

Jima, Yeshe; Guta, Dawit Diriba; Senbeta, Feyera; Simane, Belay

Article

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*Corresponding author: Yeshe Jima,
Center for Environment and
Development Study, Addis Ababa
University, Addis Ababa, Ethiopia
E-mail: kumeeby@gmail.com

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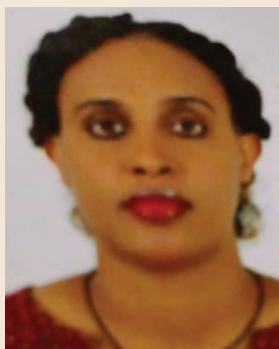
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DEVELOPMENT ECONOMICS | RESEARCH ARTICLE

The impacts of hydropower dam construction on the adjacent rural households' food insecurity in Northwestern Ethiopia

Yeshe Jima^{1*}, Dawit Diriba², Feyera Senbeta² and Belay Simane²

Abstract: This study examines the impact of two hydropower dam reservoirs, Amerti and Neshe, on the adjacent rural household food insecurity in the Abay Chome district, northwestern Ethiopia. A cross-sectional method was employed to collect data from 485 households (268 affected and 217 non-affected households) following a probability proportional to the size sampling procedure. Households' food insecurity access scale (HFIAS) and households' dietary diversity score (HDDS) were used to examine households' food insecurity status in the study area. The Endogenous Switching Regression model was employed to identify the impact of the dam construction on household food insecurity. The results revealed that the average HDDS and HFIAS in the study area were 5.1 and 10.29, respectively. The study also demonstrated that the affected household's average HDDS and HFIAS were 4.48 and 10.98, respectively. The study results further revealed that the construction of dams has significantly increased the HFIAS of displaced households by 14.6% while reducing HDDS by 24%. This study found a negative relationship between dam construction and food security, although dam construction is supposed to increase food security by increasing access to water. Thus, we recommend that hydropower reservoirs be effectively designed to reduce the impacts on adjacent communities.



Yeshe Jima

ABOUT THE AUTHOR

Yeshe Jima holds a Bachelor of Science in Economics from Adama University and a Master of Arts in Environment and Development from Addis Ababa University in Ethiopia. She is currently pursuing her PhD studies in Environment and Development at the College of Development Studies of Addis Ababa University. She is currently a lecturer at the Department of Environment and Climate Change of Ethiopian Civil Service University. She has spent the last four years studying the effects of development projects on the welfare of adjacent rural households in North-western Ethiopia. This article is part of a research project focusing on the impact of hydropower dam construction on nearby household food insecurity.

PUBLIC INTEREST STATEMENT

Hydropower dam construction has several positive outcomes; however, it always has drawbacks with far-reaching consequences for adjacent local communities. The construction of reservoir dams usually results in significant land inundation. This can result in the loss of people's homes, valuable agricultural lands, and significant environmental change, as well as an increase in food insecurity among affected households. This study examines the impact of two hydropower dam reservoirs, Amerti and Neshe, on adjacent rural household food insecurity in northwestern Ethiopia. The study findings revealed that dam construction increased household food insecurity by 14.6% and decreased dietary diversity by 24%. As a result, we recommend that future hydropower dam construction be carefully planned to reduce the negative effects on adjacent communities and the environment.

Subjects: Development Studies; Economics and Development; Environment & the Developing World

Keywords: development; food insecurity; hydropower dams; households; landlessness

1. Introduction

Development projects and climate change are inextricably linked. Future climate change will undoubtedly be impacted by alternative development trajectories, and climate change will in turn have an impact on the chances for sustainable development (Bjurström & Polk, 2011). The success of some development cooperation initiatives may be threatened by climate change, and vice versa, meaning that some development aid initiatives may unintentionally affect a country's emission levels or mitigation options as well as increase its vulnerability to climate change (Smith et al., 2003). A study that examines the impact of development projects on the livelihoods of adjacent communities and the sustainability of the environment is critical. This study attempts to highlight the potential impact of hydropower dam construction on food insecurity in adjacent rural households. Such research is critical for conceptualizing the potential impact of development projects by examining sustainability from both an environmental and societal standpoint.

Dams and reservoirs are the most common types of man-made infrastructure on the planet (Wang et al., 2022). Long before sophisticated knowledge of hydrology and hydromechanics existed, humans began building dams as a major method of utilizing water resources and avoiding natural challenges (Tahmiscioğlu & Anul, 2007). More than two-thirds of the world's renewable electricity comes from hydropower dams which facilitates multiple water resources development benefits like mitigation of adverse impacts of climate change resulting in pronounced flood and drought (by paving the way for sustainable agriculture and raising agricultural production), stabilization of the energy mix and increasing access to relatively cheap electricity (Association, 2021). It indicates that the development of water bodies (particularly dam construction), food security, and energy production have long been intertwined, with a change in one implying a change in the other two. Salam et al. (2017) summarized the nexus of water-energy-food security. The production of hydropower energy can be utilized for water pumps, drainage, water treatment, and distribution directly influencing the supply of water. The same electrical energy produced by the hydropower stations can be used to power irrigated agriculture. Water is used as an input in irrigation and for various kinds of food production. Aside from feeding households, the food produced can also be sold to generate income. The relationships described here indicate that food production, water resources, and energy needs are highly interrelated.

However, developing water resources, such as dam construction, entails numerous trade-offs, risks, and challenges (Kraljevic & Jian-hua Meng, 2013). Hydropower dam construction has several positive outcomes; however, it always has drawbacks with far-reaching consequences for local communities (Cernea, 2004; Dachaga & Chigbu, 2020), especially for the rural population that lives around where the project is undertaken. Reservoir dam constructions usually result in the inundation of significant land which ends up being covered by water. Dam construction has resulted in the displacement of millions of people worldwide, resulting in the loss of over a million people's homes, valuable cultivated lands, and significant ecological change (Jansen et al., 2019). Likewise, most development projects in Sub-Saharan Africa, including dams, are planned from the top-down, resulting in forced displacement and the existence of insufficient and unrecognized compensation systems (Olana, 2006).

Hydropower remains Africa's primary renewable energy source, accounting for 70% of the continent's renewable electricity share (Association, 2021). Like elsewhere, the Ethiopian government has been working to build various hydropower dams since the early 1930s (ETHIOPIAN MINISTRY OF WATER RESOURCES, 2001; International Hydropower Association, 2021). In 1987, Ethiopia constructed the Amarti dam in Northwestern Ethiopia, to generate electric power

(Olana, 2006). A decade later in 2010, the Nashe hydropower dam was constructed, close to the Amerti dam. As envisaged, the Amerti-Nashe dam is currently contributing to the national supply of electricity (EEPC, 2015). Added to that, the reservoirs have also marginally enhanced irrigation and fishing, and also created wetland (Olana, 2006). Notwithstanding these benefits, dams inundate large areas with different land use types and drive people from their original places of settlement (Tolessa et al., 2021). Fincha'a reservoir, adjacent to the Amerti-Nashe dams, alone has inundated a total of 239.2 sq. km of the area of which 100 sq. km was grazing land and 18 sq. km was cultivated land (Asefa, 2006). The effects of landlessness/displacement are likely to be large for a country like Ethiopia, where agriculture accounts for more than 75 percent of the economy and the land is the most important endowment (FAO, 2021).

A household with land can use it to grow crops, as a pasture for livestock, rent it out, or sharecrop it, indicating that it is a major source of existence. If a household loses its cultivable land for a hydropower dam, it will be a significant blow to its members' well-being because it will be unable to cultivate crops, resulting in a drop in food consumption and thus exacerbating the household's food insecurity. This being the case, however, the welfare effects of Ethiopian hydropower dams are not well studied. The few papers conducted so far had different objectives and thus, did not scrutinize the household food security implications of hydropower dams. (Olana, 2006) examined the impact of the Fincha'a reservoir dam on surrounding households using only descriptive data analysis. A study by (Kebede, 2009) analyzed social dimensions of development-induced resettlement in the case of the Gilgel-Gibe hydroelectric dam. It identified different social-related problems created by the construction of the dam like joblessness, landlessness, loss of common property resources, etc. (Kraljevic & Jian-hua Meng, 2013) point out the failure to address proper resettlement and compensation issues during the construction of the Gilgel Gibe III dam left most households' livelihoods in a difficult situation. (Teklewold, Kassie, Shiferaw, Köhlin et al., 2013b) studied development-induced displacement and state policy implementation in the case of the Welkayt sugar factory. Moreover, (Fahim et al., 2021) also studied reservoir-induced land deformation in the case of the Grand Ethiopian Renaissance Dam. However, none of these studies examined the impact of multi-purpose reservoir construction on household food insecurity and their broad focus area was the environmental effects of dam construction. This paper of ours fills in this gap.

The main objective of this study is to examine the impact of the construction of the Amerti-Nashe dams on the food insecurity of surrounding rural households. In particular, it looks at the impacts of the loss of home or/and cultivated land due to the reservoir dams on household food insecurity. It advances the hypothesis that hydropower dams leave rural households' food insecure. To test this hypothesis, we assembled cross-sectional data from 485 households in the neighborhoods of the Amerti-Nashe dams. From the data, households' food insecurity access scale (HFIAS) and households' dietary diversity score (HDDS) are calculated. The calculated HFIAS and HDDS are then used as measures of households' food insecurity in our analysis. We are able to identify the impact of the dam on food security is identified with the help of the endogenous switching regression (ESR) model. We find a negative relationship between dam construction and food security. In particular, the construction of dams has significantly increased the HFIAS for affected households by 14.6% while reducing their HDDS by 24%. Dams must thus be built with the utmost care to minimize their negative impact on the adjacent community and/or households. Unless carefully implemented, hydropower dam construction tends to enhance social differences and can be a precursor to social disintegration (Gebreyes et al., 2020).

To our knowledge, this paper is to examine the food insecurity impacts of hydropower dams in northwestern Ethiopia. A study like this one contributes to our understanding of the impact of multi-purpose dam construction on poor communities that rely on land and agricultural produce as their primary source of income. In this regard, our research makes the following significant contributions to the literature. First, it attempts to conceptualize the displacement-induced impact of dam construction on food insecurity in adjacent rural households in the study area. Second, our

study aims to produce robust results by employing an appropriate impact evaluation econometric tool known as the Endogenous Switching Regression model to identify the impact of displacement (either from home or from cultivated land) caused by the two reservoirs dams on adjacent households' food insecurity.

The rest of the paper is structured as follows: Section 2 is devoted to the literature review. Section 3 presents the materials and methods employed in the study. Section 4 discusses empirical results while Section 5 provides concluding remarks and policy recommendations.

2. Literature review

2.1. Theoretical and empirical literatures

There are debates as to the benefits of hydropower dams' development construction. On one hand, the ecological modernization theory (EMT) argues hydropower dam projects promote the development of new technology that developing countries receive funding from the International Monetary Fund (IMF) or the World Bank for hydropower dam projects in hopes of domestic economic growth. The reasoning is that with available funds, technological projects, such as the development of large hydroelectric dams, can stimulate economic growth and provide for a sustainable improvement in human welfare. Dams are seen means to promote international economic development, provide flood control, improve irrigation, generate hydropower, and reduce ecological damage caused by flooding and downstream sedimentation (Fujikura & Nakayama, 2009); (Kondolf & Yi, 2022); (Ledec & Quintero, 2003); (Hansen et al., 2014); (McCartney & King, 2011). In support Burrier (2016) argues that, in developing countries, dams stimulate economic growth due to increases in migration that virtually supports local businesses and infrastructural development. On the other hand, proponents of post-development theory contend that the building of hydroelectric dams alters the social, physical, and economic context of the dam site and drives locals out of their homes, farms, and other productive assets (Burrier, 2016); (Alexandra Peralta et al., 2013); (Kumar, 2003). Further anthropologists and other social scientists have emphasized its significant effects on people's psycho-social well-being in their homes, communities, and as individuals. This runs counter to economists' assertions that many of the risks related to the Internal Rate of Return framework may be managed through proper monetary compensation. Due to the shock of moving, elderly persons may feel bewilderment and physical stress (Downing & Garcia-Downing, 2009). Obviously, there is no doubt about the significance of any development activities, the issue is that they come at a high social and psychological cost- as most often the household is unaware of the project and it is abruptly implemented, disturbing the social, physical, and economic context of the dam site and forcing locals to leave their homes.

This part highlights the different empirical findings about the impacts of development projects on the adjacent community's livelihood and the environment. According to (Khan et al., 2022) world, energy trilemma and transformative energy developments can improve both economic growth and environmental sustainability. But the study also revealed that investment in non-financial assets and energy use deteriorated environmental sustainability. Empirical studies of the impact of hydroelectric dam development on households' welfare have mixed results. Some studies distinguish between the short-term and long-term effects of dams while other studies looked at case studies to generate generalizable evidence. Among those studies, (Olana, 2006) examined environmental and socio-economic changes induced by a reservoir in the Fincha'a watershed, western Ethiopia. The study mainly used descriptive data analysis techniques and it focused on the environmental and socio-economic impacts of the Fincha'a dam reservoir. The study indicated that the construction of the dams has negatively affected several households and suggested that the construction of the dam should proceed only after satisfactory recognition and compensation of the affected population and completion of environmental protection measures. (Kebede, 2009) also studied the social dimensions of development-induced resettlement in Gilgel-Gibe hydropower dam, southwestern Ethiopia. The result of the study revealed that the dam has

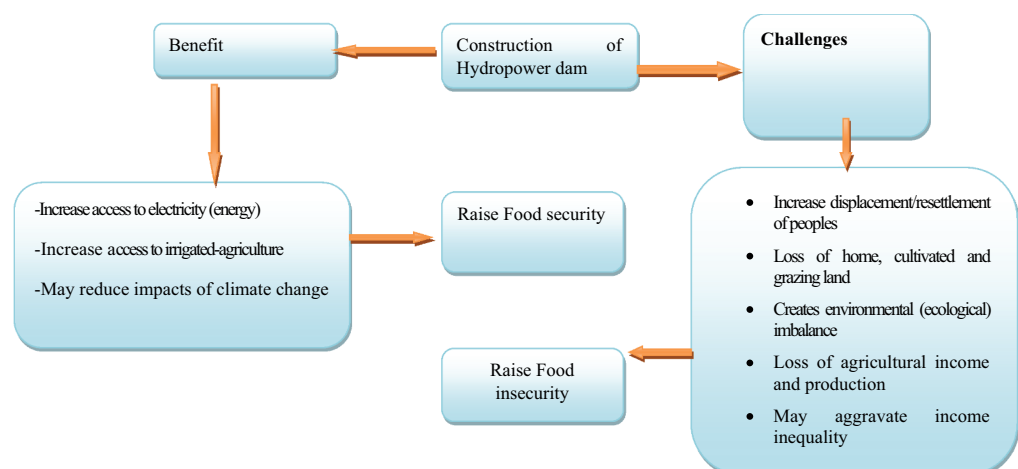
created so much joblessness, landlessness, loss of common pool resources, forced displacements, political disempowerment, social disarticulation, and raised morbidity and mortality as well as food deficiency among surrounding communities. (Wilmsen, 2016) also looked at 521 households displaced as a result of the construction of the Three Gorges Dam in China using longitudinal data. The study found that compensation and resettlement investment resulted in reduced household incomes, livelihoods were uprooted, and household members who had permanent employment were now largely employed temporarily. Displaced households were found to struggle to meet their basic needs despite infrastructure and housing investments by the government for resettled households. The author used mixed methods to match those who were displaced and later resettled with those who were not displaced in the first place, using quantitative data from the Sustainable Livelihoods Framework (SLF). This study, on the other hand, lacked an accurate measure of impact because the construction of a counterfactual was not obvious. Another study looked at the short-term impact of dam construction on household well-being (Randell, 2016). The study assessed the impact of the construction of the Belo Monte dam in the Brazilian Amazon on displaced households which were compensated in cash or credit for the land they lost. The study found that overall improvement in well-being as displaced households gained wealth, and socio-economic inequality declined. However, for households who moved further away from the study area and those who moved to urban areas, there was a strong association between displacement and deterioration of well-being. (Huang et al., 2018) used quantitative and qualitative data to examine the social impacts of dam-induced displacement and resettlement and discovered that the displacement and resettlement process created a conducive environment for improving residence conditions and facilitated the acceptance of socialized medical insurance. However, the same study found a decline in employment and income levels and the overall decline in wellbeing. Various authors (Teklewold, Kassie, Shiferaw, Kohlin et al., 2013a); (Fahim et al., 2021); (Gebreyes et al., 2020) also assessed problems associated with hydropower reservoir dam construction. However, none of these studies addressed the impact of reservoir dam construction on households' food insecurity using appropriate statistical techniques. The current study tries to address this existing gap by examining the impact of reservoir dams on households' food insecurity using endogenous switching regression.

3. Research methodology

3.1. Description of the study area

This study was conducted in the Abay-Chomen district of the Horo-Guduru Wollega zone of the Oromia regional state. The present study focused on the surrounding communities of the Amerti-Neshe reservoir dams (Figure 2). The Fincha'a hydropower dam was constructed in 1973 forming what is now known as Lake Abay-Chomen. In 1987, the Amerti Dam was built and connected to the

Figure 1. Conceptual framework of the study (Source: Own conceptualization, 2022).



Fincha'a reservoir via an underground channel, to add more water for Fincha'a hydropower. In 2012, the Neshe reservoir, a third dam on the sub-basin adjacent to the Amerti escapement, was built after 25 years (Amdihun, 2006; Asefa, 2006). According to local sources, the Fincha'a-Amerti-Neshe dams were built one kilometer apart on average and have created numerous socioeconomic and environmental challenges in the region. These reservoirs have since formed a continuous supply of water for irrigated household agriculture, Fincha'a sugar factory's sugarcane plantation, the Fincha'a hydropower station, and thriving fish production. The reservoirs have also formed a wetland ecosystem that has attracted various wildlife including bird species (Asefa, 2006).

The topography of the Amerti-Neshe catchment varies considerably from lowlands as low as 902 m a.s.l. in the downstream areas to highlands as high as 2448.5 m a.s.l. on the plateaus. This big difference in elevation has made the catchment prone to soil erosion and land degradation (Amdihun, 2006). The Amerti-Neshe watershed is predominantly located in the *Woina Dega* climate with an average annual rainfall of 1,823 mm between 1970 and 2006 with eighty percent of the rain occurring between May and September (Asefa, 2006). The mean monthly temperature varied between 14.9 and 17.5 degrees Celsius and had annual evapotranspiration¹ of 1320 mm (Asefa, 2006). The Amerti-Neshe watershed is predominantly composed of clay and haplicluvisol soil types (Asefa, 2006). The luvisol soil type is well-suited for agriculture due to its mineral and nutrient contents. Grasslands, wetlands, and forests are the common types of vegetation cover in the area. Cultivated land makes up a significant share of the vegetation cover of the Amerti-Neshe catchment. While the cultivated land cover has continually increased over the years, the grasslands and wetlands have dwindled. The smallholder cultivated land is covered by various crops that include *teff*, wheat, barley, sorghum, maize, millet, oats, lentils, beans, peas, sesame, vegetables, and fruits (Geleta & Deressa, 2021).

3.2. Description of variables used in the study

The study used different household-level variables. The Operational definition and measurement approaches used for each of these variables are presented in Table 1.

This research is critical for guiding policymakers and other stakeholders in making sound decisions. It is particularly useful in determining whether dam construction has a positive impact on household welfare (food security). Such studies are also necessary to assess the social welfare of households impacted by dam construction. Furthermore, it can have an impact on whether a given development project should be continued or halted by examining its impact on the affected community.

3.3. Sampling technique and sample size determination

Data was collected from 485 rural sample households living adjacent to the two reservoirs in the Abay-Chomen district. The multi-stage sampling procedure was followed to select 485 sample households (268 affected and 217 non-affected households). In the first stage, the Abay-Chomen district was selected because of the Amerti and Neshe reservoir dams prevalence. In the second stage, 10 villages (both affected and non-affected) were randomly selected from the district following simple random sampling. Then, after proportionally allocating the required sample size to each village, sample households were selected using a simple random sampling procedure. The study sample size was determined following (Wogu et al., 2019), a minimum required sample size for any population size at a 5% level of precision is 400. Thus, by adjusting for a 75% response rate the initial sample size (400) was increased to 533. The response rate was approximately 91 percent (485 respondents out of 533).

3.4. Theoretical framework and model specification

3.4.1. Theoretical framework

In this study, the impact of dam construction on household food insecurity status is conceptualized as part of the water-energy-food nexus (Dombrowsky, 2011; Gebreyes et al., 2020; Salam

Table 1. Summary of dependent and independent variables of the study and hypothesis

variables	Definition	Measurement	Expected Effect on food security	Source
Dependent variable: Being affected by Dam construction (first stage)	Households who lost their original cultivated land or those who lost their original home(displaced) due to the construction of the dam	Dummy, assumes 1 if HH affected, 0 otherwise		Household survey
Dependent variable on Households food security status (second stage)	Household food insecurity status as defined in (Coates et al., 2007)	The Continuous index measured between 0 and 27 inclusive.		Household survey (Coates et al., 2007)
	Households' Dietary diversity Score following FAO (2011)	Count which ranges from 0 to 15		Household survey (FAO, 2010)
Age of head	Age of the household head	measured in years	–	Household survey (Agidew & Singh, 2018)
Sex of head	Gender of the household head	dummy variable which assumes 1 if the head is male and 0 otherwise	+	Household survey (Abafita & Kim, 2014; Olana, 2006)
Family size	Number of household members	Continuous	–	Household survey (Abafita & Kim, 2014; Agidew & Singh, 2018)
Number of income sources	Number of income sources a given household has	Continuous	+	
Access to credit	Credit status of a household	Dummy assumes 1 if yes and assumes 0 otherwise	+	Household survey (Abafita & Kim, 2014; Fikire & Zegeye, 2022)
Marital status	Marital status of household head	Dummy, it assumes 1 if married, and assumes 0 otherwise	-/+	Household survey (Agidew & Singh, 2018)
Land size	Land owned by the household, both agricultural and non-agricultural	Continuous as measured in hectares	+	Household survey (Fikire & Zegeye, 2022)
Tropical Livestock Unit (TLU)	Livestock owned by all household members	Measured in Tropical Livestock Units (TLUs) as defined in Storck et al. (1991)	+	Household survey (Fikire & Zegeye, 2022); (Dula, 2019)
Access to training	Whether a household gets access to different agricultural pieces of training	Dummy, it assumes 1 if Yes and assumes 0 otherwise.	+	Household survey intuition
Use of improved seed	Whether a household uses different improved seeds	Dummy, it assumes 1 if Yes and 0 otherwise.	+	Household survey intuition

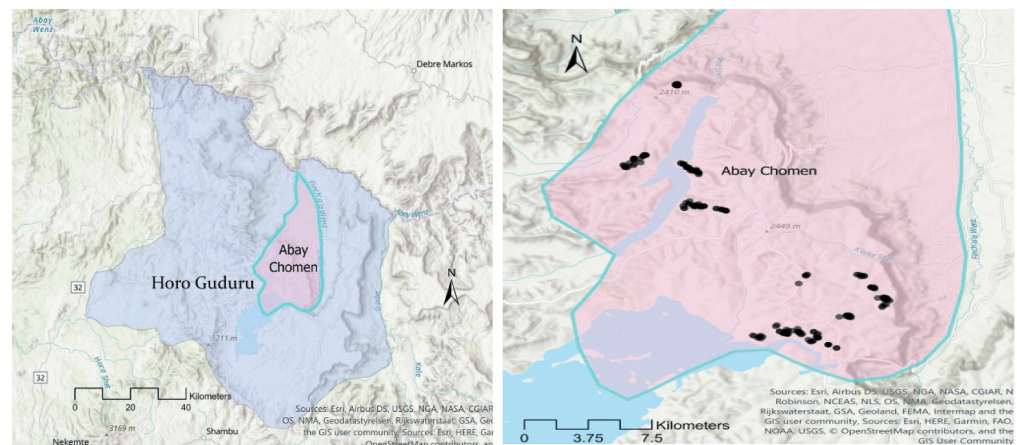
et al., 2017). With the advent of a hydro-powered generation of electricity, a profound and intricate tripartite relationship between water resources, energy production, and food production has ensued. Hence, it was argued that examining one without taking into account the other two will overlook the tripartite web of relationships. In this study, we zoom in on the impact of reservoir dams on household-level food security. The construction of a hydropower dam can have both positive (benefits) and negative (challenges) consequences (Figure 1). Among benefits, a given hydroelectric dam can increase access to electricity; it can also create the opportunity for irrigated agriculture and reduces the impacts of climate change on the agricultural sector. Creating such benefits can increase households' food security. However, on the other hand, the construction of a hydroelectric dam can cause displacement of many households and loss of their agricultural lands which in turn causes a reduction in agricultural production and income. This all aggravates households' food insecurity in the area.

3.4.2. Empirical strategy

Studying the effect of the construction of dams on household well-being, household food insecurity status, in particular, was prone to both observed and unobserved sources of endogeneity. To address this empirical problem an endogenous switching regression (ESR) was employed. To this effect, the sampled households were split into two regimes: those that were affected by the construction of the dam and those that were not. In this study, a given household has been identified as affected if either it lost its home (displaced) or it lost its cultivated land, whereas a given household was identified as non-affected if neither home nor cultivated land was lost. As common in other areas, this loss of land was not voluntary on the part of the households affected. However, it was also not arbitrary. The selection of dam construction sites was a highly systematic process (Ajayi et al., 2018; Jozaghi et al., 2018; Njiru & Siriba, 2018) and this was also true in the case of the Amerti and Neshe reservoir dams. Therefore, the parameters of selecting the dam construction sites could systematically affect the selection of those who have been displaced by the dam construction. These selection parameters, observed and unobserved, could also affect the food insecurity status of households affected as a result of dam construction. The endogenous switching regression controls for biases originating from both observed and unobserved sources (Lokshin & Sajaia, 2004).

The endogenous switching regression approach to estimate the impact of the dam on household food insecurity involves a two-step procedure (Lokshin & Sajaia, 2004). In the first step, based on (Wooldridge, 2012), the binomial probit regression was used to estimate the probability of a given household being affected by the construction of those reservoir dams in the study area. In the second stage, the Ordinary least square estimation is employed on major outcome variables of the study by inserting the inverse mills ratio as one of the independent variables in the model.

Figure 2. Map of the study area displaying the distribution of sampled households in the study area.



For exposition, consider two regimes into which households were sorted non-randomly: those affected by dam construction and those that are not affected. In the first step of the application, one estimates the likelihood of a given household being affected by the construction of the dam using a probit regression model as follows:

$$SD_i^* = \alpha Z_i + \mu_i \quad (1)$$

$$SD_i = \begin{cases} 1 & \text{if } SD_i^* > 0 \\ 0 & \text{if } SD_i^* \leq 0 \end{cases} \quad (2)$$

Where, SD_i^* is an unobserved latent variable that depends on whether a given household is affected or not due to the dam construction. It assumes a value of 1 if a given household is affected and 0 if the household is non-affected. The vector Z_i is an array of characteristics that influence the sorting of households into the affected and non-affected groups due to the construction of the dams; α stands for unknown coefficient parameters; μ_i is a stochastic term.

In the second step, one derives separate food insecurity regressions for those affected and non-affected households. These regression functions can be given as follows.

$$\text{For affected : } FI_{1i} = \beta_{1i} X_{1i} + \theta_1 \hat{\lambda}_{1i} + \varepsilon_{1i} \text{ if } SD_i = 1 \quad (3)$$

$$\text{For non – affected : } FI_{2i} = \beta_{2i} X_{2i} + \theta_2 \hat{\lambda}_{2i} + \varepsilon_{2i} \text{ if } SD_i = 0 \quad (4)$$

FI_{1i} and FI_{2i} stands for food insecurity status of affected and non-affected groups of households respectively as measured by the household food insecurity access score (HFIAS) and households dietary diversity score (HDDS). The vectors X_{1i} and X_{2i} represent various socio-economic characteristics of households affecting household food insecurity status; β_{1i} and β_{2i} are unknown coefficient parameters; $\hat{\lambda}_{1i}$ and $\hat{\lambda}_{2i}$ are inverse mills ratios generated from the first stage estimation; and ε_{1i} and ε_{2i} are stochastic terms.

A basic requirement of the ESR is that the outcome equation is identified. To make the outcome equation of endogenous switching regression identified, selection instruments are vital. To meet this requirement, at least one significant variable in the selection equation should be excluded from the outcome equation in the second stage of estimation. Following this reasoning, this study used family size as a selection instrument.²

The endogenous switching regression model depends on the assumption of trivariate joint normality of the stochastic terms ε_{1i} , ε_{2i} and μ_{2i} . This is given as follows.

$$\text{COV}(\varepsilon_{1i}, \varepsilon_{2i}, \mu_i) = \begin{bmatrix} \sigma_u^2 & \sigma_{\varepsilon 1u} & \sigma_{\varepsilon 2u} \\ \sigma_{\varepsilon 1u} & \sigma_{\varepsilon 1}^2 & \sigma_{\varepsilon 1\varepsilon 2} \\ \sigma_{\varepsilon 2u} & \sigma_{\varepsilon 1\varepsilon 2} & \sigma_{\varepsilon 2}^2 \end{bmatrix}$$

Where σ_u^2 is the variance of the disturbance term of the selection equation in the first stage of the estimation; $\sigma_{\varepsilon 1}^2$ and $\sigma_{\varepsilon 2}^2$ are the variance of the disturbance terms of the two outcome equations in the second step of the regression; $\sigma_{\varepsilon 1\varepsilon 2}$ are the covariance between the disturbance terms of the two outcome equations. Since the two outcomes—being affected and non-affected—cannot occur simultaneously for a particular household, these variances cannot be defined. $\sigma_{\varepsilon 1u}$ and $\sigma_{\varepsilon 2u}$ measure the covariance between the selection equation and the outcome equations in each of the two regimes. If this covariance or, more accurately, the correlation coefficients

$\left(\rho_1 = \frac{\sigma_{\varepsilon_1}^2 u}{\sigma_{\varepsilon_1}^2 \sigma_u^2} \text{ and } \rho_2 = \frac{\sigma_{\varepsilon_2}^2 u}{\sigma_{\varepsilon_2}^2 \sigma_u^2}\right)$ calculated thereof, are statistically different from zero, it may be due to an endogeneity problem.

To identify the impact of dam construction on households' food security, the average treatment effect on the treated (ATT) and the average treatment effect on the untreated (ATU) should be estimated after the second-stage endogenous switching regression (Lokshin & Sajaia, 2004). To this effect, the expected values of the outcome variables for both affected and non-affected households were estimated in both actual and counterfactual cases. Following the work of (Abdullah et al., 2019), (Teklewold, Kassie, Shiferaw, Köhlin et al., 2013b), and (Aseres et al., 2019), the actual expected value of food insecurity outcomes for affected households was estimated as

$$E(F1_{1i}|SD_i = 1) = E(\beta_{1i}X_{1i}|SD_i = 1) \quad (5)$$

Similarly, the actual expected value of food insecurity outcomes for non-affected households was estimated as

$$E(F1_{2i}|SD_i = 0) = E(\beta_{2i}X_{2i}|SD_i = 1) \quad (6)$$

Since it was a cross-sectional study, to finally estimate ATT and ATU, the expected values of food security outcomes in counterfactual cases should be estimated. Counterfactual indicates the expected values of food insecurity outcomes of affected households had they not been affected and the expected values of food insecurity outcomes of non-affected households had they been affected by the dam construction (Lokshin & Sajaia, 2004). Drawing from this logic, the counterfactual expected value of food insecurity outcomes for non-affected households is estimated as

$$E(F1_{1i}|SD_i = 1) = E(\beta_{1i}X_{1i}|SD_i = 1) \quad (7)$$

Using the same logic, the counterfactual expected value of food insecurity outcomes for affected households is estimated as

$$E(F1_{2i}|SD_i = 0) = E(\beta_{2i}X_{2i}|SD_i = 1) \quad (8)$$

Finally, the average treatment effect on the treated (ATT) and the average treatment effect on the untreated (ATU) are estimated as follows:

$$ATT = E(\beta_{1i}X_{1i}|SD_i = 1) - E(\beta_{2i}X_{2i}|SD_i = 1) \quad (9)$$

$$ATU = E(\beta_{2i}X_{2i}|SD_i = 0) - E(\beta_{1i}X_{1i}|SD_i = 0) \quad (10)$$

4. Results and discussion

Artificial dam construction has resulted in the displacement of millions of people worldwide, resulting in the loss of over a million people's homes, valuable cultivated lands, and significant ecological change (Jansen et al., 2019). In a country like Ethiopia, where agriculture accounts for more than 75% of the economy, the land is the most valuable asset, especially for rural households (FAO, 2010). A household with land can use it to grow crops, pasture livestock, rent it out, or sharecrop it, indicating that it is a significant source of income. However, if a household loses its land, it will be a significant blow to the well-being of its members because it will be unable to cultivate crops, resulting in a drop in food consumption and thus exacerbating the household's food insecurity.

Food insecurity is becoming a major issue in Ethiopia, particularly among small-holder rural farm households. The loss of land and displacement of households may exacerbate the food insecurity situation. The primary goal of this research is to investigate the impact of the Amerti-Neshe reservoir dam construction on the food insecurity status of surrounding rural households. This study adds to our understanding of the impact of multi-purpose dam construction on poor communities whose primary source of income is land and agricultural produce. In this regard, our research contributes significantly to the literature in the following ways. First, it attempts to conceptualize the displacement-induced impact of dam construction on food insecurity in the study area's adjacent rural households. Second, our study aims to produce robust results by employing an appropriate impact evaluation econometric tool known as the Endogenous Switching Regression model to identify the impact of displacement (either from home or from cultivated land) caused by the two reservoir dams on the food insecurity of adjacent households.

4.1. Descriptive analysis

Table 2 indicates the socio-economic characteristics of sample households in the study area. The average age of sampled household head was 45.79 years. Affected households were headed by older heads (47 years) as compared to non-affected households (44 years) and the variation was statistically significant at a 1% level of significance. The average family size of sampled households was 6.1 persons (higher than the country's average of 4.6 (Central Statistical Agency (central statistical Agency (CSA), 2016); with a minimum and maximum of 1 and 14 persons. Affected households' family size (6) was larger than non-affected households' family size (5) and the difference was also statistically significant at a 10% level of significance. The average land holding size of sampled households was 11.5 hectares with a standard deviation of 80.32 which suggests that there was a big variation in land size distribution among sample households in the study area. The average tropical livestock unit in the study area was 7.86 with a maximum value of 43.14. Moreover, affected households on average have lower tropical livestock units (7.26) than non-affected households (8.61) and the difference was also statistical significance at a 5% level of significance. This suggests that there was a real variation of TLU among affected and non-affected households, as augmented by study discussants; the affected households' tropical livestock unit was lost/reduced owing to the effects of dam construction. Table 2 also presents that affected

Table 2. Characteristics of sample households in the study area: Continuous Variables (See, Appendix A) Source: Author's computation (2022)

Variables	Mean	Std. dev.	Affected households (N = 268)	Not-affected (N = 217)	T-test
			Mean	Mean	
Age of HH head (Years)	45.79	14.11	47.3	43.9	2.63***
TLU	7.86	6.97	7.26	8.61	-2.12**
Land size(ha)	11.5	80.32	9.32	14.24	-1.41
Cost of fertilizer (Birr)	1474.7	20.62	1338	1643.6	-1.62
Cost of improved seed (Birr)	134.5	240.97	155.6	108.46	2.12**
Cost of pesticide (Birr)	235.1	326.5	227.4	241.4	0.47
Distance to water source (Minute)	15.5	14.5	16.13	14.71	1.06
Family Size	6.1	2.47	6.27	5.88	1.73*

***, ** and * indicates statistical significance at 1%, 5% and 10% level of significance respectively.

households have on average higher costs for improved seeds (155.6) than non-affected households' costs for improved seeds (108.46) and the difference was also statistically significant at a 5% level of significance respectively.

Table 3 also presents characteristics of sample households related to categorical variables. It also presents the chi-square test of linear independence between affected and non-affected households related to various categorical variables. The result indicates that about 81.65% (396) of sampled households in the study area were male while the rest were female-headed households. Only 31% (150) of sample households had access to credit services while the rest 69 % didn't have credit services in the study area. This suggests that access to credit was very low in the study area. Regarding irrigation, among sample households, only 29.48% (143) had access to irrigation while the rest 70.52% (342) sample households didn't have access to irrigation which indicates that access to irrigation was relatively low in the study area. This result demonstrated that the benefit of the dam as a source of irrigation for surrounding households was very low in the study area or households were not that much beneficiary from the dam as irrigation water-as it was not allowed to use for irrigation. Furthermore, affected households' access to electricity (61%) was found to be lower than that of non-affected households (73.2%) and the result was also statistically significant at a 1% level of significance.

Related to the displacement impact of the dams, 55.26% (268) of sample households were affected (either they lost their land or they lost their original home) while the rest 44.74% (217) households were not-affected (neither did they lose their cultivated land nor their home) by the construction Amerti-Neshe reservoir dam in the study area.

4.1.1. Measuring food insecurity

Household Food Insecurity Access Score (HFIAS) and Households Dietary Diversity score (HDDS) are widely applied measures of food insecurity (Abafita & Kim, 2014; Fraval et al., 2019; Habib et al., 2016; Jung et al., 2017; Megersa et al., 2014). HFIAS and HDDS measure households' food insecurity differently, in which a high value of HFIAS indicates a given household is more food insecure while a high value of HDDS suggests a household is more food secure. Using both of these measures makes sure that the results are consistent and reliable across households (Becquey

Table 3. Characteristics of sampled households: categorical variables

Variables			Affected households (N = 268)		Non-affected households (N = 217)		χ^2 test
		Total Freq.	Freq.	%	Freq.	%	
Gender of HH head	Male	396	219	18.3	177	18.4	0.0018
	Female	89	49	81.7	40	81.6	
Marital status	Married	445	241	89.9	204	94	2.64
	Un-married	40	27	10.1	13	6	
Credit Access	Yes	150	83	31	67	30	0.005
	No	335	185	69	150	70	
Access to Irrigation	Yes	143	76	28.4	67	31	0.36
	No	342	192	71.6	150	69	
Access to training	Yes	231	115	57	116	53.4	5.34**
	No	254	153	43	101	46.6	
Access to Electricity	Yes	323	164	61	159	73.2	7.86***
	No	162	104	39	58	26.8	

*** and ** indicates statistical significance at 1% and 5% level of significance respectively.

Table 4. Households food security indicators in the study area

Food security indicators	Mean	Standard deviation	Minimum	Maximum
HFIAS	10.29	2.7	5	22
HDDS	5.1	2.2	1	14

HFIAS is household's food insecurity access scale and HDDS

et al., 2012; FAO, 2010; Gebreyesus et al., 2015; Haile, 2005). As a result, this study utilized both measures.

The HFIAS is a continuous index measure of the intensity of food insecurity in a given household within the last four weeks. To generate the HFIAS, a standard questionnaire with nine questions capturing dimensions of household food insecurity is used (See appendix C for the questions). In the questionnaire, a household is asked to describe how often it experiences food insecurity for each question as rarely, sometimes, or often. The numerical value of HFIAS can range from a minimum of 0 indicating no food insecurity in the household to 27 indicating the most extreme case of food insecurity (Coates et al., 2007). Similarly, the household dietary diversity score (HDDS) measures how many different foods a given household consumed over the past 24 hours (FAO, 2010). This study used fifteen (15) food items that are commonly consumed in the study area to produce the HDDS. A household is asked to indicate its consumption of each food item as 1 for "Yes" or 0 for "No". This leaves the maximum and minimum value of HDDS to 15 and 1, respectively. In this measure, a household that scores 15 on HDDS has the highest dietary diversity.

Table 4 reports our results on HFIAS and HDDS. The average HFIAS of sample households in the study area was found to be 10.27 with a minimum and maximum value of 5 and 22, respectively. The average dietary diversity score of sample households was also found to be 5.1 with a minimum and maximum value of 1 and 14, respectively. These values suggest that the households in the area are food insecure.

4.2. Econometric result

A simple comparison of food insecurity levels in households affected by dam construction and those not affected is impossible to establish a cause-and-effect relationship. To establish the presence of a cause and effect relationship, we employed an endogenous switching regression (ESR) which helps us to identify and control for observed and unobserved sources of endogeneity (Khanal et al., 2018). In this case, the origins of endogeneity were the non-random sorting of households depending on those affected by the construction of the dams and those households that did not.

As explained in the methodological section, the second stage of endogenous switching regression was estimated by inserting the inverse mills ratio term and excluding the selection instrument (family size) from the first-stage estimation (binomial probit regression). Then the expected value of food security outcomes for affected and non-affected households in both actual and counterfactual cases was estimated. Following that, the average treatment effect on the treated (ATT) and average treatment effect on the untreated (ATU) were estimated as the difference between actual and counterfactual cases for affected and non-affected households respectively. The result of ATT and ATU estimation is presented in Table 5 below.

As indicated in Table 5, based on the households' food insecurity access scale, the average treatment effect on the treated (1.4) was statistically significant at a 1% level of significance. Similarly, the average treatment effect on the untreated (−1.36) was also statistically significant at a 1% level of significance. This indicates that affected households' food insecurity access scale was raised by 14.6% while non-affected households' food insecurity access scale has, on average,

Table 5. Average treatment effect of food security indicators after endogenous switching regression (see, Appendix D)

Households Status	Household Food insecurity Access Scale (HFIAS)		
	Actual	Counterfactual	ATT
Affected	10.98	9.58	1.4***
	Actual	Counterfactual	ATU
Non-affected	9.45	10.81	-1.36***
Households Status	Household Dietary Diversity Score (HDDS)		
	Actual	Counterfactual	ATT
Affected	4.48	5.91	-1.43***
	Actual	Counterfactual	ATU
Non-affected	6.01	4.63	1.38***

*** indicates statistical significance at a 1% level of significance, ATT = Average treatment effect on the treated; and ATU = Average treatment effect on the untreated

decreased by 12.58%. The result suggests that due to the construction of dams (which makes households lose their cultivated land or their home), on average, the affected household's food insecurity access scale was raised while the negative average treatment effect of non-affected households (-1.36) indicates that non-affected households, on average, have lower food insecurity access scale. The result further demonstrates that the construction of the dam in the study area has increased households' food insecurity access scale which might be attributed to the reason that insufficient compensation or the absence of equivalent compensation for households that were affected by the dams' construction. The rise in households' food insecurity might be also associated with the resettlement of affected households to a relatively marginal cultivated land which in turn decreases households' agricultural production. The result is also similar to the findings of (Wilmsen, 2016). They revealed that dam construction has a significant effect on increasing households' food insecurity through the improper displacement of adjacent households to frost and marginal lands.

Regarding households' dietary diversity score, the average treatment effect on the treated (-1.43) was statistically significant at a 1% level of significance which shows that due to the construction of the dam affected households' dietary diversity score declined. Similarly, the average treatment effect on the untreated (1.38) was also statistically significant at a 1% level of significance which indicates that non-affected households' dietary diversity score has increased since they were non-affected by the construction of the dam. Numerically, this indicated that affected households' diversity score has decreased by 24% while the dietary diversity score of non-affected households has increased by 29.8%. According to these findings, the dam's construction reduced the dietary diversity score of affected households while increasing the dietary diversity score of non-affected households. This could be due to a decrease in household cultivated land or resettlement of affected households to marginal lands, which leads to a decrease in agricultural production and an increase in unemployment among affected households. The result is consistent with the findings of (Kebede, 2009) and (Huang et al., 2018) which indicated that there was the resettlement of households to frost and waterlogged land which negatively affects agricultural production and which in turn exacerbates household's food insecurity.

As shown in Table 5, counterfactual results demonstrated that the affected households had higher HFIAS and lower HDDS than non-affected households. The counterfactual findings also show that affected households would have low HFIAS (9.58) and high HDDS (5.91) if they were not affected, whereas non-affected households would have high HFIAS (10.81) and low HDDS (4.63) if the dam construction affected them. All of this suggests that the construction of the Amerti-Neshe dam (by displacing households from their cultivated land or original home) negatively impacted

household food security by exacerbating the food insecurity situation in the study area. In general, the increase in household food insecurity caused by dam construction can be attributed to limited cultivated land for production, low productivity due to household resettlement to marginal lands, and a decline in household livestock due to the dam's reservoir flooding a significant number of grazing lands. Our hypothesis premise is that the construction of dams significantly impacted food security. Regarding the negative impacts of dam construction, the result is in line with (Olana, 2006), (Gebreyes et al., 2020), (Kebede, 2009), (Wilmsen, 2016), (Shah & Kumar, 2008), (Randell, 2016), (Sayektiningsih & Hayati, 2021) and (Richter et al., 2010). Our results are in line with post-development theory, which contends that social divisions, local resettlement problems, and food insecurity (malnutrition) can all compound one another and lead to societal breakdown. Furthermore, they argued that dams have a negative effect on households that are making changes to their livelihoods and general well-being. Regarding the Water-Energy-Food nexus hypothesis, the result of this study suggests that water energy and food are highly interlinked. Studies by (Usman Oladimeji et al., 2020), (Dillon & Fishman, 2019), and (Rasul et al., 2021) revealed that the construction of dams improves farm households' food security by providing year-round irrigation opportunities. Their result indicated that water and food have a direct relationship. However, our findings indicated that dam construction and food has negatively related in that even if dam construction is supposed to increase food security through increasing access to water, the result was found to be the reverse. As pointed out by (Mpandeli et al., 2018), (Putra et al., 2020), and (Malagó et al., 2021) water-energy-food nexus approach offers opportunities to build resilient systems and improve sustainability only if it is implemented in a well-coordinated and integrated way.

5. Conclusions

Dam construction is known to have both positive and negative consequences. While the positive effects have been well studied and documented because these initiatives were carried out by governments or financially well-off private actors who have a vested interest in seeing the dams built. The potential negative consequences of these dams, particularly on rural households with limited bargaining power, were not adequately investigated. The purpose of this study was to assess the impact of the Amerti and Neshe reservoir dams on adjacent households' food insecurity in the Abay-Chomen district, Horo-Guduru Zone, Oromia regional state, Ethiopia. A probability proportional to size sampling procedure was used to collect primary data from 485 households (268 affected and 217 non-affected households) in the study area. Loss of cultivated land and loss of original homes due to dam construction were used to demonstrate the impact of dam construction on household food insecurity (as measured by HFIAS and HDDS). To determine the impact of dam construction on household food insecurity, the Endogenous Switching Regression model was used. Results of the average treatment effects after endogenous switching regression revealed that the construction of the two reservoir dams, Amerti and Neshe, had a statistically significant impact on household food insecurity, which increases the food insecurity of adjacent households in the study area. Particularly the study results indicated that dam construction has raised HFIAS while it reduced HDDS in the study area. As a result, multipurpose reservoir dam construction projects should take into account households' well-being, particularly food insecurity when planning to construct dam projects. Moreover, it is also important to consider the resettlement areas of displaced households and the number of households displaced prior to dam construction.

This study addressed the impact of dam construction on households' food insecurity only using cross-sectional data collected at a specific point in time. However, to undertake such kinds of impact analysis longitudinal data is preferable to cross-sectional data. Hence, the study only has households' characteristics after the construction of the dam so it didn't capture the change in adjacent households' welfare before and after the dam construction using panel data. Thus, using cross-sectional data for impact analysis is one major limitation of this study. This study is also limited to the impact of dam construction on households' food insecurity caused by households' displacement from their land and residence. However, it could be also logical to examine the

impact of dam construction on households' food security in terms of the dam's benefit for increasing access to water for irrigation, access to energy, and other benefits. Moreover, the study also overlooked the impact of dam construction on environmental sustainability.

Future studies on the related topic should employ panel data rather than cross-sectional data so that households' welfare before and after the construction of the dam could be easily captured and evaluated. A similar study should also analyze the impact of dam construction in terms of enhancing households' water access for irrigation and energy security. Future studies should also evaluate dam development projects on the surrounding environmental sustainability.

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Author details

Yeshi Jima¹
 E-mail: kumeeby@gmail.com
 Dawit Diriba²
 Feyera Senbeta²
 Belay Simane²

¹ Department of Environment and Climate Change, Ethiopian Civil Service University, and a PhD candidate at the Center for Environment and Development Study, Addis Ababa University, Addis Ababa, Ethiopia.

² Center for Environment and Development, Addis Ababa University, Addis Ababa, Ethiopia.

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Data availability

The corresponding author can provide the data used in this work upon reasonable request.

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Notes

1. This measurement is based on the Penman-Monteith scale.
2. See, Di Falco et al., 2011.

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Appendix

Appendix A: Result of first stage endogenous switching regression: Selection equation

Variables	Coef.	z	P > z	Marginal effects
Gender of HH head	.065 (.18)	0.35	0.724	.026
Age of HH head	.012(.004)	2.77	0.006***	.004
Marital status	-.46 (.27)	-1.71	0.088*	-.17
Education	-.34(.128)	-2.71	0.007***	-.13
Number of income sources	-.16(.12)	-1.25	0.213	-.063
TLU	-.026(.009)	-2.70	0.007***	-.01
Land size in hectares	-.0004(.0007)	-0.58	0.564	-.00017
Credit access	.0209(.12)	0.16	0.871	.0082
Access to Training	-.18(.12)	-1.40	0.162	-.071
Family size	.073(.026)	2.79	0.005***	.028
Use of Improved seed	.17(.125)	1.40	0.160	.069
_cons	.069(.38)	0.18	0.858	

Pearson goodness-of-fit test = 9.41 LR $\chi^2 = 11=35.26$
 $p > \chi^2 = 0.31$ $p > \chi^2 = 0.0002$

Source: Own computation (2022) NB: *** and * indicates statistical significance at 1% and 10% level of significance respectively. Numbers in brackets are standard errors.

Appendix B: Questions for constructing Households Dietary Diversity Score (HDDS)

Question No	Food Groups	Examples	Yes (1)	No (0)
1	Cereals	bread, noodles, biscuits, cookies or any other foods made from millet, sorghum, maize, rice, wheat like <i>injera</i> or <i>kita</i> plus+ <i>local foods porridge or pastes or other locally available grains</i>		
2	Vitamin A rich vegetables and tubers	pumpkin, carrots, squash, or sweet potatoes that are yellow or orange inside + <i>other locally available vitamin-A rich vegetables</i>		
3	White tubers and roots	White potatoes, white yams, or foods made from roots.		
4	Dark green leafy vegetables	sweet pepper, dark green/leafy vegetables, cabbages including wild ones + <i>locally available vitamin-A rich leaves etc.</i>		
5	Other vegetables	other vegetables, including wild vegetables		
6	Vitamin A rich fruits	ripe mangoes, papayas, Bananas or <i>other locally available vitamin A- rich fruits</i>		
7	Other fruits	other fruits, including wild fruits		
8	Meat	beef, lamb, goat, wild game, chicken, or other birds, liver, kidney, heart or other organ meats or blood-based foods		
9	Eggs	Chicken egg or wild		
10	Fish	fresh or dried fish or shellfish		
11	Legumes, nuts and Seeds	beans, peas, lentils, nuts, seeds or foods made from these		
12	Milk and milk Products	milk, cheese, yogurt or other milk products		
13	Oils and fats	milk, cheese, yogurt or butter other milk products		
14	Sweets	sugar, honey, sweetened soda or sugary foods such as chocolates, sweets or candies		
15	Spices and caffeine or alcoholic beverages	Spices, coffee, tea, alcoholic beverages or <i>local beverages like tela etc ...</i>		
			Yes (1)	No (0)
Did you or anyone in your household eat anything (meal or snack) OUTSIDE of the Home yesterday?				

Appendix C: Questions for constructing Households Food Insecurity Access Scale (HFIAS)

NO.	Questions	Response Options. Assign code according to the following answers:	CODE
		1 = Yes, 0 = No = it did not happen in the past [4 weeks] if, yes, how often (1) Rarely = once or twice in the past [4 weeks] (2) Sometimes = three to ten times in the past [4 weeks] (3) Often = more than 10 times in the past [4 weeks] (4) Or locally-defined terms of frequency corresponding to these ranges	
1.	In the past [4 weeks], did you worry that your household would not have enough food?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] If yes: ask respondent "how often did this happen?" 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
2.	In the past [4 weeks], did it happen that you or any household member were not able to eat the kinds of foods you would have preferred to eat because of lack of resources?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] If yes: ask respondent "how often did this happen?" 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
3.	In the past [4 weeks], did it happen that you or any household member had to eat a limited variety of foods because of lack of resources?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] If yes: ask respondent "how often did this happen?" 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
4.	In the past [4 weeks] did it happen that you or any household member had to eat some foods that you really did not want to eat because of lack of resources?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] If yes: ask respondent "how often did this happen?" 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
5.	In the past [4 weeks] did it happen that you or any household member had to eat a smaller meal than you felt you needed because there was not enough food?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] If yes: ask respondent "how often did this happen?" 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	

(Continued)

<i>(Continued)</i>			
NO.	Questions	Response Options. Assign code according to the following answers:	CODE
6.	In the past [4 weeks] did it happen that you or any household member had to eat fewer meals in a day because there was not enough food?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] <i>If yes: ask respondent "how often did this happen?"</i> 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
7.	In the past [4 weeks] did it happen that there was no food to eat of any kind in your house, because of lack of resources to get food?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] <i>If yes: ask respondent "how often did this happen?"</i> 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
8.	In the past [4 weeks] did it happen that you or any household member went to sleep at night hungry because there was not enough food?	1 = Yes, 0 = No = it did not happen in the past [4 weeks] <i>If yes: ask respondent "how often did this happen?"</i> 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	
9.	"In the past [4 weeks] did it happen that you or any household member went a whole day and night without eating anything at all because there was not enough food?"	1 = Yes, 0 = No = it did not happen in the past [4 weeks] <i>If yes: ask respondent "how often did this happen?"</i> 1 = Rarely (1–2 times) 2 = Sometimes (3–10 times) 3 = Often (more than 10 times)	

Appendix D: Results of Second-Stage of Endogenous Switching regression

	Outcome variable: Households Food insecurity access scale						Outcome variable: Households Dietary diversity score					
	Non- Affected			Affected			Non-affected			Affected		
	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
Gender(Male)	-1.273	.4902	0.009***	-1.36	.5424	0.012**	-.1443	.532	0.786	.16013	.38904	0.681
Age	-.0153	.01184	0.195	.0007	.0146	0.960	-.0024	.0132	0.856	-.00629	.01004	0.530
Marital status(Married)	1.7997	.7439	0.016**	-.345	.7215	0.632	.418	.857	0.625	-.42901	.52261	0.412
Education (Illiterate)	.60222	.34156	0.078*	-1.48	.414	0.000**	-.193	.3971	0.626	.12061	.2791	0.666
Number of income sources	-.5178	.3413	0.129	.982	.4082	0.016**	-.52818	.3704	0.154	-.1903	.28638	0.506
TLU	-.0208	.0251	0.407	-.073	.02901	0.011**	.01221	.0272	0.654	.00841	.02097	0.688
Land size in hectare	.00063	.0017	0.724	-.005	.0026	0.038**	-.00061	.0018	0.733	-.00190	.00177	0.282
Credit access	-.2831	.346	0.414	-.139	.3737	0.708	.4015	.3825	0.294	-.19530	.26771	0.466
Access to Training	.66470	.3511	0.058*	1.175	.381	0.002***	.2991	.3985	0.453	-.20003	.2688	0.457
Use of Improved seed	-.2239	.3479	0.520	-1.42	.3606	0.000***	.3281	.4044	0.417	.4238	.2547	0.096*
_cons	7.507	1.034	0.000	13.1	1.212	0.000	6.696	1.285	0.000	3.942	.81313	0.000
r0	-2.02	.223	0.000***				.042	.5116	0.934			
r1	-.288	.257	0.263				1.014	.303	0.001***			
sigma0	2.82	.19267					2.472	.1234				
sigma1	2.75	.1671					2.103	.212				
	$\chi^2(2) = 27.79$ $p(\chi^2) = 0.0000$						$\chi^2(2) = 3.18$ $p(\chi^2) = 0.023$					

Source: Author's (2022)



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