Off-farm labor supply and the role of rainfall: A case study in Tigray, Northern Ethiopia

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Abstract

This paper addresses the question what off-farm labor supply determines and, more specifically, what is the ro rainfall and rainfall variability therein. Answering this question is important in order to gain better insights into the process of how households deal with income variability. To answer this question the discrete off-farm work decision and labor supply function were modeled for a sample of Tigray (Ethiopia) farm households observed in 1996-1997 and 2001-2002. A probit model was used to estimate the off-farm work participation mode Hausman-Taylor panel data estimator was applied in estimation of the labor supply model.

Results confirm that rainfall variability and low rainfall amounts increase the probability of off-farm la supply. Off-farm labor supply is an income smoothing strategy followed in response to rainfall variability. Al wealth, in the form of large livestock, are alternatives for off-farm labor supply to cope with income variability.

Keywords: off-farm labor supply, panel data, rainfall, Tigray, Northern Ethiopia

1. Introduction

Rural households in semi-arid areas have to cope with extreme income variability. Household survival depends on the ability to anticipate and to cope with this income variability. Through time, households hav developed a range of mechanisms for this. These include use of credit, accumulation of assets, and informal insurance arrangements. For example, Udry (1994) shows to what extent households use credit markets to sm income shocks in Northern Nigeria. Udry (1995) assessed the use of savings. Fafchamps et al. (1998) analyzed th role of livestock holdings, an asset, in a West African context. Dercon and Krishnan (2000) provide evidence informal risk-sharing arrangements in rural Ethiopia and Hoogeveen (2002) in rural Zimbabwe.

In a resource poor area like Tigray, Northern Ethiopia, the most important risk smoothing mechanism is probably the households' effort to diversify activities or to supply labor off-farm. Here the existence well-functioning of a labor market is relevant given that labor is the principal asset owned by the poor. For example, using Indian data Kochar (1999) examined household labor supply behavior in response to idiosyncrati crop income shocks. She concludes that in well-functioning rural labor markets households increase their off-fa labor supply in response to crop shocks instead of dissaving or borrowing. Similarly, Rose (2001) found that in India households are more likely to participate in off-farm employment in response to large rainfall variability. E evidence is still lacking on how participation in labor markets is affected by rainfall shocks in a non-dyna subsistence agricultural environment like Tigray, in contrast to the more dynamic rural setting in India. Specifically, this paper addresses the following question: What determines off-farm labor supply and, more specifically, what i the role of rainfall and rainfall variability in off-farm labor supply decisions. Answering this question is important in order to gain better insights into the process of how households deal with income variability, and thereb improving policies.

To answer the research question we derive an off-farm labor supply function from a household mo incorporates rainfall and rainfall variability. The function is estimated using panel data collected in Tigra non-dynamic and subsistence agricultural environment. A Hausman-Taylor panel data estimator is used fo estimation (Hausman and Taylor, 1981; Gardebroek and Oude Lansink, 2003). Estimating the off-farm labor supply function requires accounting for the censored nature of off-farm labor supply. In this paper this is done using two-step correction (Maddala, 1983: 121-122) in the Hausman-Taylor specification.

The theoretical model is discussed in section 2. Section 3 presents a description of the dataset. The empi model and estimation procedure are discussed in section 4. Section 5 provides a discussion and conclusions.

2. Theoretical model

This section develops a household model that combines the production, consumption and labor suppl decisions of farm households. The model is partly based on Rose (2001)[1]. The household model is given by:

$$Max\,U = U(C,L) \qquad (1)$$

Subject to:

$$P_C C = (P_q Q - P_x X) + wH^O + \overline{Y} \qquad (2)$$

$$Q = Q(H^F, X, \overline{A}, E(\theta), \vartheta) \qquad (3)$$

$$\overline{T} = L + H^F + H^O \qquad (4)$$

$$E(\theta) = \overline{\theta} \qquad (5)$$

$$\vartheta = \overline{\vartheta} \qquad (6)$$

$$w = w(K,Z) \qquad (7)$$

$$L \geq 0, H^F \geq 0, H^O \geq 0, C \geq 0, Q \geq 0, X \geq 0, E(\theta) \geq 0, \vartheta \geq 0, w \geq 0 \qquad (8)$$

Where: U utility; C vector of consumption goods; L leisure; P_C vector of prices of consumption goods; P_q price of output; Q quantity of output; P_x vector of prices of variable inputs; X vector of quantities of variable inputs; w off-farm wage; H^0 off-farm employment; $\overline{Y}$ exogenous non-labor income; H^F on-farm labor supply; $\overline{A}$ vector of fixed inputs; $E(\theta)$ expected rainfall (ϑ) actual rainfall; *E* is expectations operator; $\overline{T}$ total time available; K vector of household characteristics; Z vector of local labor market characteristics.

It is assumed that household preferences can be expressed by a single utility function (equation 1). T household is assumed to maximize utility from consumption and leisure under a budget constraint (equation technology constraint (equation 3) and time availability constraint (equation 4). The budget constraint (equation states that net household income equals farm income plus off-farm labor income, and other non-labor income, such as remittances. Farm income equals revenue from selling agricultural outputs minus variable costs. Off-farm l income equals off-farm wage times the amount of labor supplied off-farm. Production (equation 3) is a fu household's on-farm labor supply, variable input use and use of fixed inputs. Moreover, output is assumed to function of expected rainfall $E(\theta)$ and actual rainfall (ϑ). Expected rainfall is included because some production decisions (e.g. crop choice) depend on expected rainfall. Of course, total output also depends directly on actu rainfall. Total time available is allocated to on-farm work, off-farm work, and leisure (equation 4). Here it is assumed that household labor is homogenous, so the same type of labor is engaged in leisure, on-farm work off-farm work. This implies there is one price for labor. Constraints (5) and (6) state that the expected amount rainfall and actual rainfall are exogenously given at fixed amounts $\overline{\theta}$ and $\overline{\vartheta}$ respectively. The off-farm wage households face (equation 7) is assumed to depend on household characteristics (vector K) and local labor market characteristics (vector Z). Equation (8) gives the non-negativity constraints. Rewriting (4) and substituting (3) and (4) into (2) the bu constraint can be written as:

$$P_C C = P_q Q((\overline{T} - L - H^O), X, \overline{A}, E(\theta), \vartheta) - P_x X + wH^O) + \overline{Y} \qquad (9)$$

The household utility and production function are assumed to be concave, continuous, and twice differentiab ensuring a utility maximizing solution.

The Lagrangian (*G*) for the above constrained maximization problem is given by:

$$G(C,L) = U(C,L) + \lambda\Big[P_C C - \Big(P_q Q\big((\overline{Y} - L - H^O), X, \overline{A}, E(\theta), \vartheta\big) - P_x X + wH^O + \overline{Y}\Big)\Big] + \\ + \gamma\big(E(\theta) - \overline{\theta}\big) + \psi(\vartheta - \overline{\vartheta}) \qquad (10)$$

Where: λ is the Lagrange multiplier associated with the budget constraint, γ and ψ are the Lagrange multipliers associated with the equality constraints of expected rainfall and actual rainfall respectively.

Maximization of this Lagrange with respect to H^O yields the following first-order condition for off-farm labor supply:

$$\frac{\partial G}{\partial H^O} = -P_q \frac{\partial Q}{\partial H^O}\lambda + \lambda w = 0 \quad \text{è} \quad P_q \frac{\partial Q}{\partial H^O} = w \qquad (11)$$

Condition (11) states that off-farm labor is supplied up to the point where the value marginal product c off-farm labor equals the off-farm wage. That is the household allocates its time to off-farm labor supply up to t point where the marginal return from work off-farm is exactly equal to the off-farm wage. Equation (7) shows tha this off-farm wage is farm-specific because it depends on household characteristics (e.g. education). This assumption implies that we assume that there is a well-functioning labor market (perfect price elastic demand f labor). If the off-farm wage is lower than the reservation wage (a threshold) then the farm does not supply off-f labor. In that case the price of labor does not equal the off-farm wage anymore but becomes a shadow wage. V assume the reservation wage is just as the wage determined by household characteristics (vector $K)$ and local labor market characteristics (vector $Z)$. An increase (decrease) of the reservation wage relative to the off-farm wage reduces (increases) the probabi off-farm work participation.

Using the first order condition one can derive the off-farm labor supply function. Off-farm labor supply can be expressed as:

$$\begin{cases} H^O = f(P_q, P_x, \overline{A}, \overline{Y}, E(\theta), \vartheta, K, Z) & \text{if} \quad w > w^r \\ H^O = 0 \quad \text{if} \quad w \le w^r & \end{cases} \qquad (12)$$

Where: w^r reservation wage.

The reduced form labor supply equation (12) shows that off-farm work is expressed in terms of output prices variable input prices, amount of fixed inputs, non-labor income, household's expectation of rainfall, amount of actual rainfall, household characteristics and local labor market characteristics (the latter two determining the off-farm wage).

3. Data

The theoretical model described in the previous section is applied to a four year household dataset for Tigray, Northern Ethiopia, covering the years 1996, 1997, 2001 and 2002. The dataset consists of 199 farm households ir two districts of southern Tigray. It includes information on household time allocation, off-farm employment, number of hours worked off farm, and local labor market and household characteristics.

Off-farm working hours and off-farm labor income were recorded by growing season. For estimation purposes off-farm working hours and off-farm labor income were aggregated into yearly data. Because we do nc have information about the household specific off-farm wage, it is computed by dividing annual off-farm labc income by annual hours worked off-farm. In the off-farm participation model the dependent variable is a du indicating whether some members of the household participated in the labor market or not. 73.3 percent of households engage in off-farm employment at some point in the four year sample period. The dependent variable for the off-farm labor supply model is the total number of hours supplied off-farm. The average number of ho worked off-farm is 1530 for 412 observations.

As indicated in the theoretical framework, both expected and actual rainfall can have an effect on households' income and labor allocation decisions. The actual rainfall amount is critical for crop land preparation and cro planting, thus it has an effect on household labor allocation decisions. Therefore the actual monthly rainfall amounts for the short (March) and for the long (June) rain season are included.

Maximizing utility with a production constraint containing expected rainfall is equivalent to utilit maximization subject to a production function dependent on the certainty equivalent of rainfall. The certai equivalent depends on expected rainfall and the variance of rainfall[2]. The more variable rainfall is, the higher the risk involved and the lower the certainty equivalent. From the definition of the certainty equivalent it follows that in the empirical model there has to be an expression for expected rainfall and the variance of rainfall. For expec rainfall, we could use the mean of rainfall in previous years. However, this would imply that this variable wc perfectly correlated with the district dummies. Moreover, since we already included actual rainfall for different years, actual rainfall would also not be a good indicator. Therefore, the certainty equivalent of rainfall is represented only by rainfall variability[3]. Two variables of rainfall variability are constructed. First, rainfa variability expressed by the Gurgand index (Gurgand, 2003)[4]. This index measures how typical rainfall has been in a given year. For every calendar month, the average precipitation over the period 1993-2002 is taken as "normal" and deviation from this value for a given year is exceptional rainfall. Second, rainfall variability between years expressed by the annual deviation from the 10 year period 1993-2002 mean of rainfall.

Farmers plant a mix of crops, of which the major ones are barley, wheat, teff, grass pea, and lentil. Based or the amount of rain required the crops are aggregated into: most rain dependent crops (wheat and lentil); less dependent (barley and teff) and least rain dependent crop (grass pea). Output prices of these outputs are determine by weighting the prices of the individual crops using the output quantities as weights[5]. Output prices and variable input prices are normalized by the price of the most rain dependent crop (wheat and lentil). Variable inputs are seeds, fertilizer and an aggregate of pesticides and herbicides. Output prices are determined by asking the head of the household what the level of output was and the value of each crop would have been if they had sold total harvest. Seeds of all individual crops are aggregated into one input. Seed price is a weighted average of the prices of individual seeds. The price of individual seeds is determined by asking what the price would have been if farmers would have bought the seeds. Prices of outputs and seed are therefore farm specific. So, they vary over farms and over years. Fertilizer, pesticides and herbicides prices are determined on district level and assumed between farms. Pesticides and herbicides are aggregated into one input using quantities as weights.

Fixed inputs are cultivated land, large livestock (which includes value of cattle, horses, mules, camels donkeys) and small livestock (value of sheep and goats). Including large livestock enables to see if off-farm la supply and assets are competing strategies to cope with income variability. Household characteristics are family size, which is measured by the number of persons living in the household for at least 9 out of 12 months, ag measured as completed years, and education of the household head. For education an education dummy is indicating whether the household head is literate or illiterate. A district dummy is also included in the off-farm labor supply function. This dummy captures labor market characteristics of different regions.

Non-labor income (remittances from relatives, food aid from government, gifts or others) is also recorded. The descriptive statistics of the variables used in the analysis are reported in the Table 1.

Table 1 Descriptive statistics[1]

Definition	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Dependent variables					
Off-farm participation (=1 if household members engage in off-farm work)	708	0.51	0.50	0	
Off-farm number of hours supplied	412	1530.23	1303.31	24	992
Farm Characteristics					
Cultivated land in hectares	708	2.01	1.13	0.25	10.6
Price of less rain dependent crop in Eth Birr / kg	560	0.86	0.23	0.08	2.3
Price of least rain dependent crop in Eth Birr / kg	195	0.82	0.43	0.04	5.3
Seed price in Eth Birr / kg	573	1.04	0.37	0.11	4.8
Insecticide and herbicide price in Eth Birr / kg	26	53.35	69.83	0.67	277.7
Fertilizer price in Eth Birr / kg	322	1.41	0.45	0.15	4.8
Value of large livestock in Eth Birr	659	4162.80	3520.69	150	2520
Value of sheep & goat in Eth Birr	63	323.57	340.28	50	160
Rainfall[2]					
Gurgand index	708	48.29	17.09	14.20	70.7
Annual deviation from the 10 year period mean of rainfall	708	-8.60[3]	17.10	-37.38	26.6
Rainfall amount in March	708	23.37	14.92	0	48.2
Rainfall amount in June	708	31.65	11.463	11	52.2
Other household income					
Non-labor income Eth Birr	708	132.26	480.94	0	625
Household head characteristics					
Head age	708	49.93	11.75	22	8
Education household head (=1 if head is literate, 0 if illiterate)	708	0.40	0.49	0	
Household characteristics					
Family size	708	6.08	2.03	1	1
Market characteristics					
District dummy variable[4] (1 for Enderta district and 0 for Adigudom district)					

4. Empirical model and estimation

In this section an off-farm work participation model and off-farm labor supply function are estimated. Given that we have many zero observations, the off-farm labor supply function is estimated as a Tobit model. In estimating this Tobit model a two-stage approach (Maddala, 1983: 221-222) is used in stead of ML in order to take the structure of our dataset into account in estimation.

The off-farm labor participation model

The participation model is binary and models the probability of each farm household engaging in off-fa employment. Equation (12) is used to derive the off-farm work participation model. The probability of off-farm work (I=1) participation is specified as:

$$P(I=1|x)=F(x'\beta) \qquad (13)$$

Where: x is a vector of independent variables that are hypothesized to influence households' off-farm participation, F is the cumulative distribution function and β is a vector of coefficients.

The distribution function is assumed to be normal, and is estimated using a pooled probit model. Explanatory variables included in the participation equation are normalized output prices (prices of less and least rain depen crop), normalized prices of variable inputs (seed, fertilizer, and an aggregate of pesticides and herbicides), fixe inputs (area of cultivated land, value of large livestock, and value of sheep and goat), family size, household head age, education of the household head, rainfall variables (Gurgand index, annual deviation from the 10 year peri mean of rainfall, rainfall amounts in March and June), non-labor income and district dummies.

The off-farm labor supply model

The labor supply function is specified as:

$$H_{it}^{*} = X_{it}'\beta + \varepsilon_{it} \qquad (14)$$

Where H_{it}^{*} is a latent variable of off-farm hours worked and is observed for values greater than 0 and is censored for values less than or equal to 0; and ε_{it} is a random error. If the disturbance term in (14) is written as $\varepsilon_{it} = \eta_i + u_{it}$, where u_{it} an error term with mean zero and variance σ_u^2 , and $E(u_{jt}u_{it}) = 0$ for all $j \neq i$ and $E(u_{it}u_{is}) = 0$ for all $s \neq t$ then the appropriate estimation technique depends on the nature of η_i . η_i is the household specific effect and measures household specific unobserved variables as management skills.

In the presence of a household specific effect (η_i), the fixed effects estimator yields consistent parameter estimates. However, since the fixed effects estimator requires transforming the data into deviations from indivi means or first differences to get rid of the fixed effects, time-invariant variables also drop out of the model, ev though they could be of interest. If explanatory variables are uncorrelated with the household specific error te random effects estimation technique can be used. An advantage of the random effects estimator is that it al estimation of parameters from the time-invariant variables in contrast to the fixed effects estimator. Howev assumption that all explanatory variables are uncorrelated with the household specific effects does not hold in many cases. Hausman and Taylor (1981) proposed a generalized estimation technique that combines the desirabl properties from both the fixed effects and random effects estimators. Based on Hausman and Taylor equation (14) is rewritten as:

$$H_{it}^{*} = X_{1it}'\beta_1 + X_{2it}'\beta_2 + Z_{1i}\alpha_1 + Z_{2i}\alpha_2 + \eta_i + \varepsilon_{it} \qquad (15)$$

Where X_{1it} are the variables that are time varying and uncorrelated with η_i (time varying exogenous variables); X_{2it} are time varying and correlated with η_i (time varying endogenous variables); Z_{1i} are time invariant and uncorrelated with η_i (time varying exogenous variables); Z_{2i} are time invariant and correlated with η_i (time invariant endogenous variables) and it is assumed that $E[\eta_i] = E[\eta_i | X_{1it}, Z_{1i}] = 0$, $E[\eta_i | X_{2it}, Z_{2i}] \neq 0$, $Var[\eta_i | X_{1it}, Z_{1i}, X_{2it}, Z_{2i}] = \sigma_\eta^2$ and $Var[\eta_i + \varepsilon_{it} | X_{1it}, Z_{1i}, X_{2it}, Z_{2i}] = \sigma_\eta^2 + \sigma_\varepsilon^2$.

The presence of X_{2it} and Z_{2i} would cause estimation bias in case the model would be estimated using a random effects approach. Hausman Taylor showed how the available model variables can be used to instrument for these variables. The time in variables Z_{2i} are instrumented by the individual means $\overline{X}_{1it}$. The time varying variables X_{2it} are instrumented by their deviations from individual means $(X_{2it} - \bar{X}_{2i})$. By definition, Z_{1i} and X'_{1it} are uncorrelated with the household specific error term η_i so that Z_{1i} can serve as its own instrument and $(X_{1it} - \bar{X}_{1i})$ serves as instrument for X_{1it} (Greene, 2003).

In the short-run cultivated land and family size are assumed fixed, and therefore, they are treated as tim varying exogenous variables.[6] Rainfall variables are considered exogenous. Prices of insecticides and herbicides and fertilizer are include exogenous variables, because these prices vary across years but not across households. The Hausman-Taylo estimator is identified if the number of variables that are time varying and uncorrelated with the individual spec effect is greater than the number of variables that are time invariant and correlated with the specific effects. The district dummy, which is a measure of market characteristics, is considered to be a time invariant exogenous variable. Non-labor income received by the household, which is exogenous income that adds to the wealth household is treated as a time variant exogenous variable.

Prices of outputs and seed are treated as time-varying endogenous variables. These prices are determi household level and vary over households and over years. Differences between farms can be interpreted as differences (Thijssen, 1992). Household head age and education are also assumed to be correlated with the household specific effects. The former as a time variant endogenous variable while the latter is a dummy a considered as a time invariant endogenous variable.

Inverse Mills ratio’s obtained from the probit off-farm labor participation model are included in equation (15 yielding a Tobit specification that is estimated using a two-step approach (Maddala, 1983: 221-222). This account for the censored nature of off-farm labor supply.

5. Results

The off-farm work participation model

Estimation results for the off-farm employment participation model are reported in Table 2.[7] The likelihood ratio test outcome of 214.85 indicates that the null hypothesis that all slope coefficients are zero is rejected at the 5 percent significance level.

The Gurgand index is positively related to the off-farm work participation decision. If the Gurgand in increases by one unit, probability of off-farm work increases with 0.09. The annual deviation from the 10 year period mean of rainfall also significantly and positively influences the probability of off-farm employment. marginal effect indicates that a 1 mm increase in the annual rainfall deviation increases the probability of off-fa work by 0.05. Note that marginal effects in Table 2 are calculated at the sample mean and vary over the data rang due to the non-linear character of the probit model. These findings indicate that high rainfall variability, as indicator for expected low rainfall, encourages households to engage in off-farm work as an income and consumpti smoothing strategy. This result is consistent with Rose (2001), who concluded that the probability of ho participation in off-farm employment increases if it expects low and variable rainfall.

The rainfall amounts in March and June are significantly and negatively related to the probability employment. This indicates that as the rainfall amount in March and June increases by 1 mm the probability working off-farm decreases by 0.05 and 0.10 respectively. These are the critical months in which on-farm lab needed for land preparation and sowing. So, in these months on-farm labor increases with good rainfall.

As expected the coefficient of value of large livestock is negatively and significantly related to the probability of off-farm work participation. This suggests that an increase in the value of livestock reduces the probability off-farm employment. As livestock value is a proxy for wealth, the negative relationship explains that relativ wealthy households are less likely to participate in off-farm work. This finding is consistent with the general beli that livestock is used as an income and consumption smoothing strategy in most developing countries[8]. Another interpretation could be that since large livestock is used in crop production an increase in large livestock leads increase in the marginal productivity of farm labor. This leads, given a fixed external wage, to a decrease in off-farm employment. Similarly, the amount of cultivated land negatively influences the probability of o employment. The marginal effect suggests that a 1 hectare increase in the size of the farm reduces the probability of off-farm work by 0.02.

The coefficient for household head age indicates that households with older heads are less likely to participate in off-farm employment. The age of household head also proxies the stage in the family life cycle. Younge household heads have both the ability and the need (to take care of dependent family members in the household) work off-farm. Contrary to expectations education of the household head had no influence on the probability off-farm work participation. This is possibly because of insufficient variability between households[9].

The probability of off-farm employment participation positively increases with family size. This suggests that larger households have a tighter budget constraint (insufficient farm income) thus a higher need for additiona income. Another reason could be that a large family size results in a low on-farm marginal productivity of labor. An increase with 1 extra member increases the probability of off-farm employment with 0.06. This result is consiste with Woldehanna (2000) and Matshe and Young (2004).

Finally, normalized output and variable input prices do not have a statistically significant relation wi probability of off-farm work. The normalized price of the less rain dependent crop has the expected sign. As the price of the less rain dependent crop increases by 1 Birr the probability of off-farm work decreases with 0.04, but not significantly. Contrary to expectations, the price of the least rain dependent crop is positively related to probability of off-farm work. The price of seed is negatively related to the probability of off-farm employment. A high seed price is to be expected if farms have the expectation that growing crops is profitable. This reduces off-farm labor supply. This is consistent with the situation of the farmers in the study area where farmers usually save their own seed for sowing. Price of insecticides and herbicides is positively related to the probability participation in off-farm employment. Herbicides and insecticides represent a labor saving technology and ha positive effect on the decisions to work off-farm. However the coefficient is not significantly different from zero.

In sum, the general picture that emerges is that off-farm employment is an important income stabilizati strategy for rural farm households in Tigray that maintain traditional production systems primarily o self-consumption.

Table 2 Estimation results and marginal effects of the probability of household off-farm work participation[10]

Variable	Coefficient	t-value	Marginal effect
Intercept	-3.0894*	-5.41	
Price of less rain dependent crop	-0.1078	-0.55	-0.04
Price of least rain dependent crop	0.0436	0.33	0.02
Seed price	-0.0680	-0.43	-0.03
Insecticide & herbicide price	0.0036	0.79	0.00
Fertilizer price	-0.1438	-1.71	-0.06
Rainfall variability: Gurgand index	0.2160*	9.61	0.09
Annual deviation from the 10 year period mean of rainfall	0.1201*	9.21	0.05
Rainfall in March	-0.1281*	-8.53	-0.05
Rainfall in June	-0.2594*	-9.65	-0.10
Non-labor income	-0.0000	-0.36	-0.00
Value of large livestock	-0.0001*	-4.08	-0.00
Value of sheep & goat	0.0001	0.17	0.00
Cultivated land	-0.0458*	-2.56	-0.02

Family size	0.1412*	5.02	0.06
Head age	-0.0180*	-3.81	-0.01
Dummy head education	-0.2091	-1.85	-0.08
Dummy district	12.4025*	9.89	1.00
Log likelihood	-383.25		
LR chi2(17)	214.85*		
Pseudo R2	0.22		
Number of observations	708		

*significant at 0.05

The labor supply model

The labor supply model was estimated using the procedure described in the previous section. A standard Haus (1978) test comparing random effects and fixed effects estimates was performed to determine whether random-effects estimator would have been appropriate. The test statistic of 28.01 is larger than the critical value $\chi^2_{15;0.95} = 25.00$. So, it is concluded that there is correlation between at least one of the included variables and the household specific effect, so that the random-effects estimator would give biased estimates. An additional Hausman te conducted to test the Hausman-Taylor model specification against a fixed-effects model. The test statistic of 7.20 less than the critical value of 25.00, indicating that the chosen specification for the Hausman-Taylor model g unbiased estimates.

Estimation results for the labor supply model are presented in Table 3. As expected, rainfall and ra variability relate positively, and significantly, to the number of hours worked. Households increase off-farm la supply in response to an increase in the Gurgand index and the annual deviation from the 10 year period mean rainfall[11]. In response to a 1% increase in the Gurgand idex the number of hours worked off-farm increases 9.32%. Similarly the number of hours supplied off-farm increases by 0.98% if the annual deviation from the 10 year period mean of rainfall increases by 1%. Rainfall amounts in March and June are negatively correlated off-farm labor supply. As expected, rainfall amounts in March and June and on-farm labor are complements. During the growing season of the cropping year, on-farm labor productivity increases, and households are encouraged to supply more labor on-farm. A 1% increase in rainfall in June reduces the off-farm employment 6.55%. June is the month, where most of the crop planting takes place.

The coefficients of the values of large livestock and small livestock have a negative sign. The coefficient for large livestock is statistically significant, while for small livestock it is not significant. This shows that if the value of large livestock increases with 1% the number of hours worked reduces with 0.38%. This confirms that large livestock, an asset, is an alternative for off-farm labor supply as a way to cope with income variabilit Moreover, given that large livestock is used in crop production, a large livestock increases the marginal productivity of on-farm labor reducing the supply of off-farm labor. The sign of the coefficient representin cultivated land is negative suggesting that as farm size increases the number of hours supplied to off-farm w declines. However, the coefficient is not statistically significant. Non-labor income has a negative effect on off-farm labor supply. However, the coefficient is not statistically significant. Off-farm hours supplied increase if family size increases (statistically significant). The elasticity shows that as the number of family size increases by 1% off-fa hours supplied increase by 0.76%.

Table 3 Estimation results and elasticities of household’s off-farm labor supply

Variable	Coefficient	t-value	Elasticity’s at mean value
Intercept	-1229.23	-1.05	
Time variant exogenous variables			
Insecticide & herbicide price	6.17*	2.61	0.02
Fertilizer price	-248.01*	-3.38	-0.21
Gurgand index	144.41*	2.73	9.32
Annual deviation from the 10 year period mean of rainfall	84.87*	2.83	0.98
Rainfall in March	-98.11*	-3.09	-3.06
Rainfall in June	-154.90*	-2.45	-6.55
Non-labor income	-0.11	-1.29	-0.02
Value of large livestock	-0.07*	-2.24	-0.38
Value of sheep & goat	-0.05	-0.15	-0.00
Cultivated land	-25.55	-1.33	-0.27
Family size	93.43	1.91	0.76
Inverse Mills ratio	386.11	0.88	
Time variant endogenous variables			
Price of less rain dependent crop	-227.95	-1.61	-0.21
Price of least rain dependent crop	25.71	0.25	0.01
Seed price	102.55	0.92	0.12
Head age	-32.51*	-3.64	-2.17
Time invariant endogenous variable			
Dummy head education	765.33	1.51	0.41
Time invariant exogenous variable			
Dummy district	8438.50*	2.76	5.43
Wald chi2(18)	168.50*		
Number of observation	708		

*significant at 0.05. The inverse Mills ratio is obtained from the equation on the probability of working off-farm and is used as an explanatory variable in the off-farm labor supply function (equation 15).

None of the normalized output prices have a significant effect on off-farm labor supply. The sign of the price of the less rain dependent crop has the expected negative sign. This implies that if the price of the less rain dependent crop increases off-farm labor supply decreases. Normalized prices of seed and insecticides and herbicides have the expected sign. The price of insecticides and herbicides has a significant and positive effe off-farm labor supply. This suggests insecticides and herbicides and off-farm labor supply are alternatives to dea with income variability. The coefficient for the price of seed is not significantly different from zero. Househol reduce the number of hours supplied to off-farm work in response to a fertilizer price increase. This indicate fertilizer is a substitute for labor.

In the face of rainfall variability and low rainfall amounts households supply more hours to off-farm work. This is more likely to be the case when the household is poor (has no livestock). Off-farm labor supply is used as an income smoothing and mitigation mechanism.

6. Discussion and conclusions

This paper addresses the following question: What determines off-farm labor supply decisions and, m specifically, what is the role of rainfall and rainfall variability therein. To answer this question the discrete off-farm work decision and labor supply function were modeled for a sample of Tigray farm households observed i 1996-1997 and 2001-2002. A probit model was used to estimate the off-farm work participation mode Hausman-Taylor panel data estimator was applied in estimation of the labor supply model.

Results confirm that rainfall variability and low rainfall amounts increase the probability of off-farm lab supply. Off-farm labor supply can be therefore be seen as an income smoothing strategy followed in response rainfall variability. These finding are consistent with Rose (2001) who confirmed the existence of ex-ante and ex-post labor supply responses to rainfall risk. Wealth, in the form of large livestock, has a negative effect o off-farm work participation and hours worked. This confirms that a large livestock is an alternative for off-farm labor supply to cope with income variability. The price of insecticides and herbicides has a significant and posi effect on off-farm labor supply. So, also insecticides and herbicides are a possible alternative for off-farm labo supply to deal with income variability. As expected also family size has a positive effect on off-farm labor sup Output prices and farm size did not have a significant effect on off-farm employment.

The analysis in this paper is subject to some qualifications. First, this study has only addressed off-farm labor participation and labor supply responses in reaction to rainfall and rainfall variability. However, there are other sources of risk then ri related to rainfall, e.g. market price risk. Second, here we looked at off-farm labor isolated from other decisions taken on the farm. Especially, we ignored gender issues. Men and women tend to invest in different skills and th could face different labor market opportunities. Woldehanna (2000) makes such a distinction but he does not focus on the role of rainfall and rainfall variability.

We conclude that off-farm labor supply is important in mitigating and coping with income variability related to rainfall variability. This shows the importance of economic development outside and inside agriculture creating job opportunities.

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[1] For details on agricultural household models, see Singh et al. (1986), Sadoulet and de Janvry (1995), and Taylor and Adelman (2003). To simplify presentation we omit indices indicating households.

[2] The certainty equivalent is defined as: $CE(\theta) = E(\theta) - \frac{1}{2} \cdot \gamma \cdot \mathrm{var}(\theta)$, where *g* is the Arrow-Pratt measure of absolute risk aversion.

[3]

Note that this model set-up corresponds to Rose (2001) who tests the impact of rainfall expectations on labor supply via the variables average rainfall and rainfall variability.

[4] Rainfall variability within a year is computed using the Gurgand index (2003). That is, $\sigma^2_{dt} = \sqrt{1/12 \sum_{m=1}^{12} (r_{dmt} - \bar{r}_{dm})^2}$ where *d*, *t*, and *m* denote district, a given year and a given month respectively. r_{dmt} measures monthly rainfall amount in district *d* during year *t* and in a specific month *m*, whereas $\bar{r}_{dm}$ measures the average monthly rainfall amount in district *d* and month *m* over the period 1993 to 2002. This index measures how typical rainfall has been in a given year. For every calendar month, the average precipitation over the period is taken as “normal” and deviation from this value for a given year is exceptional rainfall (Gurgand, 2003).

[5] Alternatively cost and revenue shares could have been used.

[6] In Ethiopia

there is no formal land market. Access to land is based on membership to village communities. Although there is an informal land market in the study area, it is not frequently used by many farmers and it is natural to think of cultivated land as a fixed input in the short run. Family size is also considered fixed in short run.

[7]

Marginal effects are calculated as the derivatives of the cumulative normal distribution at the mean of the explanatory variables; for dummies the marginal effect is expressed as the discrete change from 0 to 1.

[8] Fafchamps et al. (1998) show for West Africa

that during drought years livestock sales compensated for 15 to 30 percent of the income fluctuations.

[9]

This is an unexpected result because most of the literature, for example Matshe and Young (2004), report a positive and significant relationship between the probability of off-farm employment and household head education.

[10]

Since the left hand side variable is binary the farm-specific wage variable would be perfectly collinear, and is therefore excluded from estimation.

[11] Kochar (1999) also finds that households increase their off-farm labor supply in response to an income shock.