained in section 2.3.1. The household who received input voucher cultivates less area for maize; is more likely to belong to SACCO; and has a household head with higher education. The differences of those variables are statistically significant. Although the input voucher was provided to subsidize inorganic fertilizer or improved seeds, it affected the adoption of other technologies. Table 2.12 displays the differences of the adoption rate of farming technology between households who received input vouchers and who did not. Except for animal traction and tractor use, for all other farming technologies the households who received input vouchers have higher adoption rates than the households who did not. The difference of the adoption rates is statistically significant at the one percent confidence level except for irrigation. Although the input voucher had a strong effect on the adoption of farming technologies, because only 10.75 percent of maize farmers received input voucher at least once between 2008 and 2013, the overall adoption rates did not change drastically over years (see Table 2.10).

The potential yield gain from the adoption of the technology also determines the technology adoption. I generated the data of potential yield gain by taking the difference between

**Table 2.11 Targeting of the input voucher scheme**

| | (1) Not received input voucher | | (2) Received input voucher | | (3) Total | | t-test |
|---|---|---|---|---|---|---|---|
| | Mean | Sd | Mean | Sd | Mean | Sd | (1)=(2) |
| Total area under maize (acres) | 2.01 | 4.00 | 1.70 | 2.41 | 1.98 | 3.90 | ** |
| Household head education (years) | 4.79 | 3.51 | 6.01 | 2.94 | 4.89 | 3.49 | *** |
| 1 = household head is female | 0.23 | 0.42 | 0.18 | 0.38 | 0.23 | 0.42 | *** |
| 1 = belongs to SACCO | 0.05 | 0.22 | 0.13 | 0.34 | 0.06 | 0.24 | *** |

*Notes:* *** p<0.01, ** p<0.05, * p<0.1.

**Table 2.12 Adoption of farming technology by input voucher**

| Farming technology | (1) Not receive input voucher | (2) Receive input voucher | (3) Total | t-test (1) < (2) |
|---|---|---|---|---|
| Organic fertilizer | 0.14 | 0.19 | 0.14 | *** |
| Inorganic fertilizer | 0.09 | 0.65 | 0.14 | *** |
| Improved seed | 0.23 | 0.30 | 0.23 | *** |
| Irrigation | 0.02 | 0.02 | 0.02 | |
| Pesticide or herbicide | 0.08 | 0.18 | 0.09 | *** |
| Sprayer | 0.07 | 0.11 | 0.07 | *** |
| Animal traction | 0.14 | 0.14 | 0.14 | |
| Tractor | 0.04 | 0.02 | 0.04 | |

*Notes:* *** p<0.01, ** p<0.05, * p<0.1.

the simulated yield potential of maize and the actual yield in 2001, when the farming technologies were hardly adopted by farmers in Tanzania. Simulated yield potential and the actual yield in 2001 are collected from GYGA (GYGA, 2019) and FAO-Agromaps (FAO, 2019) respectively. Table 2.13 shows the means of computed potential yield gains of household who adopted the farming technology and who did not. Except for irrigation, for all other farming technologies, the households who adopted technology have higher potential yield gain than the household who did not. The potential yield gain is unobservable for the farmers, but it affects their decision on the adoption of technology. The households who adopted irrigation have smaller potential yield gains than those who did not because the simulated yield potential is

**Table 2.13 Yield potential and technology adoption**

| Potential yield gain (ton/acre)<br>Farming technology | (1)<br>Not adopted | (2)<br>Adopted | t-test<br>(1)=(2) |
|---|---|---|---|
| Organic fertilizer | 4.97 | 5.03 | |
| Inorganic fertilizer | 4.95 | 5.18 | *** |
| Improved seed | 4.98 | 4.98 | |
| Irrigation | 4.98 | 4.76 | ** |
| Pesticide or herbicide | 4.95 | 5.25 | *** |
| Sprayer | 4.97 | 5.09 | ** |
| Animal traction | 4.95 | 5.19 | *** |
| Tractor | 4.96 | 5.46 | *** |

generated by rainfed maize data, hence, it takes smaller values if the household faces limited rain. And households with limited water availability are more likely to adopt the irrigation.

### 2.3.4 Robustness Check

#### 2.3.4.A Test of Propositions with Unobserved Separation

Heterogeneous households choose their optimal labor allocations by maximizing their income from farm production and off-farm activities. The household does or does not face a binding constraint on off-farm labor opportunities. When a household faces a binding constraint, the application of farm technology does not affect the on-farm family labor, but has an effect on on-farm hired labor. Suppose the off-farm opportunity is constrained and binding at $\bar{O} > 0$. Then, the on-farm family labor is given as $F = \bar{M} - \bar{O}$. Assume again there is no land market, and the on-farm labor market is perfectly competitive. The corresponding household income is, then, given as:

$$Y = [pQ(L, \bar{A}; Z^q) - w^h H] + w^o \bar{O} \tag{2.56}$$

The household maximizes its income with respect to hired labor ($H$). The optimal hired labor ($H^*$) satisfies the FOC which is equivalent to equation (2.30). The interior solution of on-farm hired labor is, therefore, given as equation (2.32), which is equivalent to the case of no binding constraint on off-farm labor. The on-farm family labor is, on the other hand, determined by $\bar{M}$, the number of adults of working age in the household, and $\bar{O}$, the level of off-farm labor's binding constraint. The adoption of farming technology also has a different effect on the optimal level of off-farm labor when the household faces a binding constraint on off-farm labor. Without a binding constraint, the optimal off-farm labor is given as $O = \bar{M} - F^*$. Hence, the land endowment, adoption of land- and labor-augmenting farming technologies, and off-farm wage relative to production price all have opposite effects on off-farm labor compared with the effects on the optimal on-farm family labor. When the off-farm constraint is binding, the off-farm labor is determined by the level of a binding constraint, which is determined by regional and household exogenous factors. These relations are summarized in the proposition 2.7.

Proposition 2.7. *Under an unrestricted labor market with no land market,*

*a) if the household does not face a binding constraint on off-farm labor, the optimal on-farm family labor holds a), b), and c) of Proposition 2.6;*

*b) if the household faces a binding constraint on off-farm labor, the optimal on-farm family labor increases as the number of adults of working age increases; it depends on household and regional exogenous variables which determines the level of binding constraint on off-farm labor;*

*c) if the household does not face a binding constraint on off-farm labor, the optimal off-farm labor increases as the number of adults of working age increases; it decreases as the endowed land increases; it increases as off-farm wage relative to production price increases; land-augmenting technical change decreases the optimal off-farm labor;*

*labor-augmenting technical change increases the optimal off-farm labor unless the elasticity of substitution between labor and land is sufficiently small;*

d) *if the household faces a binding constraint of off-farm labor, the optimal off-farm labor depends on household and regional exogenous variables which determines the level of binding constraint on off-farm labor.*

For the test of the proposition 2.7, I apply a switching regression model with unobserved sample separation (Maddala, 1986) because whether the off-farm constraint is binding is unobservable. The estimation model is specified as:

$$Y_{hjt}^{r} = \begin{cases} Y_{hjt}^{1} = X_{hjt}^{1}\xi^{1} + c_h + c_j + \mu_{hjt}^{1} & if\ \ Y_{hjt}^{*} < 0 \\ Y_{hjt}^{2} = X_{hjt}^{2}\xi^{2} + c_h + c_j + \mu_{hjt}^{2} & if\ \ Y_{hjt}^{*} \geq 0 \end{cases}$$
$$Y_{hjt}^{*} = X_{hjt}^{3}\xi^{3} + c_h + c_j + \mu_{hjt}^{3} \qquad \mu_{hjt}^{3} \sim N(0,1) \tag{2.57}$$

where $Y$ represents the household's on-farm family labor or off-farm labor; the vector of explanatory variables, $X_{hjt}$, consists of number of adults aged 15-65 in the household ($M_{hjt}$), a vector of household characteristics which affect the household's production ($Z_{hjt}^{q}$), total area of plots ($A_{hjt}$), dummy variables of biased technological growth ($T_{hjt}^{A}$ and $T_{hjt}^{L}$), an interaction term of the dummy variable of labor-augmenting technology and the EOS between labor and land ($T_{hjt}^{L} \cdot \sigma_j$), the off-farm wage relative to the producer price of maize ($w_{jt}^{o}$), and the vector of variables which determine the level of binding constraint on off-farm labor ($Z_{hjt}^{o}$); $c_h$ and $c_j$ are household and regional heterogeneities; $\mu_{hjt}$ is independent and identically distributed by normal distribution with zero means where variance of $\mu_{hjt}^{3}$ is standardized at one, and $\mu_{hjt}^{1}$ and $\mu_{hjt}^{2}$ have same variance, $\sigma_{\mu}^{2}$. While $Y^{r}$ is observed, $Y^{1}$, $Y^{2}$, and $Y^{*}$ are unobserved latent variables. Whether we observe $Y^{1}$or $Y^{2}$ depends on the value of the latent variable, $Y^{*}$.

Since the idiosyncratic error term, $\mu_{hjt}^3$, is distributed by the standard normal distribution, the probability of observing $Y^1$ is given as $\theta = \Phi(-X^3\xi^3 - c_h - c_j)$, and the probability to observe $Y^2$ is written as $1 - \theta = \Phi(X^3\xi^3 - c_h - c_j)$. The probability density function of observed labor allocation is, therefore, expressed as:

$$f(Y_{hjt}^r) = \theta\, \varphi_1(Y_{hjt}^r - X_{hjt}^1\xi^1 - c_h - c_j) + (1 - \theta)\, \varphi_2(Y_{hjt}^r - X_{hjt}^2\xi^2 - c_h - c_j) \qquad (2.58)$$

where $\varphi_1$ and $\varphi_2$ are the probability density function of $\mu_{hjt}^1$ and $\mu_{hjt}^2$. Using equation (2.42), the likelihood function of a sample of *N* observations is written as:

$$L(\xi^1, \xi^2, \xi^3, \sigma_\mu) = \prod_{i=1}^{N} f(Y_{hjt}^r) \qquad (2.59)$$

By maximizing equation (2.43) with respect to $\{\xi^1, \xi^2, \xi^3, \sigma_\mu\}$, I estimate the maximum likelihood estimators. Following Vakis et al. (2004), I apply the E-M method (Dempster et al., 1977) after deciding on the initial values of the parameters by pre-estimation procedure (Kiefer, 1978). For the estimations, $c_h$ and $c_j$ are represented by the time-invariant household and region variables as the proxies of the unobserved heterogeneities.

### 2.3.4.B Test of Propositions with Observed Separation

The switching regression with unobserved separation uses all observations and the estimated probability of a household's being in two separate regimes as the weight of each household. In this section, I present the estimations by assigning households into two separate regimes using the ex-post observed information. Following Hartley (1978), I assign a household as with a binding constraint if the conditional expectation of the latent variable ($Y^*$) is equal or greater than zero, $[Y_{hjt}^* | Y_{hjt}^r, X_{hjt}] \geq 0$, and as a household without a binding constraint if the conditional expectation of the latent variable is smaller than zero, $E\left[Y^{*}_{hjt}|Y^{r}_{hjt},X_{hjt}\right]<0$. By assigning households to two regimes, I present fixed effect estimations using the observations in each regime separately. The conditional expectation is computed by observed variables as:

$$\begin{aligned} E[Y^*|Y^r,X] &= X^3\xi + E[\mu^3|Y^r,X] \\ &= X^3\xi + E\left[\mu^3|\mu^3 < -X^3\xi - c_h - c_j\right]Pr\left[\mu^3 < -X^3\xi - c_h - c_j|Y^r,X\right] \\ &\quad + E\left[\mu^3|\mu^3 \geq -X^3\xi - c_h - c_j\right]Pr\left[\mu^3 \geq -X^3\xi - c_h - c_j|Y^r,X\right] \\ &= X^3\xi + \frac{-\phi\left(-X^3\xi - c_h - c_j\right)}{\Phi\left(-X^3\xi - c_h - c_j\right)} \cdot \frac{\theta\,\varphi_1\left(Y^r - X^1\xi^1 - c_h - c_j\right)}{f(Y^r)} \\ &\quad + \frac{\phi(-X^3\xi - c_h - c_j)}{1-\Phi(-X^3\xi - c_h - c_j)} \cdot \frac{(1-\theta)\,\varphi_2\left(Y^r - X^2\xi^2 - c_h - c_j\right)}{f(Y^r)} \end{aligned} \tag{2.60}$$

The reduced form estimations are specified as:

$$\begin{aligned} Y^r_{hjt} = M_{hjt}\xi_1 + Z^q_{hjt}\xi_2 + A_{hjt}\xi_3 + T^A_{hjt}\xi_4 + T^L_{hjt}\xi_5 + \left(T^L_{hjt}\cdot\sigma_j\right)\xi_6 + w^o_{jt}\xi_7 \\ + w^h_{jt}\xi_8 + Z^o_{hjt}\xi_9 + c_h + c_j + u_{hjt} \end{aligned} \tag{2.61}$$

For the estimations, the ex-post computed conditional expectation of the latent variable is included as one of the explanatory variables to control for selection bias of each regime.

### 2.3.5 Estimation Result

#### 2.3.5.A Bias of Farm Technology and On-Farm Labor

Table 2.14 presents the results of the estimations of on-farm family labor to test Proposition 2.6 a), b), and c). The table shows that the signs of the estimates by the fixed effect, two stage least squares (2SLS), two stage generalized method of moments (2SGMM), and limited maximum likelihood estimations all satisfy the propositions. The total area of plots and the adoption of land-augmenting technology both show positive effects on on-farm family labor while the interaction term of the adoption of labor-augmenting technology and EOS between land and

**Table 2.14 Test of propositions I: on-farm family labor**

| Dependent variable: On-farm family labor (person*day) Explanatory variables | Vector | (1) Fixed effect | (2) 2SLS[a] | (3) 2 stage GMM[a] | (4) LIML[a] |
|---|---|---|---|---|---|
| **Technology adoption** | | | | | |
| 1 = adopt land augmenting technology | $T^A$ | 14.50** | 11.43 | 36.87** | 23.10 |
| | | (5.901) | (18.86) | (16.15) | (28.03) |
| 1 = adopt labor augmenting technology | $T^L$ | 40.44* | 93.84 | 68.41 | 132.8 |
| | | (21.94) | (78.65) | (78.05) | (97.93) |
| Interaction term: (labor tech=1)*(EOS) | $T^L\sigma$ | -112.0*** | -235.6 | -356.2** | -348.2 |
| | | (43.27) | (146.2) | (138.8) | (224.6) |
| **Household variables** | | | | | |
| Total area of plot with maize (acres) | $A$ | 3.370*** | 4.869*** | 6.678*** | 5.161*** |
| | | (0.878) | (1.023) | (0.760) | (1.256) |
| **Local variables** | | | | | |
| Real off-farm wage (USD/hour) | $w^o$ | -4.755*** | -2.638** | -1.492 | -2.442* |
| | | (1.145) | (1.269) | (1.192) | (1.419) |
| Real hired in wage (USD/day) | $w^h$ | -0.0117 | -0.587 | -0.941 | -0.868 |
| | | (0.971) | (0.746) | (0.731) | (0.895) |
| **Control variables** | | | | | |
| Time invariant household variable | $c_h$ | NO | YES | YES | YES |
| Time invariant regional variable | $c_j$ | NO | YES | YES | YES |
| Time variant production variable | $Z^q$ | YES | YES | YES | YES |
| ***Hypothesis Tests*** | | | | | |
| Chi sq. from endogeneity test ($H_0$: technology is exogenous) | | - | 15.38*** | 15.38*** | 15.38*** |
| Chi sq. from overidentifying restriction test ($H_0$: IVs are not jointly valid) | | - | 7.12** | 7.12** | 6.64** |
| Observations | | 5966 | 5926 | 5926 | 5926 |
| Log likelihood | | -34273 | -36883 | -37675 | -37191 |
| Adjusted R-squared | | 0.096 | 0.150 | -0.110 | 0.057 |

*Notes:* Time dummies are included in all estimations but not reported. USD used in the table are 2011 PPP USD. Standard errors clustered at household level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
[a] Technology adoption is instrumented by dummy variables of input voucher receipt, potential yield gain from applying inputs, fitted values of probabilities of adopting labor- and land-augmenting technology respectively from the first stage probit estimation, and the fitted value of probability of adopting labor-augmenting technology multiplied by the EOS.

labor displays negative effects. The real off-farm wage also shows the negative effects on on-farm family labor. The fixed effect and 2SGMM estimates are statistically significant at five percent confidence level for both adoption of land-augmenting technology and the interaction term of labor-augmenting technology and the EOS between land and labor. On average, the adoption of land-augmenting technology increases 21.5 person-days of on-farm family labor. Because the EOS between land and labor takes the values between 0.303 and 1.258 (see Table 2.7), the effect of labor-augmenting technology ranges from 4.2 person-days to -247.0 person-days on average. The effect of the adoption of labor-augmenting technology is negative unless the EOS between land and labor is smaller than 0.319. For the two-step estimations, the technology adoptions are instrumented by the dummy variable of input voucher receipt, potential yield gain from applying input, fitted values of probabilities of adopting labor- and land-augmenting technology respectively from the first stage probit estimations, and the fitted value of the probability of adopting labor-augmenting technology multiplied by the EOS between land and labor. The exogeneities of the adoption of land- and labor-augmenting technologies are both rejected at the one percent confidence level in all estimations. The instrumental variables also pass the overidentifying restriction test at five percent confidence level in all estimations. The results of the first stage probit estimations of the adoption of land- and labor-augmenting technologies are reported in column (1) and (2) of Table 2.A.1.

Table 2.15 displays the results of the estimations of on-farm hired labor to test Proposition 2.1 d), e), and f). Again, all the signs of the coefficients satisfy the propositions. The total area of plots and land-augmenting technological change both have the positive effects on on-farm hired labor while the interaction term of the labor-augmenting technological change and EOS between labor and land shows a negative effect. The real on-farm hired-in wage also has negative effects. The land-augmenting technology increases on-farm hired labor by on average 5.23 person-days. Because the EOS between land and labor takes the values between 0.303 and 1.258 (see Table 2.2), the effect of adoption of labor-augmenting technology takes the values between 25.81 person-days and -26.93 person-days. The effect is negative if the EOS

**Table 2.15 Test of propositions II: on-farm hired labor**

| Dependent variable: On-farm hired labor (person*day) Explanatory variables | Vector | (1) Tobit RE | (2) Heckman 2SLS[a] | (3) Heckman 2SGMM[a] | (4) Heckman LIML[a] |
|---|---|---|---|---|---|
| **Technology adoption** | | | | | |
| 1 = adopt land augmenting technology | $T^A$ | 5.746*** | 5.103 | 4.672 | 5.379 |
| | | (2.107) | (4.241) | (3.667) | (6.537) |
| 1 = adopt labor augmenting technology | $T^L$ | 13.35** | 39.02 | 75.55*** | 42.24 |
| | | (6.451) | (43.37) | (28.04) | (55.21) |
| Interaction term: (labor tech=1)*(EOS) | $T^L\sigma$ | -13.91* | -37.78 | - | -42.31 |
| | | (8.216) | (76.94) | (46.01) | (110.6) |
| **Household variables** | | | | | |
| Total area of plot with maize (acres) | $A$ | 1.764*** | 1.004*** | 1.124*** | 1.000*** |
| | | (0.112) | (0.193) | (0.185) | (0.248) |
| **Local variables** | | | | | |
| Real off-farm wage (USD/hour) | $w^o$ | -0.402 | -0.677* | -0.719** | -0.695* |
| | | (0.619) | (0.363) | (0.302) | (0.357) |
| Real hired in wage (USD/day) | $w^h$ | - | - | - | -0.634** |
| | | (0.408) | (0.187) | (0.134) | (0.251) |
| **Control variables** | | | | | |
| Inverse mills ratio from probit | | - | 15.79*** | 15.63*** | 15.81*** |
| | | - | (0.595) | (0.542) | (0.629) |
| Time invariant household variable | $c_h$ | YES | YES | YES | YES |
| Time invariant regional variable | $c_i$ | YES | YES | YES | YES |
| Time variant production variable | $Z^q$ | YES | YES | YES | YES |
| ***Hypothesis Tests*** | | | | | |
| Chi sq from endogeneity test ($H_0$: technology is exogenous) | | - | 8.36** | 8.36** | 8.36** |
| Chi sq from overidentifying restriction test ($H_0$: IVs are not jointly valid) | | - | 6.16** | 6.16** | 6.15** |
| Observations | | 5926 | 5926 | 5926 | 5926 |
| Log likelihood | | -13746 | -28269 | -28860 | -28285 |
| Adjusted R-squared | | - | 0.223 | 0.052 | 0.219 |

*Notes:* Time dummies are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Standard errors clustered at household level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

[a] Technology adoptions are instrumented by dummy variable of input voucher receipt, potential yield gain from applying input, fitted values of probabilities of adopting labor and land augmenting technology respectively from the first stage probit estimation, and fitted value of probability of adopting labor augmenting technology multiplied by EOS.

between labor and land is greater than 0.770. For the two stage estimations, I apply the same instrumental variables as the estimations of the on-farm family labor. The endogeneity test rejected the exogeneity of the technology adoptions at the five percent confidence level in all estimations. The instrumental variables pass the overidentifying restriction at the five percent confidence level in all estimations. For the Heckman estimations, I use the inverse mills ratio taken from the probit estimation of the binary variable of whether the household hires on-farm labor as the additional explanatory variable in the estimations of the test of propositions. The coefficient of the inverse mills ratio is statistically significant at the one percent confidence level in all estimations. It indicates that selection bias exists and is controlled in the estimations. The result of the first stage probit estimation of the binary variable of whether household hires on-farm labor is reported in the column (3) of Table 2.A.1

#### 2.3.5.B Result of Robustness Check

Table 2.16 shows the results of switching regressions of on-farm family labor to test Proposition 2.2 a) and b). For estimation with the observed separation, ex-post assignment of the regimes classifies 1,801 households into those who do not face a binding constraint on off-farm labor, and it classifies 4,125 households into those who face a binding constraint. The households without binding constraints satisfy the proposition 2.2 a) except the total area of plot by a switching regression with observed separation. The land-augmenting technology increases on-farm family labor by an average of 30.99 person-days. Taking the range of the EOS into account, the effect of labor-augmenting technology on on-farm family labor ranges from 21.63 person-days to -149.98 person-days. It takes a negative value unless the EOS between land and labor is less than 0.423. The real off-farm wage decreases on-farm family labor. For the households with a binding off-farm constraint, the number of adults aged 15-65 has a positive effect on on-farm family labor. The effect of the number of children is, however, not clearly different between the households with a binding constraint and those without. Hence, proposition

**Table 2.16 Test of propositions III: on-farm family labor (switching regression)**

| Dependent variable: On-farm family labor (person*day) | | Unobserved separation | | Observed separation (ex-post predicted) | |
|---|---|---|---|---|---|
| Explanatory variables | Vector | Not binding Pooled MLE | Binding Pooled MLE | Not binding Fixed effect | Binding Fixed effect |
| **Technology adoption** | | | | | |
| 1 = adopt land augmenting technology | $T^A$ | 24.167 | -2.094 | 37.819*** | 7.863 |
| | | (29.314) | (2.825) | (12.793) | (5.209) |
| 1 = adopt labor augmenting technology | $T^L$ | 146.085* | -23.047** | 6.072 | -9.479 |
| | | (76.870) | (9.865) | (42.440) | (15.848) |
| Interaction term: (labor tech=1)*(EOS) | $T^L\sigma$ | -348.057*** | 29.341** | -11.333 | -20.768 |
| | | (100.448) | (12.975) | (82.183) | (72.484) |
| **Household variables** | | | | | |
| Total area of plot with maize (acres) | $A$ | 4.687*** | 3.858*** | -0.697 | 5.116*** |
| | | (1.600) | (0.512) | (0.701) | (0.613) |
| Number of adults aged 15-65 | $M$ | 27.660*** | 15.082*** | 34.064*** | 21.084*** |
| | | (8.930) | (1.082) | (6.893) | (2.355) |
| Number of children aged 0-3 | $Z^o$ | -13.185 | -0.262 | -6.148 | 2.709 |
| | | (14.568) | (1.807) | (11.078) | (3.328) |
| Number of children aged 4-6 | $Z^o$ | -14.204 | 0.736 | 10.525 | -1.735 |
| | | (17.798) | (1.984) | (9.048) | (3.655) |
| Number of children aged 7-14 | $Z^o$ | -33.649*** | 2.775** | 41.154*** | 3.788 |
| | | (9.207) | (1.206) | (9.167) | (3.448) |
| **Local variables** | | | | | |
| Real off-farm wage (USD/hour) | $w^o$ | -5.425 | -0.152 | -7.565*** | -4.954*** |
| | | (10.633) | (0.463) | (2.771) | (1.028) |
| **Control variables** | | | | | |
| Time invariant household variable | $c_h$ | YES | YES | NO | NO |
| Time invariant regional variable | $c_i$ | YES | YES | NO | NO |
| Time variant production variable | $Z^q$ | YES | YES | YES | YES |
| Observations | | 5926 | 5926 | 1801 | 4125 |
| Log likelihood | | -35628 | -35628 | -9630 | -21595 |
| Adjusted R-squared | | 0.095 | 0.150 | 0.371 | 0.211 |

*Notes:* Time dummies are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Standard errors clustered at household level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2.17 Test of propositions IV: off-farm labor (switching regression)

| Dependent variable: On-farm family labor (person*day) | | Unobserved separation | | Observed separation (ex-post predicted) | |
|---|---|---|---|---|---|
| Explanatory variables | Vector | Not binding Pooled MLE | Binding Pooled MLE | Not binding Fixed effect | Binding Fixed effect |
| **Technology adoption** | | | | | |
| 1 = adopt land augmenting technology | $T^A$ | -25.340 | 2.757 | -16.753* | 13.283 |
| | | (23.166) | (2.269) | (9.991) | (8.374) |
| 1 = adopt labor augmenting technology | $T^L$ | 62.584 | -26.163*** | 13.286 | 12.955 |
| | | (66.343) | (7.721) | (33.407) | (25.561) |
| Interaction term: (labor tech=1)*(EOS) | $T^L\sigma$ | -121.138* | 25.565** | 182.376 | 76.062 |
| | | (71.894) | (10.605) | (141.397) | (108.134) |
| **Household variables** | | | | | |
| Total area of plot with maize (acres) | $A$ | 3.021 | -0.534*** | 0.491 | -0.539 |
| | | (2.190) | (0.102) | (0.454) | (0.342) |
| Number of adults aged 15-65 | $M$ | 43.980*** | 8.510*** | 4.282 | 14.919*** |
| | | (8.788) | (0.849) | (3.624) | (3.927) |
| Number of children aged 0-3 | $Z^o$ | -34.265*** | -2.732** | 4.628 | -3.604 |
| | | (9.629) | (1.183) | (5.954) | (4.936) |
| Number of children aged 4-6 | $Z^o$ | 21.054 | 0.035 | -10.451 | -3.672 |
| | | (16.643) | (1.396) | (6.853) | (6.232) |
| Number of children aged 7-14 | $Z^o$ | -1.505 | -1.864** | -3.778 | 0.188 |
| | | (8.348) | (0.821) | (5.049) | (3.986) |
| **Local variables** | | | | | |
| Real off-farm wage (USD/hour) | $w^o$ | -26.124*** | -2.589*** | 2.223 | -1.761 |
| | | (9.727) | (0.531) | (1.980) | (2.009) |
| **Control variables** | | | | | |
| Time invariant household variables | $c_h$ | YES | YES | NO | NO |
| Time invariant regional variable | $c_i$ | YES | YES | NO | NO |
| Time variant production variables | $Z^q$ | YES | YES | YES | YES |
| Observations | | 5926 | 5926 | 1,815 | 4,111 |
| Log likelihood | | -35466 | -35466 | -9090 | -23014 |
| Adjusted R-squared | | 0.382 | 0.121 | 0.064 | 0.054 |

*Notes:* Time dummies are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Standard errors clustered at household level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

2.2 b) may hold, but the number of children is not likely the exogenous variable to determine the level of a binding constraint on off-farm work opportunities.

Table 2.17 shows the results of estimations to test Proposition 2.2 c) and d). Using the off-farm labor as the dependent variable, the ex-post assignment of the regimes classifies 1,815 households into those without a binding constraint and 4,111 households into those with a binding constraint. The number of households assigned in each regime corresponds to the case of on-farm family labor. Although the results are not as obvious to satisfy the propositions as on-farm family labor or hired labor, for the households without a binding constraint, the land-augmenting technology has a negative effect on off-farm labor. The adoption of land-augmenting technology decreases off-farm labor by an average 21.05 person-days. The effect of labor-augmenting technology, on the other hand, is positive on off-farm labor. The effects range from 47.21 person-days to 76.45 person-days. The number of adults also has a positive effect on off-farm labor. For the households with a binding constraint, the land-augmenting technology does not have a statistically significant effect in both estimations. Again, the effect of the number of children is not clearly different between the households with a binding constraint and those without, and it is not likely the exogenous variable determines the level of a binding constraint of off-farm work opportunities.

### 2.3.6 Conclusion

This study provides micro economic evidence of the effect of land- and labor-augmenting farming technologies on households' decisions on labor allocations. I use data of Tanzanian maize farmers from the Tanzanian National Panel Survey waves 1 to 3. I exploit the variation of the adoption of farming technologies during the input voucher scheme implemented in the country from 2008 to 2013. The estimations of the farm production function provide the estimates of the elasticity of substitution between land and labor by climate zone. The estimated values range from 0.303 to 1.258. By comparing the change in the labor to land ratio and area of land to yield one ton of maize among the farming technologies, I classify organic fertilizer, inorganic fertilizer, and irrigation into land-augmenting technologies, and sprayer, pesticide, herbicide, animal traction, and tractor use into labor-augmenting technologies.

Estimation results show that the labor- and land-augmenting technologies can have opposite effects on the household's decisions on labor allocation. The adoption of land-augmenting technology increases on-farm family labor and on-farm hired labor by an average 30.99 person-days and 5.23 person-days respectively and decreases off-farm labor by an average of 21.05 person-days. The adoption of labor-augmenting technology, on the other hand, decreases on-farm family labor by an average 85.91 person-days when the elasticity of substitution between land and labor is less than 0.423 and on-farm hired labor by 21.24 person-days when the elasticity of substitution between land and labor is less than 0.770. It increases off-farm labor by on average 65.58 person-days.

The results suggest depending on the conditions of a country such as the level of elasticity of substitution between land and labor, which is partly determined by the land availability and constraints on the land market, that labor-augmenting agricultural technologies have a good potential for accelerating structural transformation. Considering that the average size of the smallholder farm holdings in Tanzania remains small, and only 26 percent of 50 million hectares of potentially arable land are currently farmed (World Bank, 2014), Tanzania still has much potential of the growth of agricultural labor productivity by scaling up the landholdings and the adoption of labor-augmenting technologies. However, it depends on the land and other market constraints, labor-augmenting technologies, which have been less emphasized in the history of the agricultural policies in Tanzania, may play important roles in the development of the agricultural sector and economic growth in the country.

# APPENDIX

**Table 2.A.1 Result of first stage estimations (pooled probit)**

| Dependent variable:<br>1 = adopt technology or 1 = hire labor<br>Explanatory variables | (1)<br>Land-augmenting technology | (2)<br>Labor-augmenting technology | (3)<br>On-farm hired labor |
|---|---|---|---|
| **Instrumental variables** | | | |
| 1 = receive input voucher | 0.540*** | 0.120*** | 0.067** |
| | (0.023) | (0.025) | (0.026) |
| Yield potential by input (ton/acre) | 0.030*** | 0.051*** | -0.001 |
| | (0.006) | (0.005) | (0.006) |
| **Technology adoption** | | | |
| 1 = adopt land augmenting technology | - | - | 0.162*** |
| | - | - | (0.044) |
| 1 = adopt labor augmenting technology | - | - | 0.052*** |
| | - | - | (0.015) |
| Interaction term: (labor tech=1)*(EOS) | - | - | -0.047 |
| | - | - | (0.060) |
| **Household variables** | | | |
| Total area of plot with Maize (acres) | 0.001 | 0.008*** | 0.009*** |
| | (0.001) | (0.001) | (0.001) |
| Number of adults aged 15-65 | 0.014*** | 0.029*** | -0.024*** |
| | (0.004) | (0.004) | (0.005) |
| Number of children aged 0-3 | -0.012 | 0.008 | 0.007 |
| | (0.007) | (0.007) | (0.008) |
| Number of children aged 4-6 | -0.008 | 0.006 | -0.006 |
| | (0.009) | (0.008) | (0.010) |
| Number of children aged 7-14 | 0.015*** | 0.025*** | -0.015** |
| | (0.005) | (0.005) | (0.006) |
| HH education (years) | 0.014*** | 0.003 | 0.010*** |
| | (0.002) | (0.002) | (0.002) |
| 1 = HH is female | -0.028 | -0.057*** | 0.014 |
| | (0.017) | (0.016) | (0.017) |
| 1 = member belong to SACCO | 0.066** | 0.055** | 0.206*** |
| | (0.028) | (0.025) | (0.029) |
| **Local variables** | | | |
| Real off-farm wage (USD/hour) | -0.016*** | 0.008** | 0.001 |
| | (0.004) | (0.003) | (0.004) |
| Real hired in wage (USD/day) | 0.007*** | -0.003 | -0.013*** |
| | (0.002) | (0.002) | (0.003) |
| **Production variables** | | | |
| 1 = have plot with title | 0.057*** | -0.004 | 0.042** |
| | (0.018) | (0.016) | (0.019) |
| 1 = experienced drought or flood | -0.062*** | -0.004 | 0.038*** |
| | (0.013) | (0.011) | (0.014) |
| 1 = experienced crop disease | 0.010 | 0.016 | 0.008 |
| | (0.014) | (0.013) | (0.015) |
| 1 = experienced price decrease of crop | -0.022 | 0.037*** | -0.012 |
| | (0.014) | (0.014) | (0.016) |

Table 2.A.1 (cont'd)

| | | | |
|---|---|---|---|
| 1 = experienced price rise of input | 0.117*** | 0.059*** | 0.018 |
| | (0.015) | (0.014) | (0.016) |
| 1 = experienced water shortage | -0.044*** | -0.016 | 0.005 |
| | (0.014) | (0.013) | (0.015) |
| 1 = rural | -0.015 | 0.087*** | -0.147*** |
| | (0.020) | (0.016) | (0.022) |
| | | | |
| Observations | 5,926 | 5,926 | 5,926 |
| Log likelihood | -3157.9177 | -2777.4589 | -3651.1058 |

*Notes:* Time dummies are included in all estimations but not reported. USD used in the table is 2011 PPP USD. Standard errors clustered at household level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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