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Article

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FINANCIAL ECONOMICS | RESEARCH ARTICLE

Impact of Awash irrigation on the welfare of smallholder farmers in Eastern Ethiopia

Dagninet Asrat^{1*}, Adugnaw Anteneh², Mohammed Adem² and Zewdu Berhanie³

Abstract: Ethiopia's agriculture is dominated by small-scale rain-fed production in combinations of natural and manmade factors have resulted in serious poverty. Irrigation farming is increasingly being used as a strategy in Ethiopia. However, lack of consensus on the role of the irrigation sector on the welfare of smallholder farmers and pitfalls in impact study methodologies resulted in mixed findings. This study evaluated the impact of Awash irrigation on the welfare of rural smallholder farmers. Two-stage stratified sampling technique employed to select sample households. Cross-sectional household level data from a survey of 315; 165 irrigation users and 151 non-users smallholder farmers in Asiyta district, Ethiopia used for the analysis. This study employed endogenous switching regression model to control for endogeneity problems associated with adoption decision. Accordingly, the correlation coefficient result proved that the existence of self-selection and endogeneity. Results indicated, irrigation users' per capita consumption expenditure and income were 16 percent and 35 percent, respectively, higher compared to non-irrigation-users significantly. Endogenous switching regression model further identified amount of own land cultivated, education status, number of extension contact, livestock holding, nearest market distance, access to non-farm job and nearest canal distance significantly determine irrigation participation. The study concluded



Dagninet Asrat

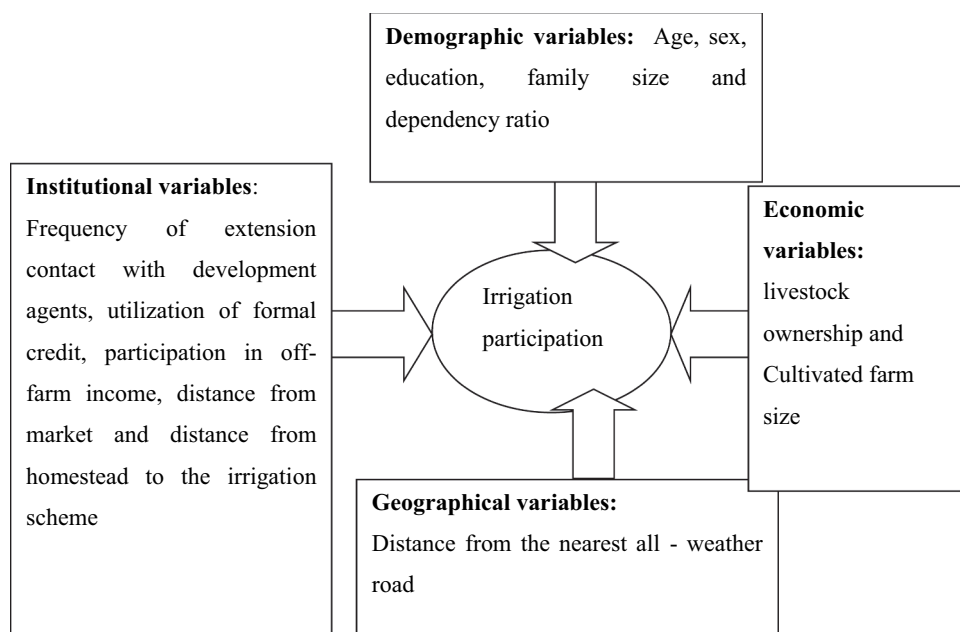
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Dagninet Asrat is a full-time lecturer in the Department of Agribusiness and Value Chain Management at Samara University, Ethiopia. He has MSc degree in Agricultural Economics from Bahirdar University, Ethiopia. He had teaching several courses for agribusiness and value chain management, agricultural economics, natural resource economics and management, and rural development students. He has carried different community service development projects related to improving the livelihood of smallholder farmers and work with community and development agents. He has also engaged in supervising various research projects. His research interest includes on different areas of impact studies, climate smart agriculture, food security, value chain management, supply chain, market chain, agribusiness development projects and industry community linkage research with particular inclination of Sub-Saharan Africa and the world in general.

PUBLIC INTEREST STATEMENT

Irrigation is regarded as a strategy for improving natural production by increasing the productivity of available land and thereby expanding total agricultural production. In Ethiopia, irrigation development can be considered as a cornerstone of food security and poverty reduction tool as it has a power to stimulate economic growth and rural developments, and defending smallholder farmers' livelihood against economic vulnerability. Accordingly, Ethiopia has huge potential both in water and irrigable land used for a wide range of irrigation development projects. Even though less than 5–10 percent of the estimated potential is actually irrigated, and Ethiopia holds up behind in its ability to grow enough food to feed its teeming population and likewise maintains some of the lowest level of access to basic services, and results one of the poorest countries in the world. Thus, our study was meant to investigate the impact of irrigation on the welfare of smallholder farmers in Eastern Ethiopia, revealed irrigation increased consumption expenditure and income significantly.

Figure 1. Conceptual framework for determinants of irrigation participation.
Source: Modified from Mengistie and Kidane (2016)



that Awash irrigation is one of the viable solutions to improve the welfare of smallholder farmers in the study area. Therefore, governmental and non-governmental organization should promote, improve and expand Awash irrigation in all areas of the Woreda in particular and irrigation agriculture in general.

Subjects: Agriculture & Environmental Sciences; Environment & Business; Environment & Economics

Keywords: consumption expenditure; income; poverty; endogenous switching regression

1. Introduction

Agriculture is the leading sector for the economic growth of many low-income countries. In Ethiopia, agriculture is still a mainstay of the economy and food supplier to the nation, and it relies largely on rainfall. In Ethiopia, 95% of the total area is cultivated by smallholder farmers and 90% of the country's agricultural output is produced by smallholder farmers (Mazengia, 2016; Taffesse et al., 2012). Approximately, it contributes 43% of the GDP, 80% of employment and 75% of export commodity values (Bayleyegn et al., 2018). In general, crop production dominates 67% of the agricultural GDP (Molden, 2013).

Agriculture in the country is typically small-scale, rain-fall dependent, traditional and subsistence farming with limited access to technology and institutional support services (Hundie, 2014). Furthermore, the sector is susceptible to weather fluctuations (Salami et al., 2010). Hence, traditional smallholder agriculture less rewarding that threatens the welfare of the rural poor (Urama & Ozor, 2010). This results low farm production, widespread lower income and subsequent food shortages and famines.

Ethiopia is the land of promise with great yet mostly untapped irrigation potential and agricultural land, and highly diverse agro-ecological zone that are suitable for the production of wide varieties of crops (Awulachew et al., 2010). In Ethiopia, irrigation development can be considered as a cornerstone of food security and poverty reduction tool as it has a power to stimulate economic growth and rural developments (Hagos et al., 2009). Irrigation is one means by which

agricultural production can be increased to meet the growing food demands. In Ethiopia, irrigation is a key to increase smallholder farmers' income, household employment and defending smallholder farmers' livelihood against economic vulnerability by producing higher value crops and harvest more than once per year (Haji & Jirane, 2015; Kidane, 2016).

Moreover, irrigation is an optional allocation of household labour. On the other hand, irrigation is a means for self-employment in household labour (Temesgen, 2017). In turn, this provides them to build up their assets, buy more food and non-food household items, educate their children and reinvest in further increasing their production by buying farm inputs or livestock (James & Maryam, 2014).

Ethiopia has huge potential both in water and irrigable land using for a wide range of irrigation development programmes, and considered as the water tower of Africa (Makombe et al., 2007). While a lot of effort is exerted towards irrigation development, little attempt is done to quantify the contribution of irrigation to national income of Ethiopia. The government of Ethiopia has taken irrigation agriculture as main strategies in the overall country's development agenda and investment framework from 2010 to 2020 (Demese et al., 2010). However, less than 5–10 percent of the estimated potential is actually irrigated (Awulachew et al., 2010).

The existing literature on irrigation and its impact studies are mixed. The literature on this issue is not only scant, but also polarized. Bhattarai et al. (2002) could not found a straightforward relationship between irrigation and poverty alleviation in selected Asian countries: India and China. Finally, the study recommended, restructuring of irrigation commands could be achieved through reforming of institutional, technical, managerial and operational factors. Passarelli et al. (2018) evaluated the pathways from irrigation to dietary diversity evidence from Ethiopia and Tanzania. The study revealed that irrigation has no effect on the diversity of crops produced and income from agricultural production after controlling for other factors in Tanzania. Similarly, Kibret et al. (2014) reported malaria transmission increased in irrigated villages of Central Ethiopia.

On the other hand, Moyo and Machethe (2016) found irrigation farming significantly improved household food security through improved food availability and dietary diversity in South Africa. Ogunniyi et al. (2018) also reported a significant and positive effect of irrigation technology use on crop yield, crop income and household food security in Nigeria. Similarly, Abdissa et al. (2017), Gebrehiwot et al. (2017), Tefera and Cho (2017), Zeweld et al. (2017), and Mekore and Yaekob (2018) conducted the impact of irrigation in different areas of Ethiopia. And, these studies indicated that a positive and significant impact of irrigation on smallholder farmers' welfare. However, in eastern Ethiopia which is dry land areas, irrigation impact studies were not employed, while realizing irrigation potential requires innovations, as it poses significant changes related to traditional lifestyles such as sedentary farming to commercial agriculture.

Impact studies are also influenced by the methodology approach. Most of previous studies did not address the selection and endogeneity bias that could arise between the adoption decision and the outcome equation in the model specification and estimation process. According to Mendola (2007), not account selection bias result upwards or downwards bias of true impact estimates and lead to misleading policy implications. Therefore, to fill these gaps, this study adopted the most current and robust endogenous switching regression model, and conducted the impact of Awash irrigation on smallholder farmers' consumption expenditure and income, and factors affecting participation of smallholder farmers in Awash irrigation in Asayta Woreda, Ethiopia.

2. Material and methods

This study adopted cross-sectional household level data survey procedure, carried out in the course of February to April, 2019 production season from Asayta Woreda, Eastern Ethiopia. Two-stage stratified sampling procedure were employed to select representative respondent households. In the first stage, the 11 rural Kebeles (Peasant Association) found in Asayta Woreda were stratified in to three

categories as high (>55%), medium (<55-33%) and low (<33%). The classification was based on irrigation user households to total households' proportion in each *Kebeles*. Awash River has the potential to irrigate fully Asayta *Woreda* (the 11 *Kebeles*) because demographically the river rotates most of the land area. Then, six *Kebeles* were selected using proportional to size simple random sampling technique from each stratified *Kebeles*. In the second stage, using a sampling frame from the respective agriculture office of sample *Kebeles*, households in each selected *Kebeles* were stratified in to two strata, namely irrigation users and non-users. Irrigation users are households using Awash irrigation scheme, while non-users are households not using Awash irrigation farming at all. In ^{the} area, there is no rain-fed farming and other irrigation practice. The only crop production practice is using Awash River. Finally, having the sampling frame from the *Woreda* agricultural office, irrigation user and non-user sample households selected randomly based on probability proportional to size principle from the selected *Kebeles* of stratified sub-groups. Accordingly, 315 sampled households; 151 irrigation users and 164 non-users were used in the study.

Thus an appropriate determination of the sample size used in a study is a crucial step in the design of a study. In arriving at this sample size, account was taken of the constraints imposed by limitation of Budget and time, the need to ensure a manageable and controllable sample structure. Moreover, the study adopted cross-sectional household survey, the dynamics of per capita consumption expenditure and per capita income of smallholder farmers over time was not adequately covered in the study.

Both secondary and primary data were utilized in this study. Secondary data was used as base for primary data utilization. Secondary data were reviewed and organized from published and unpublished materials, while primary data were collected using two-survey procedure, formal and informal surveys. In the informal survey, key informant interview and focus group discussion were adopted using checklist interview questions. According to Elder (2009) key informant interview is conducted on those individuals having further enriched knowledge about the area and can give clear information on major issues of the study. Therefore, irrigation facilitator development agents, general manager of each water user association commute and coordinator of each irrigation scheme from *Woreda* agriculture office were participated in the interview. These were the first activities, for rapid appraisal of the irrigation system, to develop and/or refine workable hypothesis and to develop semi-structure questionnaire for formal survey.

3. Analytical framework

In examining the impacts of irrigation on per capita consumption expenditure and income; it is be too simplistic and biased to just attribute the differences in consumption expenditure and income between irrigation users and non-users. The problem of causal inference is not an issue under experimental data, in which the counterfactual situation is known (Miguel et al., 2004). Even though cross-sectional survey data are not trivial because of the need to identify the counterfactual situation had they not had participated in irrigation is a big issue. The selection bias due to observed and unobserved household and farm characteristics makes it difficult to perform ex-post assessment of gains from an intervention using observational data (Asfaw et al., 2012). Thus, the problem can be resolved by investigating the impact of irrigation participation by analysing the differences in outcomes among farm households participating in irrigation and those not participating using econometric models.

The endogenous switching regression model developed by Lee (1982) as a general model of the Heckman selection correction model, can account for selection bias by treating selectivity as an omitted variable problem (Heckman, 1979). Endogenous switching regression model accounts both endogeneity and sample selection bias, and allow interactions between the selection and other covariates in the welfare outcome functions (Alene & Manyong, 2007). It also accounts the differential impact of Awash irrigation on household welfare outcomes; separate welfare outcome functions for irrigation users and non-users. The description of variables of the model and their hypothesized relationships are shown in Table 1.

3.1. Specification of endogenous switching regression model

The critical issue in impact study is acknowledging the potential biases. In the study area, irrigation participation is modeled under the random utility theory, farmers choose themselves as irrigation users and non-users based on the expected utility they will receive. It is assumed that farmers are risk neutral, and their decision to participate in irrigation is influenced by the utility they will derive from irrigation participation. For this, two sources of biases are mentioned. The bias may result from both observed (observed to the researcher) and unobserved (observed to the respondent but not the researcher) characteristics. Therefore, self-selection into the intervention (Awash irrigation) utilization would be the source of endogeneity, and failure to account this bias would obscure the true impact of the intervention (Alene & Manyong, 2007). Most of previous impact studies were not take in to account selection bias in their estimation, makes this study unique.

Endogenous switching regression model design account both endogeneity and selection bias by estimating a simultaneous equations model using full information maximum likelihood method developed by Lokshin and Sajaia (2004, 2011). In this study, selection bias may be arising from unobserved factors that potentially affect both the decision to use irrigation and the outcome functions (per capita consumption expenditure and income). In addition to, endogenous switching regression model can control structural differences between irrigation user and non-user outcome functions (Alene & Manyong, 2007; Seng, 2016).

Following Lokshin and Sajaia (2004, 2011), in this approach, there are two stages: first, irrigation participation (the selection equation) is modeled by standard limited dependent variable model. Then, the outcome variables are estimated separately for each group as irrigation users and non-users, conditional on having the selection equation. The following model specifies the selection equation S_i^* , where S_i^* is the latent variable which is not observed.

$$S_i^* = \beta Z_i + \nu_i \quad (1)$$

$$S_i = \begin{cases} 1 & \text{if } S_i^* > 0 \\ 0 & \text{if } S_i^* \leq 0 \end{cases}$$

The selection equation is a dummy variable, symbolized as S_i taking a value 1 if households participate in irrigation and 0 otherwise. The Z represents factors that affect the decision to use irrigation. The β denotes the vector of parameters, indicating the magnitude and direction of each explanatory variable effect on the decision to participate in irrigation. The residual ν_i captures the unobserved factors and measurement errors.

The two regimes of outcome functions that households' fall in to, conditional on the selection equation are represented by the following two regression equations

$$\text{regim 1 : } W_{1i} = \begin{cases} C_{1i} \\ Y_{1i} \end{cases} = \alpha_1 X_{1i} + \varepsilon_{1i} \text{ if } S_i = 1 \quad (2)$$

$$\text{regi 2 : } W_{2i} = \begin{cases} C_{2i} \\ Y_{2i} \end{cases} = \alpha_2 X_{2i} + \varepsilon_{2i} \text{ if } S_i = 0 \quad (3)$$

The W_{1i} and W_{2i} are dependent outcome variables determined by the exogenous variables. The α_1 and α_2 are parameters that show the direction and strength of the relation between the outcome variables $\left(\begin{cases} C_{1i} \\ Y_{1i} \end{cases} \text{ and } \begin{cases} C_{2i} \\ Y_{2i} \end{cases} \right)$ (Per capita consumption expenditure and income of irrigation users and non-users, respectively) and the independent variables. Accordingly, X_{1i} and X_{2i} are vectors of

Table 1. Variables of the model and their hypothesized relationships

Variable label	Description	Unit	Expected signs (ESRM)		
			Expenditure	Income	Irrigate
	Household characteristics				
Gender	Male headed households (1 if male = 1, otherwise = 0)	Dummy	+	+	+
Age	Age of the household head	Years	-	-	-
Age square	Age of household head square	Years	+	+	+
Adult labour	Household member adult labour	Number	+	+	+
Education	Literacy of household head (literate = 1, illiterate = 0)	Dummy	+	+	+
	Asset				
Land holding	Amount of land owned by household head	Hectares	+	+	-
Livestock holding	Total livestock holding	TLU	+	+	-
	Institutional characteristics				
Accredit	Access to credit (yes = 1, Otherwise = 0)	Dummy	+	+	+
Extcontact	Number of extension contact in a year	Number	+	+	+
Marktdis	Distance from respondents' live home to the nearest market	In kilometre	-	-	-
Schdis	Distance from homestead to irrigation scheme	In kilometre	-	-	-
	Output (outcome)				
Consumption expenditure	Per capita consumption expenditure	In kilogram			

(Continued)

Table 1. (Continued)					
Variable label	Description	Unit	Expected signs (ESRM)		
			Expenditure	Income	Irrigate
	Household characteristics				
income.	Per capita income				
Irrigate	If the household head participate in irrigation = 1, if not = 0	In kilogram Dummy			

explanatory variables assumed to be weakly exogenous, whereas ε_1 , ε_2 are error terms. The Z and X variables can overlap but there must be at least one variable included in Z but not included in X to properly identify the outcome equations.

The error terms (ε_{1i} , ε_{2i} , and ν_i) have a trivariate normal distribution with mean vector zero and covariance matrix (0, Σ) due to the endogenous behavior of households (Lee, 1982). Thus, the selection equation error term (ν_i) is correlated with the outcome equation of error terms (ε_1 and ε_2). Accordingly, the expected values of error terms (ε_1 and ε_2) would be non-zero, conditional upon the selection equation. The covariance matrix Σ is expressed as follows:

$$\text{cov}(\nu_i, \varepsilon_1 \text{ and } \varepsilon_2) = \begin{Bmatrix} \sigma_\nu^2 & \sigma_{1\nu} & \sigma_{2\nu} \\ \sigma_{1\nu} & \sigma_1^2 & . \\ \sigma_{2\nu} & . & \sigma_2^2 \end{Bmatrix}$$

Where $\text{var}(\nu_i) = \sigma_{\nu_i}^2$ is the variance of the error term in the selection equation, whereas $\sigma_{\varepsilon_1}^2$ and $\sigma_{\varepsilon_2}^2$ are variances of the error terms in the outcome equations (per capita consumption expenditure and income). The covariance of error terms ν_i , and ε_{1i} and ε_{2i} are $\sigma_{\varepsilon_1\nu}$ and $\sigma_{\varepsilon_2\nu}$, respectively. On the other hand, the covariance of the outcome function error terms ($\text{cov}(\varepsilon_1, \varepsilon_2)$) is not defined because the two outcome functions are not observed simultaneously (Maddala, 1983). This structure of the error terms indicates that the error terms of the outcome equation and the error term of the selection equation are correlated, results in non-zero expected value of ε_{1i} and ε_{2i} given ν_i —error term of the selection equation (Abdulai & Huffman, 2014). Therefore, having the disturbance terms, the log likelihood equation can be derived as:

$$\ln L = \sum_i \left(S_i \varphi_{1i} \left[\ln \{F(\varphi_{1i})\} + \ln \left\{ \frac{f\left(\frac{\varepsilon_{1i}}{\sigma_1}\right)}{\sigma_1} \right\} \right] + (1 - S_i) \varphi_{2i} \left[\ln \{1 - F(\varphi_{2i})\} + \ln \left\{ \frac{f\left(\frac{\varepsilon_{2i}}{\sigma_2}\right)}{\sigma_2} \right\} \right] \right)$$

Where $f(\cdot)$ is a normal probability density function (pdf) and $F(\cdot)$ is a normal cumulative distribution function (cdf) of the standard normal distribution.

$$\varphi_{ji} = \frac{(\beta Z_i + (\rho_j \varepsilon_{ji} / \sigma_j))}{\sqrt{1 - \rho_j^2}} \text{ Where } j = 1, 2$$

The key issue in controlling endogeneity is identification. Following Wooldridge (2010), this study controlled the endogeneity problem by finding instrumental variable that could be strongly correlated with the selection equation (Equation 1) but not the outcome equations (Equations 2 and 3). Therefore, refereeing to the data set, distance from the nearest irrigation scheme to the household homestead (Schdist) used as an instrumental variable to properly identify the model. Accordingly, following Di Falco et al. (2011), the validity of the selected instrumental variable was tested.

Consequently, estimations of treatment effects were made. The average treatment effect on the treated (ATT) and untreated (ATU) were computed by comparing the expected values of irrigation user and non-user households in actual and counterfactual outcome scenarios.

Actual expected outcome: irrigation users

$$E\left(\begin{Bmatrix} C_{1i} \\ Y_{1i} \end{Bmatrix} | S = 1, X_{1i}\right) = \alpha_1 X_{1i} + \sigma_1 \rho_1 f(\beta) / F(\beta Z_i) \quad (4)$$

Counterfactual expected outcome: irrigation users

Table 2. Endogenous switching regression results for irrigation participation and impact on expenditure									
Explanatory variables	Irrigation participation		Per capita consumption expenditure						
			User		Non-user				
	Coef.	Stt. Err.	Coef.	Stt. Err.	Coef.	Stt. Err.			
Age of the farmer	-.080	.073	-.035**	.014	-.029	.031			
Age square of farmer	.00073	.00075	.0003***	.0001	.0003	.0003			
Gender	-.187	.499	-.020	.084	.361**	.154			
Adult labour	.039*	.104	-.062***	.020	-.122***	.038			
Education	.368*	.209	.042	.047	.047	.074			
Land holding size	.312***	.115	-.027	.022	.039	.044			
Livestock holding	-.225***	.045	-.019	.013	-.012	.010			
Access to credit	.141	.236	.085	.053	.191**	.077			
Number of extension contact	.034***	.006	-.001	.002	.003	.002			
Nearest local market Distance	-.267***	.049	-.033**	.015	.002	.017			
Access to non-farm job	-.994***	.229	.030	.054	-.063	.074			
Nearest scheme distance	-.365***	.074							
Constant	-.567***	.097	10.358***	.334	9.320***	.516			
/lns1	1.318	.0561	.277***	.015	.419***	.026			
/lns2	-.877	.063	.0455	.339	.385**	.165			
/r1	-.199	.288							
/r2	.276***	.173							
sigma_1	.268***	.015							
sigma_2	.416	.026							
rho_1 (ρ_{12})	.197	.277							

(Continued)

Table2. (Continued)		Per capita consumption expenditure					
Explanatory variables	Irrigation participation	User			Non-user		
		Coef.	Stt. Err.	Coef.	Stt. Err.	Coef.	Stt. Err.
rho_2 (ρ_k)		.385**	.165				
Log likelihood		-220.721					
Wald chi2(11)		50.98***					
LR test of independent equations χ^2 (1) 3.34*							

*** 1% level of significance; **5% level of significance; *10% level of significance.
Source, Own survey (2019).

Table 3. Endogenous switching regression results for irrigation participation and its impact on income

Explanatory variables	Irrigation participation		Per capita income			
			User		Non-user	
	Coef.	Stt. Err.	Coef.	Stt. Err.	Coef.	Stt. Err.
Age of the farmer	−.123*	.070	−.019	.023	.0008**	.0003
Age square of farmer	.001	.0007	.0002	.0002	−.0002	.0003
Gender	−.196	.401	−.068	.146	−.380 **	.176
Adult labour	.119***	.099	.068**	.034	.108**	.044
Education	.223*	.178	.075	.083	.043	.084
Land holding size	.199*	.112	−.033	.037	.056	.051
Livestock holding	−.251***	.045	−.062***	.022	.023*	.012
Access to credit	.141	.236	.442***	.087	.144	.088
Number of extension contact	.0301***	.008	.006**	.003	.006**	.003
Nearest local market distance	−.038***	.017	−.091***	.023	.013	.020
Access to non—farm job	−1.065***	.211	.191**	.083	.085	.087
Nearest scheme distance	−.368***	.075				
Constant	5.771***	1.683	9.972***	.566	10.216***	.843
/lns1	−.863	.054				
/lns2	−.802	.059				
/r1	.025	.551				
/r2	.036	.214				
sigma_1	.506***	.039				
sigma_2	.477	.028				
rho_1 (ρ_{1Y})	.899***	104				
rho_2 (ρ_{1Y})	.079	.237				
Log likelihood	−314.945					
Wald chi2 (11)	61.55***					

LR test of independent equations χ^2 (1) 6.92 ***

$$E\left(\left\{\begin{matrix} C_{1i} \\ Y_{1i} \end{matrix} \middle| S = 0, \chi_{1i}\right\}\right) = \alpha_2 \chi_{1i} - \sigma_1 \rho_1 f(\beta Z_i) / \{1 - F(\beta Z_i)\} \quad (5)$$

Counterfactual expected outcome: non-users

Table 4. Impact of irrigation on expenditure and income using endogenous switching regression model

Outcome variable	Household type and treatment effects	Decision stage		Treatment effects
		Irrigation user	Non-user	
Per capita consumption expenditure	Irrigation user	(a) 8564.084 (112.348)	(c) 7178.786 (117.778)	$ATT_c = 1385.29^{***}$ (162.769)
	Non-user	(d) 7588.329 (91.445)	(b) 5865.995 (89.539)	$ATU_c = 1722.33^{***}$ (127.982)
	Heterogeneous effects	$BH_{1c} = 975.755^{***}$ (146.447)	$BH_{2c} = 1312.79^{***}$ (149.989)	$TH_c = -337.04$
Per capita income	Irrigation user	(e) 8824.714 (209.280)	(g) 5719.953 (146.399)	$ATT_y = 3104.761^{***}$
	Non-user	(h) 7326.186 (192.967)	(f) 5393.873 (107.124)	$ATU_y = 1932.313^{***}$ (165.358)
	Heterogeneity effects	$BH_{1y} = 1498.53^{***}$ (1317.231)	$BH_{2y} = 326.08^*$ (184.187)	$TH_y = 1172.45$

*, ** and *** represent significance at 10%, 5% and 1% levels, respectively.

The values in the parenthesis are standard error

Source: Own survey result (2019)

ATT_c = average treatment on treated for per consumption; ATU_c = average treatment on untreated for per consumption; TH_c = transitional heterogeneity; BH = base heterogeneity; Y subscript = per capita income

$$E\left(\left\{\begin{matrix} C_{2i} \\ Y_{2i} \end{matrix} \middle| S = 1, \chi_{2i}\right.\right) = \alpha_1 \chi_{2i} + \sigma_2 \rho_2 f(\beta Z_i) / F(\beta Z_i) \quad (6)$$

Actual expected outcome: non-users

$$E\left(\left\{\begin{matrix} C_{2i} \\ Y_{2i} \end{matrix} \middle| S = 0, \chi_{2i}\right.\right) = \alpha_2 \chi_{2i} - \sigma_2 \rho_2 f(\beta Z_i) / \{1 - F(\beta Z_i)\} \quad (7)$$

The effect of average treatment on treated (ATT) is computed as the difference between Equations (4) and (5):

$$ATT = E\left(\left\{\begin{matrix} C_{1i} \\ Y_{1i} \end{matrix} \middle| S = 1, \chi_{1i}\right.\right) - E\left(\left\{\begin{matrix} C_{1i} \\ Y_{1i} \end{matrix} \middle| S = 0, \chi_{1i}\right.\right) \quad (8)$$

Similarly, the average effect of treatment on untreated (ATU) is the difference between Equations (6) and (7):

$$ATU = E\left(\left\{\begin{matrix} C_{2i} \\ Y_{2i} \end{matrix} \middle| S = 1, \chi_{2i}\right.\right) - E\left(\left\{\begin{matrix} C_{2i} \\ Y_{2i} \end{matrix} \middle| S = 0, \chi_{2i}\right.\right) \quad (9)$$

Finally, the effect called “transitional heterogeneity” (TH) estimates whether the effect of using irrigation is larger or smaller for households that use irrigation or for the households that did not use in the counterfactual case that they did use. It is the difference between (Equation 8) and (Equation 9), i.e. (ATT) minus (ATU):

$$TH = ATT - ATU \quad (10)$$

4. Result and discussion

4.1. Impact of Awash irrigation on welfare and factors influencing irrigation participation

The endogenous switching regression model with full information maximum likelihood procedure has a dual role in this paper. One, it used as a criterion equation in differentiating irrigation user households with their non-user counter parts with respect to per capita consumption expenditure and per capita income. Two, it used as to find out the determinants that determine smallholder farm households' decision to participate in Awash irrigation. The estimated impact of irrigation on per capita consumption expenditure, and the determinants of irrigation participation are presented in Table 2. The determinants of irrigation participation (selection equation) under per capita consumption expenditure presented in columns 2 and 3, and the determinants of per capita consumption expenditure for irrigation users and non-users are presented in columns (4 and 5) and (6 and 7), respectively. Similarly, the estimates of impact of irrigation on per capita income and determinants of irrigation participation are presented in Table 3. Accordingly, The determinants of irrigation participation (selection equation) under per capita income are presented in columns 2 and 3, and the determinants of per capita income for irrigation users and non-users are presented in columns (4 and 5) and (6 and 7), respectively.

4.1.1. Factors influencing irrigation participation

From the results, as expected, the model diagnostics are satisfactory; Wald chi2 (11) is statistically significant at less than 1% significance level for both outcome variables at Tables 2 and 3. This indicates the overall fitness of endogenous switching regression model, and use of the endogenous switching regression model is justified. Consequently, the likelihood ratio test is statistically significant, indicates independence of the selection and outcome equations. Thus, reject the null hypothesis of no correlation between irrigation participation, and per capita consumption expenditure and income, shown in Tables 2 and 3, respectively.

The correlation coefficients of non-user per capita consumption expenditure (ρ_{2c}) and irrigation user per capita income (ρ_{1Y}), conditional on the selection equation (S_i) are significantly different from zero at 5% and 1% significance level, respectively. This indicates, endogenous switching regression model confirms the presence of selection bias, evidence of endogeneity and the model controlled the bias for obtaining consistent and unbiased treatment effect of Awash irrigation. The significance and positive sign of ρ_{1c} and ρ_{1Y} clearly indicates positive selection bias. This shows, irrigation users had better expectation of more per capita consumption expenditure and per capita income in the decision to use Awash irrigation due to unobserved characteristics than a random smallholder farm household in that regime.

The explanatory variables on both the selection equations had the same sign of coefficient and statistically significance level, whereas the only difference is in magnitude (Tables 2 and 3 in columns 2 and 3 of both tables). Accordingly, land holding, education and number of extension contact visited by development agents (Extcontact) were positively and significantly determine the decision to participate in Awash irrigation. On the other hand, livestock holding in tropical livestock unit, nearest local market distance (marktdis), access to non-farm job (Accnfjob), nearest irrigation scheme distance (Schdist) were negatively and significantly determine the decision to participate Awash irrigation.

The result indicates, education happened to have positively and significantly determined the decision to participate in irrigation of both per capita consumption expenditure and income (Tables 2 and 3, in columns 2 and 3, respectively). According to Norris and Batie (1987), education tends to have positive association with new technology adoption among farmers because of better access to and comprehension of information on the technologies. Literate (can read and write) households are active and responsible to take training, demonstration, experience sharing and easily understand the benefit of irrigation. Similarly, Gebrehiwot et al. (2017) and Tigga (2018) found that education positively and significantly determined the decision to use irrigation in northern part of Ethiopia.

Land holding happened to have positively and significantly determined the decision to participate in irrigation of both per capita consumption expenditure and income (Tables 2 and 3, in columns 2 and 3, respectively). This indicates, in the study area; land holding size is a decisive factor to participate in Awash irrigation. Abdissa et al. (2017), Tefera and Cho (2017), and Tigga (2018) found a similar figure in different areas of Ethiopia.

The number times the respondents visited by development agents (Extcontact) happened to have a positive and significant effect on the decision to participate Awash irrigation of both per capita consumption expenditure and income (Tables 2 and 3, in columns 2 and 3, respectively). Smallholder farmers frequently taking extension service can access updated information, leads the probability of adopting new technology and can use the resources wisely with proper management of input for better production and productivity of high value crops. Abdissa et al. (2017), Gebrehiwot et al. (2017), and Tigga (2018) found a similar figure, whereas Zeweld et al. (2017) found that extension contact negatively and significantly determined the decision to use irrigation.

Livestock holding in TLU happened to have a negative and significant effect to participate in Awash irrigation of both per capita consumption expenditure and income (Tables 2 and 3, in columns 2 and 3, respectively). This result indicates, in the study area, households having more livestock were less likely to use Awash irrigation because waste match of their time in animal production. Regassa (2015), and Mekore and Yaekob (2018) found a similar figure. On the other hand, Anteneh (2016) investigated the impact of small-scale irrigation schemes on household income in Bahir Dar Zuria Woreda, Ethiopia, and found livestock holding significantly and positively determined irrigation participation.

Distance from sampled households' homestead to the nearest local market (marktdis) determined the decision to use irrigation negatively and significantly of both per capita consumption expenditure and income (Tables 2 and 3, in columns 2 and 3, respectively). As the nearest local market distance is far from the homestead of households, they might choose to sell their product with cheaper price to neighbor traders. In fact, market distance constrained households in selling their agricultural products, and to purchase agricultural inputs easily. This result is consistent to previous studies conducted in different areas of Ethiopia (Solomon & Ketema, 2015; Zeweld et al., 2017).

Access to non-farm job activities negatively and significantly determined the decision to participate in Awash irrigation of both per capita consumption expenditure and income (Tables 2 and 3, in columns 2 and 3, respectively). Smallholder farmers participating in non-farm job activities including off-farm job were less likely to participate in irrigation because alternatively, searching non-farm activities as a source of income. Mekore and Yaekob (2018) found a similar figure in northern Ethiopia. In contrast, Anteneh (2016) found an opposite figure in Bahir Dar Zuria Woreda, Ethiopia.

Nearest irrigation scheme distance from household homestead (Schdist) used as instrumental variable due to data availability and formal testing procedures. The result revealed that distance from the nearest irrigation scheme to the homestead had a negative and significant relationship to participate in irrigation (Tables 2 and 3, in columns 2 and 3, respectively). Further justification, as distance from the nearest irrigation scheme to the households' homestead increases, the probability to use irrigation significantly decreasing. Owusu et al. (2011), and Kuwornu and Owusu (2012) found a similar figure in northern Ghana. Similarly, Gebrehiwot et al. (2017) investigated the impact of micro-irrigation on households' welfare in the northern part of Ethiopia, and found a negative and significant relationship to participate in irrigation and income of households.

4.1.2. Factors determining the welfare of irrigation users and non-users

The estimated results presented in (Tables 2 and 3 in columns 4 and 5, 6 and 7), demonstrate that, a significant variation on the impacts has been revealed across the two groups of households. These variations were accounted for irrigation use statuses of households, keeping other things

remain constant. This implies that the condition to use irrigation, distorted the effect of explanatory variables across the two groups of households.

Accordingly, gender and access to credit significantly and positively determined per capita consumption expenditure of non-irrigation users, whereas adult labour negatively and significantly determined non-users per capita consumption expenditure (Table 2 in column 6 and 7). On the other hand, nearest local market distance negatively and significantly determined per capita consumption expenditure of irrigation users (Table 2 in column 4 and 5).

Similarly, access to non-farm job and access to credit positively and significantly determined irrigation users' per capita income, whereas nearest local market distance negatively and significantly determined (Table 3 in columns 4 and 5). Gender negatively and significantly determined non-users per capita income (Table 3 in columns 6 and 7), whereas adult labour and number of extension contact significantly determined both irrigation users and non-users per capita income positively. Livestock holding significantly determined irrigation users and non-user per capita income positively and negatively, respectively (Table 3 in columns 4 and 5, 6 and 7), whereas age of the household head positively and significantly determined non-users per capita income (Table 3 in columns 6 and 7).

4.1.3. *Estimates of impact of Awash irrigation on per capita expenditure and income*

An important question in this paper is whether smallholder farmers those used Awash irrigation have a significant impact on the per capita consumption expenditure and per capita income, compared to non-irrigation users (Table 4).

The endogenous switching regression model revealed that irrigation users' actual expected per capita consumption expenditure was approximately ETB 8565, while the expected per capita consumption expenditure the same irrigation users would have enjoyed if they did not use irrigation (counterfactual of the irrigation users) was approximately ETB 7179. Therefore, the observed per capita consumption expenditure gap, average treatment on treated (ATT) was found ETB 1385 (16%). The difference is statistically significant. Similarly, Zeweld et al. (2015), and Ketema and Sisay (2016) were found that irrigation significantly increase the per capita consumption expenditure of smallholder farms in northern Tigray and Bahirdar-Zuria Woreda, respectively.

In similar estimation, irrigation users actual expected per capita income was approximately ETB 8825, while the expected per capita income that the same irrigation users would have enjoyed if they did not use irrigation (counterfactual of irrigation users) was approximately ETB 5720. Therefore, the observed per capita income gap, average treatment on treated (ATT) was found ETB 3105 (35%). The difference is statistically significant. Similarly, Yihdego et al. (2015), Gebrehiwot et al. (2017), Tefera and Cho (2017), Zeweld et al. (2017), and Ogunniyi et al. (2018) were found a similar figure.

The transitional heterogeneity result revealed that ETB 337 more per consumption expenditure and ETB 1172 less per capita income, respectively. This shows that non-users under the status of access to irrigation were performing better than irrigation users in per capita consumption expenditure, whereas the opposite is true for per capita income.

5. Conclusions

This study presented evidence on the impact of Awash irrigation on smallholder farmers' welfare in Asayta Woreda, Afar Regional State, Ethiopia. Two-stage stratified proportional to size random sampling techniques was employed. Cross sectional household level data, gathered from 315 randomly selected households (164 irrigation users and 151 non-users) from six rural Kebeles through formal household survey was used. The informal survey; ki-informant interview and focus group discussion used to narrate. The most robust and current endogenous switching regression model employed for econometric analysis. The endogenous switching regression model account

selection bias associated with endogeneity of programme participation, often encountered in most programme evaluations. As expected, the study confirmed the presence of selection bias, suggesting that addressing selection bias issue by accounting both observable and unobservable factors were a prerequisite for obtaining consistent and unbiased treatment effect of Awash irrigation.

Endogenous switching regression model revealed that irrigation users' had 16% higher per capita consumption expenditure compared to the same irrigation users would have enjoyed if they did not use irrigation (counterfactual group). This indicates that per capita consumption expenditure gap was 16% which is the average treatment on treated (ATT). Similarly, the irrigation users had 35% higher per capita income compared to their counterfactual group. This indicates that per capita income gap was 16% which is the average treatment on treated (ATT). Both outcome variables were statistically significant at less than 1% significance level.

Endogenous switching regression model also revealed that land holding, education and number of extension contact positively and significantly influence the decision to participate Awash irrigation of both outcome variables. On the other hand, livestock holding in tropical livestock unit, nearest local market distance, access to non-farm job activities, distance from the irrigation scheme to homestead significantly and negatively influence the decision to participate in Awash irrigation.

If effectively managed, Awash River has the capacity to irrigate the whole land cover of Asayta Woreda. Therefore, governmental and non-governmental organizations should give attention and support with technology based as well as change the perception of smallholder farmers to increase their irrigated land coverage by modernizing the extension system. The concerned governmental organizations should form farmers' cooperative, and connect directly with wholesalers for price advantage, and to avoid loss of perishable farm products. The irrigation system in the study area is furrow or flooding. This is a very traditional system of irrigation practiced in ancient times in other areas. Therefore, both governmental and non-governmental as well as farmers should construct distributional canals in concrete and form more additional canals to avoid water loss. Moreover, still know, the distribution of the water is managed by Gossa leaders in each Kebeles. Hence, the government in collaboration with the farmers should form water association committees in each Kebeles, and efficiently manage the water distribution.

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