

Impact of Irrigation on Household Multidimensional Poverty Reduction in the *Koga* Irrigation Development Project, Northern Ethiopia

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Agriculture remains the mainstay of the Ethiopian economy. However, the sector is affected by climate change induced extreme weather events that aggravates rural poverty. As a result, the Ethiopian government has been making different interventions to alleviate poverty. Koga irrigation development project (KIDP) is one of such initiatives. However, due to political unrest, poor water management practice, limited market linkages and other institutional challenges, the project has not reached its desired goals. This paper is thus intended to evaluate the efficacy of the KIDP to reduce poverty. Data were collected from 395 sample farm households (220 irrigators and 175 non-irrigators) drawn using multi-stage sampling technique. Multidimensional poverty index and endogenous switching regression model were employed to measure poverty and estimate the impact of irrigation on household poverty, respectively. The study found that poverty intensity and multidimensional poverty index of the study area were lower than the national and regional averages. Nonetheless, the trend of poverty reduction was not evenly progressed in irrigator and non-irrigator households. The proportion of non-irrigator poor and MPI poor households were greater than irrigators. The endogenous switching model and key informant interviews proved that irrigation has positive impact on multidimensional household poverty reduction. However, the incidence of poverty among the sample households, regardless of access to irrigation, is still higher. This implies access to irrigation should be accompanied by institutional supports and complementary production inputs. So as to excel the impact of irrigation, the government shall also expand the technology over non-irrigated areas.

Keywords: Irrigation, Household, Multidimensional poverty index, Switching regression

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INTRODUCTION

Poverty is still continued being a glaring and persistent issue in the world today. More than 1,300 million people in the world are found in absolute poverty where the share of rural poverty is higher (Alkire et al., 2015). Over half of the people in African countries suffer from multidimensional poverty in which the highest pockets of poverty occur in the Sahel and Sudanian Savanna belt (Alkire et al., 2016). The incidence of poverty in Ethiopia was the highest among Sub-Saharan countries (Alkire et al., 2015; Beegle et al., 2016). In 2011, more than 30% of the Ethiopian population was lived below the national poverty line (MoFED, 2012). Climate change

induced recurrent drought, periodic floods, high agricultural dependency on variable rainfall accompanied by severe soil and landscape degradation and underdeveloped production technologies are considered as major causes of rural poverty (Dawit & Balta, 2015; Regassa et al., 2008; Turrall et al., 2011).

Cognizant of this reality, agrarian countries have been promoting rural poverty reduction strategies as one of their main goals of development (Lipton et al., 2003). Past poverty reduction evidences suggest that amongst strategies, intervention in agriculture, particularly establishing irrigation technologies is vital (Gebregziabher & Namara, 2008; Lipton et al., 2003; Omilola, 2009). As one of the agrarian countries, Ethiopia has been following poverty reduction policies and strategies facing towards enhancing productivity of smallholder farmers through building agricultural infrastructures (Holden et al., 2006). Accordingly, Ethiopia has made large investments on irrigation projects to reduce poverty by minimizing rainfall dependency and vulnerability to climate change induced extreme weather events (Awulachew et al., 2008; Teshome, 2006). The *Koga* irrigation development project (hereafter KIDP) is one of the recently established projects to reduce poverty in *Mecha Woreda*, the central highlands of Ethiopia (MacDonald, 2004). Despite efforts to reduce poverty in the *Woreda* over last decades, farmers, herders and other rural people remain poor. Oftentimes, the study area was ravaged by soil erosion, land degradation, erratic rainfall and population pressure, leading to food insecurity and poverty (MacDonald, 2004). The development of irrigation is seen as a way of reducing the area's dependency on the annual availability of rainfall because irrigation technology, especially in the small holder sub-sector has significant importance in adapting strategies to cope up with the challenging climate change (Bacha et al., 2011; Hagos et al., 2009).

The existing literature and empirical studies pertinent to irrigation-poverty linkage are numerous. Most of the evidences from elsewhere have confirmed that irrigation has positive impacts on poverty reduction (Awulachew et al., 2008; Bacha et al., 2011; Bhattarai & Narayanamoorthy, 2004; Gebregziabher & Namara, 2010; Mangisoni, 2008; Omilola, 2009). Paradoxically, Pender et al. (2000) argued that modern irrigation has been associated with less adoption of fertilizer and improved seeds and hence less improvement in yields. Consistently, Hussain & Wijerathna (2004) found that investments in irrigation does not directly reduce poverty in any significant way unless accompanied by other complementary interventions such as proper maintenance, equal distribution of available water and improved cultivation technology. Furthermore, the studies measured poverty using proxy of income or consumption expenditure. However, Senaratna Sellamuttu et al. (2014) and Alkire et al. (2015) argued that poverty is multidimensional and dynamic in concept so that these measures could not cover all dimensions of poverty and lack the ability to indicate the actual meaning of poverty in the lives of those people who experience it. As a result, the structures of contribution of irrigation intervention in poverty reduction remain largely unaddressed in the literature. To our best knowledge, empirical studies on irrigation-multidimensional poverty linkage are scanty. Most studies also did not control sample selection biases. Moreover, the aforementioned results indicate that the findings of poverty impact of irrigation are controversial and not conclusive but suggest for the needed of further system and location wise investigations on irrigation schemes. But, the impact of the *Koga* irrigation development project was not studied in this regard.

Therefore, to fill these literature gaps, this study is intended to evaluate the impact of KIDP on household poverty by applying multidimensional poverty measurement and switching regression model to control selection bias.

THE CONCEPT OF POVERTY AND THEORETICAL UNDERPINNINGS

The Concept of Poverty

Before addressing the household poverty and irrigation nexus, it is important to clarify the concept of poverty and its indices.

Poverty is a widely used and multidimensional social phenomenon in all countries of the world, but its definition is often contested. The literature on poverty is full of controversies; possibly most of these controversies arise from opinion differences and misunderstandings between definition and measurement (Pantazis et al.,

2006). As a result, poverty has no clear cut common definition.

In the World Summit conference for social development in Copenhagen in 1995, the UN has broadly discussed on the concept of poverty and it was defined by considering various issues such as lack of income and productive resources, hunger and malnutrition, lack of access to education and health services, increased morbidity and mortality, homelessness and inadequate housing, unsafe environments and social discrimination and exclusion. It was also characterized by lack of participation in decision-making and in civil, social and cultural life (United, 1995).

Researchers commonly agreed up on a definition that “poverty is having an insufficient command of resources over time”. In economics poverty has broadly defined by two research traditions; welfarist and non-welfarist. The welfarists believe that the preference (utility) of individuals has a great deal in determining poverty (Ravallion, 1994). They understand welfare as utility derived from personal satisfaction of a certain state of being and these utilities are both additive and comparable across different persons. In this mono-dimensional case, per capita income or expenditure is used as a proxy for the possible set of utilities. Poverty is then defined as the state when per capita income or expenditure is not sufficient to meet a normative reference level of utility (money) that every person must have to not starve, or fulfill basic consumption needs, or have a relatively acceptable lifestyle (Neubourg et al., 2010). On the other hand, the non-welfarists understand poverty based on certain achievements such as being adequately nourished, clothed and sheltered, as well as intrinsically multidimensional. They believe that instead of pursuing a universally applicable proxy for all states of welfare, it seeks to directly measure the outcomes achieved on certain predefined notions of needs (Neubourg et al., 2010; Ravallion, 1994). Analogously, Peter Townsend (1979) has also thought that poverty should understand objectively rather than subjectively. In his argument individuals, families and groups in the population said to be in poverty when they lack the resources to obtain the types of diet, participate in the activities and have the living conditions and amenities which are customary, or at least widely encouraged or approved, in the society to which they belong (Townsend, 1979). In order to understand the dynamics of poverty, one can also draw the attention on the notions of ‘capabilities’ and ‘entitlements’ (Sen, 2000). Sen’s work focuses on the idea that income shortfalls are the main attribute of poverty. He emphasizes the importance of the bundle of assets or endowments held by the poor, as well as the nature of the claims attached to them (Namara et al., 2008).

While the criticisms of the income approach to welfare have always existed, it was not until the innovation of multidimensional poverty measurements such as the work of OPHI and UNDP in 2010. An emerging body of research has argued that income and consumption expenditure measures only cover certain dimensions of poverty and lack the ability to indicate the actual meaning of poverty in the lives of those people who experience it (Senaratna Sellamuttu et al., 2014). To date, the literature on multidimensional poverty measurements is vibrant and marked by recurrent innovations. It is an aggregation technique and building a composite index to define poverty rather than using a single proxy.

Generally, the definitions discussed above clearly show that poverty does not mean absolute basket of goods, but it is defined in terms of the minimum acceptable standard of living applicable to a person’s/household’s own society. Accordingly, researchers defined poverty based on the context of the target population and the way they measured it. This study also focuses on analyzing poverty identified through the multidimensional index. Though it is scientifically impossible to determine an accurate, uniquely valid poverty line or a financial threshold (Atkinson et al., 2004), the poor are therefore, those who do not have enough resources to put them above defined adequate minimum threshold.

Theoretical Underpinnings

In development economics and other social sciences there are various theories that argue about the nature poverty and poverty inequality. An influential literature, advocated mostly by economists is the ‘opportunity’ theory. This thought was originally inspired by political philosophers during the 1970s and 1980s. Beginning with John Rawls (1971), a number of authors revived the idea by progressively moving the “demand for equal-

ity” from the realm of individual achievements to the space of opportunities. Economists soon followed the thought of political philosophers. After influential contributions by John Roemer and Marc Fleurbaey in 1990s, a substantial literature has emerged which considers personal responsibility and opportunities to evaluate the opportunity-equalizing effects of social and economic policies. The focus of the economists was to examine what part of the inequality observed in a particular country is due to unequal opportunities, rather than to differences in individual efforts or luck. Inequality of opportunity has been then analyzed in different spheres of human life and for different domains of public policy, ranging from income distribution to anti-poverty strategies.

In development economics and other social sciences there are various theories that argue about the nature and causes of poverty.

In economics, the opportunity theory argues that welfare inequality observed in a particular country is due to unequal/limited opportunities, rather than to differences in individual efforts or luck (Ferreira & Gignoux, 2011). In line of this, people view that economic inequality is neither all bad nor all good and the gaps are arisen from limited opportunities rather than the application of different levels of efforts (Roemer & Trannoy, 2015). The kinds of opportunities that are detrimental to welfare outcomes include access to good schools, financial markets, irrigation technologies, health centers or access to information technologies (Bourguignon et al., 2007). There is a widespread normative view that inequality of such opportunities matters for outcome inequality. This has commanded considerable attention in the analysis of poverty inequality. The typical stance taken is that many poor people lack access to those opportunities which are defined as legitimate avenues for poverty reduction (Cernkovich & Giordano, 1979). Therefore, opportunity deprivations lower economic achievement levels which in turn lead to variations in poverty level. Hence, regardless of individual efforts, limited access to irrigation technology may be strongly associated with the poverty level of irrigator and non-irrigator households at the study area.

Another influential literature, in studying the origins of “poverty traps” argues that persistent poverty is imposed by constraints that are external to the individual such as institutional or governmental failures, coordination problems and malnutrition (Bardhan, 1997; Da Rin & Hellmann, 2002). However, in a different approach, economists advocated that besides to extrinsic circumstances, a poverty trap is perpetuated by intrinsic factors such as aspirations and beliefs. In the theory of ‘aspirations’, economists believe that poverty has close and brutal association with a failure of aspirations (Ray, 2006). According to Guney et al. (2011), our aspirations shape our choices and influence countless aspects of the economic part of our daily lives. Therefore, the capacity to aspire is a key ingredient in any notion of empowerment (Dalton et al., 2016; Ray, 2006) which includes both the ability to set goals and the knowledge of how to achieve them (Appadurai, 2004; Dalton et al., 2016). Contrary to this, poor people lack the capacity to aspire, contest and alter the conditions of their own poverty. Lack of aspirations in turn self-limiting mental shortcuts and restricts the future minds to those of necessity, reinforcing and perpetuating the cycle of poverty (Dalton et al., 2016; Tanguy et al., 2014). Expand the poor’s aspirational horizon by means of programs which provide the poor to develop capabilities is, therefore, a possible way out of this trap.

The assumptions of ‘limited opportunity’ and ‘aspirations’ theories seem consistent with the findings of various poverty researches which are discussed in the next section. The findings, in most cases, revealed that the proportion of poor households in non-irrigating agriculture remains high. Also, regardless of access to irrigation, poverty stays significant. This could be either due to limited irrigation opportunities or failure of aspirations in the society which may restrict them to underinvest against poverty. The focus of the present research has been to show the association of these thoughts to the explanation of poverty impact of irrigation.

EMPIRICAL EVIDENCES ON POVERTY IMPACT OF IRRIGATION

Adoption of irrigation technologies and its consequences on poverty reduction continue to receive wide interest of the agriculture sector and poverty policy researchers in the world. In recent years, it has been increasingly realized that poverty is a multidimensional concept, extending from monetary values to nonmonetary dimen-

sions and includes other livelihood dimensions. Hence, when conducting researches on poverty-irrigation linkage, researchers could follow different methodologies to measure poverty. While nonmonetary dimensions are important to measure poverty, most empirical work on poverty measurement is based on monetary values. When even estimating poverty using monetary measures, one may have a choice between using income or consumption or yield as the indicator of well-being. Therefore, for ease of presentation, based on the employed indicator, this study has classified the existing literature into the following themes; these are researches which use income indicator, consumption expenditure indicator and productivity or yield indicator as a proxy to measure poverty.

The Impact of Irrigation on Poverty Reduction Using Income Indicator

Among the existing literature on irrigation and its impact on poverty reduction which are done by using income as a proxy to measure poverty, most of the estimations are based on the FGT model. These types of literatures face a problem to control sample selection bias. Case studies undertaken by Meliko & Oni (2011), Bacha et al. (2011), Namara et al. (2008) and Senaratna Sellamuttu et al. (2014) are some of examples which highlighted the positive impacts of irrigation on poverty by using income proxy and FGT model. Meliko & Oni (2011) found that poverty incidence, depth and severity were higher among non-irrigation households in South Africa. Similarly, based on descriptive statistics, the FGT poverty indices, and Heckman's selectivity model methods of data analysis, Bacha et al. (2011) has found that the incidence, depth, and severity of poverty were significantly lower among those farm households with access to irrigation in the Ambo district of western Ethiopia. They indicated that regardless of access to irrigation, the proportion of poor people at the area is alarmingly high, indicating the deep-rooted and critical situation of poverty in rural Ethiopia. Namara et al. (2008) has also examined the impact of small scale irrigation on rural poverty and inequality in Ethiopia. The study was based on extensive data set generated from 11 small-scale irrigation schemes. Besides to the FGT, multivariate analysis was used and the finding revealed that poverty incidence was significantly lower among households with higher irrigated area. Even if accesses to irrigation moves up the mean income, farmers have different capacity in making better use of the available irrigation water and therefore irrigation widens the income gap. Relatively with a different approach, Senaratna Sellamuttu et al. (2014) has used income proxy through livelihood choices and estimate from a two stage income regression model. The result shows that irrigation access has a positive effect on income through livelihood choices in Sri Lanka.

Despite of the studies that confined themselves on FGT, there are some researches which employ propensity score matching and switching regression models. These types of literature controlling for sample selection bias and are methodologically rigorous. Among these, one of the studies that attempt to deal with irrigation poverty linkages is a study conducted by Nkhata (2014) in Malawi. The study used endogenous switching regression and propensity score matching models to examine the impact of irrigation on poverty and to assess the impact with those growing one irrigated crop versus growing two crops for traditionally marginalized groups (female headed households, the youth, and low income households), respectively. He found that irrigation had a positive impact on annual agricultural income and the impact was different among the irrigators, with those cultivating both rice and maize irrigation earning more agricultural income than their counterparts growing rice only. Traditionally marginalized groups were also attaining higher income than what they could have earned if they did not irrigate. Analogously, Gebregziabher & Namara (2008) have attempted to evaluate the impact of small scale irrigation on poverty in Tigray, Ethiopia. The study used propensity score matching with a data set generated from 613 sampled households representing different agro-ecological zones and irrigation typologies. The average income of irrigating households was found above the regional average, whereas it was 50 percent less than the regional average for non-irrigating households. Both Nkhata (2014) and Gebregziabher & Namara (2008) argued that significant income improvement is accompanied by poverty reduction among farmers with access to irrigation in the study area.

Furthermore, using a quite different methodology, Fitsum et al. (2009) has assessed the importance of irrigated

agriculture to the Ethiopian economy by capturing the direct net benefit contribution of irrigation to the national economy. They used “with minus without” irrigation approach, adjusted for changes in farm type and scale. It was argued that net gross margin from irrigation is more than twice higher than the gross margin from rainfed agriculture. The bulk of the contribution to national economy comes from the smallholder managed irrigation schemes, most importantly from the traditional schemes. However, the contribution of irrigation to national income is found still very small.

The Impact of Irrigation on Poverty Reduction via Expenditure and Yield/Productivity Indicators

Hussain & Wijerathna (2004) undertake comparative assessments on 26 different irrigation systems and analyze their contribution to poverty alleviation in developing Asia. The analysis was based on measuring expenditure and on primary household-level data and it found that, while irrigation has contribution for poverty alleviation, the magnitude of antipoverty impacts varies greatly across systems and depends on a range of factors. These include size and equity in land holdings, equity in water distribution with proper maintenance, improved cultivation technology, cropping patterns, and level of crop diversification supported by market infrastructure to facilitate marketing of inputs and outputs. Therefore, the antipoverty impacts of irrigation decreases as one or more of these conditions do not hold.

Among others, the work of Bhattarai & Narayanamoorthy (2004) have received a good deal of attention who has made a macro level analysis on the impact of irrigation on agricultural growth and poverty alleviation in India. In their review of empirical studies, they confirmed that some of the recent aggregate level studies have proved the positive impact of irrigation on poverty reduction. However, they assured that no straightforward relationship has been shown between irrigation and poverty alleviation; and the impact of irrigation on poverty alleviation depends on several other intermediate factors. Thus, they feel that an improved understanding of the structure of the impact of various factors and a quantification of marginal impacts of each of the factor inputs on poverty measures is important. As a result, they quantified the incremental impact of irrigation and other factor inputs on growth of total factor productivity and its implications on poverty alleviation. Finally, the weighted least square regression results of the study show that the marginal impact of irrigation on growth of productivity of all inputs is positive and significant. Among all the variables selected for analyzing the poverty measures in this study, irrigation has the strongest influence in explaining the reduction in poverty.

Despite of others, a study carried out by Pender et al. (2000) is one of the studies which attempts to indicate the possibilities that irrigation might not directly improve poverty unless accompanied by other complementary interventions. Using yield estimation method of measurement, Pender et al. (2000) has argued that although irrigation development was found to contribute to some livelihood strategies, it did not lead farmers to adopt improved technologies and hence yields or welfare indicators were not increased as expected. Many farmers continue to use traditional technologies even when irrigation is available which limiting the productivity impact of irrigation and hence poverty reduction is not improved. These results are not conclusive, but suggest that making more researches on the impacts of irrigation investments is fundamental to increase productivity in the field. Consistently with Pender et al. (2000), Jin et al. (2002) and Shenggen et al. (2000) have found negative and/or weak relationship between irrigation and agricultural productivity implying negative or no impact on household income and poverty reduction at large.

Generally, the reviewed studies indicated that there is lack of consensus among researchers regarding the linkages between irrigation and poverty reduction. Most of the studies suggested that irrigation-poverty linkage is a complex issue so that investigation in every irrigation system is recommended. The review also insights as there is no empirical evidence in the literature which shows multidimensional poverty index is used to measure poverty and analyze the impact of irrigation on it. Moreover, only few studies have been found controlling their sample selection bias. Therefore, this paper aims to make the following contributions in the literature. The first is methodological that is controlling sample selection bias and estimating the impact of irrigation on poverty by using multidimensional poverty index. Secondly, unlike other studies that focused on small scale schemes, this

study intends to evaluate the *Koga* irrigation scheme which is large and modern scheme and is not yet evaluated.

METHODOLOGY

Study Area Description

*Mecha Woreda*¹

Mecha *woreda* is one of the thirteen *woredas* in West Gojam Administrative Zone, Amhara regional state. It is located 34 kms south-west of Bahir Dar town, the capital of Amhara Region and 526 km far from Addis Ababa. According to Mecha *woreda* administrative office (2017), the *woreda* administers 50 *kebeles*² with an estimated total population of 400,000. Among the total *kebeles*, seven were selected as a study sites for this research (Figure 1). The *woreda* is well known for its flat topography and the altitude ranges from 1,800 to 2,500 meters above sea level with 'Dega' and 'Woyina Dega' agro-climatic zones. The mean annual rainfall in the *woreda* varies from 1,000 mm to 2,000 mm. From the total area of the *woreda* (156,027 ha), nearly half, 72,178 ha is cultivated area. The land covered by water bodies' accounts 1,386 ha.

Agriculture and trade are the main livelihood activities in the *woreda*. Particularly, subsistence level mixed farming is practiced in all parts of the *woreda*. The main crops grown in the area include maize, teff, finger millet, wheat, barley, chickpea, beans, Niger seed and cabbage. In the livestock sub-sector, cattle are dominant and large numbers of poultry, sheep and goats are kept. Oxen, cows, heifers, bulls, calves, chickens, goats and sheep are found in numbers in most households (Bahir Dar University, 2014).

The Koga irrigation development project

The *Koga* irrigation and water shade management project (currently renamed as "*koga* irrigation development

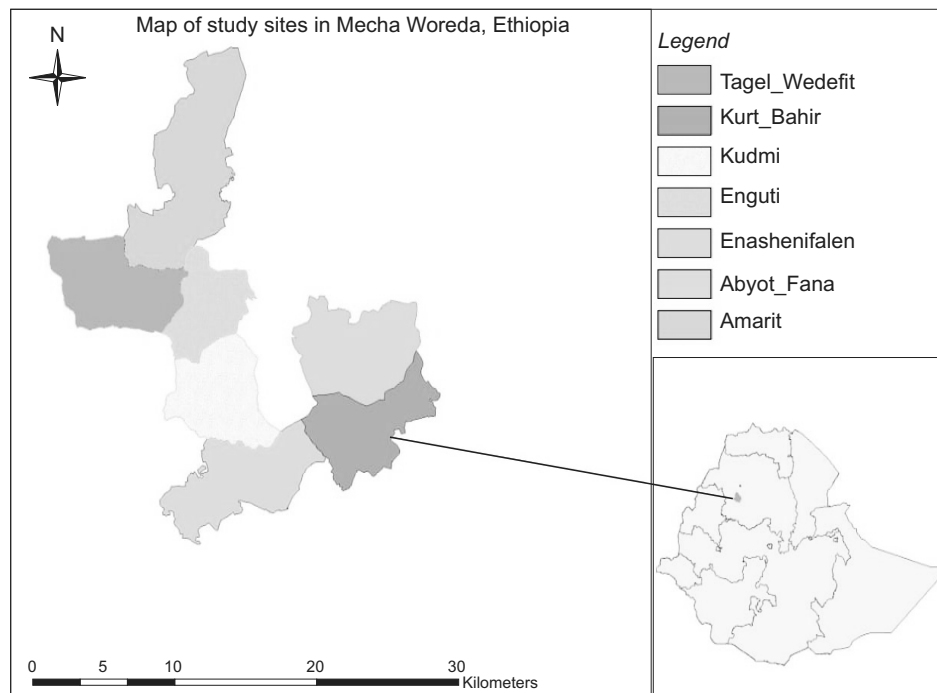


Fig. 1. Map of the selected study sites. Source: Author's own sketch using CSA's GIS data 2006.

¹*Woreda* is a division of Administration that administers a population up to 400 thousand.

²*Kebele* is the smallest administrative unit (administrative neighborhood units) of Ethiopia similar to a ward or peasant association.

project”) is one of the large-scale modern irrigation schemes in Ethiopia (MacDonald, 2004). It is found in *Mecha woreda*, Northern Ethiopia at the head of the Blue Nile basin within Lake Tana Watershed (Haileslassie et al., 2009). The project area was first surveyed by the *Derg* regime in the 1980’s to establish the irrigation scheme (Eriksson, 2012). The current government has resumed the plan and started the construction in October 2004 and completed in 2012. In collaboration with the Ethiopian government, the cost of the project was covered by African development bank (Eriksson, 2012). The project was supposed to improve the formerly used rain fed agriculture by allowing two crop seasons thereby reducing poverty and enhance food security. In addition to basic irrigation development activities, it integrates forestry, livestock, soil management, water and sanitation.

The *Koga* irrigation development project irrigates 7004 ha land within a 22,000 ha catchment area. The Project has two dams, called main and saddle dam. The saddle dam is smaller with an embankment length of 1162 m and a maximum height above the riverbed of 9 m. The main dam has 1730 m length and 21 m height and its water impound capacity is 83.1 million m³. 11 night water storage reservoirs in the area are used to store water at night when the smaller canals discharge is down. In addition, 95 tertiary and 469 quaternary unlined canals are available in the scheme to serve areas larger than 80 ha and 8-16 ha, respectively. The command area has 12 blocks irrigated by tertiary canals which takes off from a secondary canal. The size of a block varies from 300-900 ha (*Koga* irrigation development office, 2017). The main cultivated crops under the project are wheat, potato, shallot, pepper, garlic, onion, tomato and maize.

The project area comprised about 14,000 households in and around the vicinity. The urban population of Merawi and Wetet Abbay, with estimated population of 15,000 is also benefited directly and indirectly from increased economic activities. The majority of the households in and around the vicinity are dependent on farming for their livelihood (McCartney & Awulachew, 2006). The *Koga* Project is unique in Ethiopia because it integrates forestry, livestock, soil management, water and sanitation beyond basic irrigation development activities.

Sampling Design and Data Sources

The sample households for this study were selected from irrigated and non-irrigated adjoining areas using a multi-stage sampling technique. The first stage involved identification of *Koga* irrigation beneficiary *kebeles* by consulting with *Koga* irrigation development project head office. As a result, a total of 9 beneficiary *kebeles* were identified. In the second stage, these *kebeles* were purposively divided in to three strata (i.e., upper, middle and lower catchment areas) and proportional to the size of the strata, four sample *kebeles* were randomly selected. In stage three, seven adjoining rain-fed *kebeles* were purposively identified on the basis of their similarity in agro-ecology, distance closeness, agricultural practice during rain-fed time, land potential to produce, and cultural practices with irrigating *kebeles*. And then, three of them were randomly selected. The logic behind this is to examine the impact of irrigation on poverty through comparing irrigation users with that of non-irrigation users. In the final stage, a total of 395 sample households (220 irrigating and 175 non-irrigating) were selected from sample *kebeles* using random sampling technique. Note that for the purpose of preventing spillover effects, households listed as non-users in irrigating *kebeles* were not considered in the sampling frame because it is assumed that they use the service in one or another way more than adjoining *kebeles*. It was decided after we made pilot interviews with these households. Furthermore, two key informant farm households and the director of KIDP were selected randomly and purposively, respectively.

The study used both primary and secondary data sources. The primary sources were household survey, and the key informant interviews. The interviewer administered household survey data was collected from the selected sample households. The data through key informant interview was gathered from *Koga* irrigation development project office and farm households. Mainly, household surveys were targeted to gather information on irrigating and non-irrigating households’ demographic and socio-economic characteristics, income, asset ownership, size of farm holdings and living standards. For the interviews, both semi-structured and structured questionnaires were used to assess the perceptions and opinions of farmers and officers about the contribution of the project on the life of farming community. To enrich primary sources, relevant secondary data were also

collected.

Prior to the actual survey, preliminary information based on informal discussions with community members and block controllers in the command area at the grass-root levels was gathered. To increase data validity and reliability, enumerators who are fluent in the local language (Amharic) were selected to administer the interviews with the selected sample farm households.

EMPIRICAL ANALYSIS

Poverty analysis: application of multidimensional poverty index (MPI)

The mono-poverty measurements do not consider the dynamic and multidimensional nature of poverty and hence failed to address the structures of poverty reduction. As a result, this research employed Multidimensional Poverty Index (MPI) developed by OPHI and UNDP in 2010. The Alkire_Foster (2015) methodological approach (AF methodology hereafter) is the main methodology.

The main purpose of applying MPI based on the AF methodology was to measure acute poverty in which the proportion of households who experienced multiple deprivations and the intensity of such deprivations are identified. By taking the joint distribution of deprivations into account, it tracks the same household across multiple dimensions and counts the number of deprivations simultaneously experienced by the household. In this case, household members' combined achievements were used as a unit of identification for a population-wide measure, and all household members received the same deprivation score.

With the AF method, many key decisions are left to the researcher (Alkire & Foster, 2011). As shown in the subsequent section, this study, therefore, followed normative judgments to select the measure's purpose, unit of analysis, dimensions, deprivation cut-off, weights or values, and poverty cut-off.

Dimensions, indicators, weight and thresholds

Dimensions are conceptual categories into which indicators are arranged (possibly weighted) for intuition and ease of communication (Alkire et al., 2015). The deprivation dimensions and thresholds considered here were chosen with reference to the standard of living and public consensus about people's values in Ethiopia. Accordingly, by following Neubourg et al. (2010) four deprivation dimensions (education, health, living standards and

Table 1. The dimensions, indicators, deprivation thresholds and weights of the MPI

Dimension	Indicator	Deprived if.....	Weight
Education	Years of Schooling	No household member has completed eight years of Schooling	1/8
	Child school attendance	School-age child in years up to 7 is not attending school.	1/8
Health	Child Mortality	Any child has died in the household in the year under study.	1/8
	Access of health center/facility	The household has no access to health facility or access more than an hour trip	1/8
Living Standards	Electricity	The household has no electricity, generator or solar.	1/16
	Improved Sanitation	The household has no Improved sanitation	1/16
	Safe Drinking Water	The household does not have access to safe drinking water (according to MDG guidelines) or safe drinking water is more than a 30 minutes walk from home, round trip.	1/16
Productive assets	Roofing	The household has live in a house thatched by grass.	1/16
	Livestock index	The household does not own more than one group or two numbers in one group of beef cattle, milk cow, breeding bull, farm ox, goat and/or sheep and equine (donkey/horse/mule)	1/8
	Durable asset	The household own none of the following: Car, Bajaj, motorbike, bicycle, cassette player, radio, mobile, hand insecticide pump and water pump	1/8

Source: adapted from Neubourg et al. (2010) and Alkire et al. (2015).

productive assets) with ten indicators were selected (Table 1). The first three are internationally acknowledged dimensions, but are modified in to the local context. The fourth dimension was selected by assuming that it is contextual to the study area and relevant to the country's policies. All the indicators were defined at the household level, which is the unit of analysis.

Within this approach, indicators were first assigned for household poverty line and then they were aggregated into predefined dimensions of poverty, which are in turn combined into an overall poverty index. Even though there is no a priori reason to assume that the indicators used are all equally relevant across the sample population (Neubourg et al., 2010), for the ease of interpretation, this study follows equal weighting strategy among dimensions and indicators.

Following (Alkire & Foster, 2009), the study used a dual cut-off approach to identify multidimensional poor households. The first cut-off is used to determine whether a household is deprived in a particular indicator. Determinations of threshold given for each indicator were decided on the glance of theoretical assumptions, practicalities and policy relevancies. The second cut-off is the weighted sum of indicators which are counted towards identifying the multidimensional poor. This cutoff will show what combined share of weighted deprivations is sufficient to identify a household as poor. Following Alkire et al. (2015), households were defined as MPI poor if they are deprived in at least a third of the weighted indicators ($k \geq 33$) set out in the Table 1.

The thresholds selected for the two education indicators are based on the Ethiopian education policy that describes children of 7 years should be enrolled in school and everyone within a country should at least complete primary school.

There are two health dimension indicators. The first indicator which lies on Ethiopian health policy is an access to health center. The household is considered as deprived when it has no access to health center or an accessed more than an hour trip; assume that the availability of health stations prevents child death through counseling mothers about nutrition and hygiene. The second is child mortality. Since most child deaths caused by infectious disease are preventable (Alkire & Foster, 2011), a household is considered to be deprived if there has been at least one observed child death in the household under year of study. Within the living standard dimension, access to electricity/type of lighting source used in the study is a frequently used indicator on various welfare questionnaires. For example, Alkire et al. (2015) and Neubourg et al. (2010) use electricity, generators/solar power as indicators to estimate quality of life in Ethiopia and Senegal, respectively. For improved sanitation threshold, a household is assumed to be non-deprived, if it is provided with sanitation facilities such as sewers or septic tanks, pour-flush latrines and simple pit or ventilated improved pit latrines, but when they are not publicly shared (Alkire et al., 2015). According to the MDG guideline and Ethiopian government, a household has access of safe drinking water when the water source is either of the following types: piped water, public tap, borehole or pump or developed spring and when it is within a distance of 30 minutes' round trip. Roofing is another non-MDG indicator of the quality of house for households. For example, (Alkire et al., 2015) use flooring categories (dirt, sand or dung floor) to assess the quality of housing in Ethiopia. In this case, roofing will be used in place of flooring because house floor is commonly similar in the study society but their house quality varies in their roofing material such as grass and steel sheet. A house thatched with grass is considered as an inferior house type.

The final dimension covers the ownership of productive assets. Since the research setting is rural area, both livestock and durable asset indicators will provide rudimentary information about the farmer's farming equipment assets and functions as an income proxy. To the context of the area, it sounds that a household is considered as deprived if it does not own more than one group or two numbers in one group of livestock assets such as beef cattle, milk cow, breeding bull, farm ox, goat and/or sheep and equine (donkey/horse/mule). Based on the current farmers' ability to afford an asset in the study area, a threshold for durable asset were set in a way that a household is considered as non-deprived if it owns any of the following: car, Bajaj, motorbike, bicycle, cassette player/radio, mobile or hand insecticide pump.

In summary the analysis of poverty follows three steps. First, proportion of households under multiple deprivations was identified. Second, multidimensional poor households were identified when they are deprived in 1/3

of dimensions. Third, poverty profile was constructed for irrigators and non-irrigators.

Mathematical Expression

Poverty was analyzed by emphasizing on multidimensional headcount, the adjusted headcount, the mean number of deprivations, the poor and the non-poor, as well as the decomposed contributions of the single dimensions towards the overall headcount.

The adjusted headcount ratio, $(Mo(X; z))$, can be written as the product of two partial indices. The first partial index is the headcount ratio or poverty incidence $H = H(X; z)$ which is the proportion of the population that is poor. It is defined as $H = q/n$, where q is number of HHs identified as poor among total population n using the dual-cutoff approach.

The second index (A) is poverty intensity that is the average deprivation score across the poor. Notice that the censored deprivation score $c_i(k)$ represents the share of possible deprivations experienced by a poor person i . So, the average deprivation score across the poor is given by $A = \sum_{i=1}^n c_i(k)/q$. This partial index convey households who experience simultaneous deprivations in a higher fraction of dimensions have a higher intensity of poverty and are poorer than others having a lower intensity (Alkire et al., 2015).

Thus, Mo is given by

$$Mo = H \times A \quad (1) \quad \text{Or}$$

$$Mo(X; z) = \mu(c(k)) = H \times A = \frac{q}{n} \times \frac{1}{q} \sum_{i=1}^q c_i(k) = \frac{1}{n} \sum_{i=1}^n c_i(k) = \frac{1}{n} \sum_{i=1}^n \sum_{j=1}^d w_j g_{ij}^0 \quad (2)$$

The Switching Regression Model

The evaluation of the impact of technology adoption on household outcome is hampered by the fact that the “before” and “after” activities of a household are rarely observed. Instead, researchers are usually left to compare adopters with non-adopters (Fuglie and Bosch, 1995). But due to the possible systematic differences in mode of access and participation in an irrigation project sample selection bias may result. Irrigation participation thus becomes the selection criterion governing observation household poverty. Depending on the assumption regarding the relationship between the residuals of the selection regime and the outcome equations, both exogenous and endogenous switching regressions can be developed (Kuwornu & Owusu, 2012). Let I_i represents an irrigation participation dummy where $i \in [0,1]$, an irrigation selection criterion function can be expressed as

$$I_i = y'Z_i + u_i \quad (3)$$

Where, Z_i is a vector of household characteristics as well as instruments deemed to influence irrigation participation or adoption decision of household i , y is the vector of parameters to be estimated, and u_i is the error term.

Based on equation (3), let Y_i represent the level of household multidimensional poverty which will be observed for two different regimes (1) irrigator (2) non-irrigator (Fuglie & Bosch, 1995; Kuwornu & Owusu, 2012).

$$\text{Regme 1: } Y_{1i} = \beta_1'X_{1i} + v_{1i}, \text{ if and only if } y'Z_i + u_i > 0: \text{ irrigators } (I_i = 1) \quad (4)$$

$$\text{Regme 2: } Y_{2i} = \beta_2'X_{2i} + v_{2i}, \text{ if and only if } y'Z_i + u_i \leq 0: \text{ non-irrigators } (I_i = 0) \quad (5)$$

Where, X_i is a vector of exogenously determined variables of household i included in Z , β is the coefficient vector and v_i , the residuals.

Following Kuan (2002) and Kuwornu & Owusu (2012), this research first assume that the unobserved residual effects on poverty between irrigators and non-irrigators are independent of the unobserved effects on irrigation participation condition.

$$E[v_{1i}|I_i = 1] = E[v_{2i}|I_i = 0] = 0, \text{ and } cov(u_i, v_i) = 0$$

This implies that sample partitioning between irrigators and non-irrigators is entirely exogenous to their behavior so that an exogenous switching structure results, as in equations (4) and (5).

The unconditional expectation of these models can be expressed as applying least squares to equations (6) and (7) gives consistent estimate of the β .

$$E[Y_{1i}|X_{1i}] = \beta_1'X_{1i} \quad (6)$$

$$E[Y_{2i}|X_{2i}] = \beta_2'X_{2i} \quad (7)$$

However, there is a high likelihood that uncontrolled factors (e.g. farmer's inherent managerial ability) in the disturbance term, u_i , influencing participation in irrigation also simultaneously will influence the level of outcomes (Kuwornu & Owusu, 2012) so that $cov(u_i, v_i) \neq 0$. Under this situation sample separation between irrigators and non-irrigators become endogenous to their behavior, and governed by an irrigation participation regime. In order to obtain consistent standard errors, the full information maximum likelihood (FIML) method was employed to simultaneously fit the binary and continuous parts of the model. Here, the error terms v_{1i} , v_{2i} and u_i are assumed to follow a trivariate normal distribution with mean vector zero and covariance matrix Σ , i.e., $(u, v_1, v_2)' \sim N(0, \Sigma)$ (Di Falco et al., 2011; Kuwornu & Owusu, 2012).

$$\Sigma = \begin{bmatrix} \sigma_u^2 & \sigma_{1u} & \sigma_{2u} \\ \sigma_{1u} & \sigma_1^2 & \cdot \\ \sigma_{2u} & \cdot & \sigma_2^2 \end{bmatrix}$$

Where, σ_u^2 is the variance of the error term in the selection, σ_1^2 and σ_2^2 are the variances of the error terms in the continuous equations; σ_{1u} is the covariance of u_i and v_{1i} ; and σ_{2u} is the covariance of u_i and v_{2i} . Note that, the covariance between v_{1i} and v_{2i} is not defined since Y_{1i} and Y_{2i} are never observed simultaneously (reported as dots in the covariance matrix). It is assumed that $\sigma_u^2 = 1$, since y is estimable only up to a scalar factor (Maddala, 1986).

The expected (conditional) outcomes of a household for the two regimes are expressed as

$$E(Y_{1i}|I = 1) = \beta_1'X_{1i} + \sigma_1\rho_1 W_{1i} \quad (8)$$

$$E(Y_{2i}|I = 0) = \beta_2'X_{2i} + \sigma_2\rho_2 W_{2i} \quad (9)$$

Where σ_1 and σ_2 are the standard deviations of the two outcome equations, respectively; ρ_1 is the correlation coefficient between v_{1i} and u_i ; ρ_2 is the correlation coefficient between v_{2i} and u_i . W_{1i} and W_{2i} are the non-selection hazard terms for the respective regimes.

Following (Asfaw et al., 2012; Di Falco et al., 2011; Nonvide, 2018), the study compared the expected household MPI of the irrigators with respect to the non-irrigating farmers, and investigate the expected MPI in the counterfactual cases that the irrigators did not adopt irrigation, and that the non-irrigators did adopt. As shown in Table 2 below cases (a) and (b) indicates the actual expectations and the counterfactual expected outcomes are shown in cases (c) and (d).

The effect of irrigation adoption on irrigators is expressed by equation (10). It is the “treatment effect on the treated” (TT) which is the difference between cases (a) and (c) (Asfaw et al., 2012; Nonvide, 2018).

$$E(y_{1i}/D_i = 1) - E(y_{2i}/D_i = 1) \quad (10)$$

Similarly, the difference between cases (d) and (b) is the treatment effect on the untreated (TU) for the non-

Table 2. Conditional expectations, treatment and heterogeneity effects

Sample groups	Decision stage		Treatment effects
	Irrigate	Not irrigate	
Irrigators	(a) $E(y_{1i}/D_i = 1)$	(c) $E(y_{2i}/D_i = 1)$	TT
Non-irrigators	(d) $E(y_{1i}/D_i = 0)$	(b) $E(y_{2i}/D_i = 0)$	TU
Heterogeneity effects	BH ₁	BH ₂	TH

Note: (a) and (b) are the observed expected MPI; (c) and (d) are the counterfactual expected MPI.

$D_i = 1$ if farmers adopted irrigation; $D_i = 0$ if farmers did not adopt.

y_{1i} : MPI of farmers adopted; y_{2i} : MPI of farmers did not adopt.

TT: Effect of the treatment on the treated; TU: Effect of the treatment on the untreated.

BH_i: Base heterogeneity effect for farmers that adopted ($i = 1$), and did not adopted ($i = 0$).

TH = (TT – TU): Transitional heterogeneity.

Source: Adapted from (Asfaw et al., 2012; Di Falco et al., 2011; Nonvide, 2018).

irrigators, expressed by Equation (11).

$$TU = E(y_{1i}/D_i = 0) - E(y_{2i}/D_i = 0) \quad (11)$$

The study differentiates the treatments effects from the heterogeneity effects. For instance, the irrigators may have more or less MPI than the non-irrigators regardless of the fact they adopted irrigation but rather because of unobservable factors that affect the MPI. This “base heterogeneity effect” is expressed in Equation (12) as the difference between cases (a) and (d) for the group of irrigators (Asfaw et al., 2012; Nonvide, 2018):

$$BH1 = E(y_{1i}/D_i = 1) - E(y_{1i}/D_i = 0) \quad (12)$$

Similarly, for the group of non-irrigating farmers, the “base heterogeneity effect” is given by equation (13) as the difference between cases (c) and (b):

$$BH2 = E(y_{2i}/D_i = 1) - E(y_{2i}/D_i = 0) \quad (13)$$

Lastly, the study investigated whether the effect of adoption of irrigation is greater or smaller for irrigators or for rain-fed farmers if they did adopt. That is the “transitional heterogeneity effect” calculated as:

$$TH = TT - TU \quad (14)$$

RESULTS AND DISCUSSIONS

Household Multidimensional Poverty Analysis in the Study Area

Household deprivation in indicators

Prior to identifying multidimensional poor households, the AF methodology determines whether a household is deprived in a particular indicator (i.e., the first cut-off), as indicated in Table 3. It is used to know the minimum achievement level required from a household to be considered as non-deprived in that indicator (Alkire & Foster, 2009).

The rank order of indicators displayed that the first, the second and the third highest deprivation rates is found in the ‘productive asset’ and ‘living standard’ dimensions: durable asset (61.3%), livestock (32.7%) and electricity ownerships (29.9%), respectively. The figures indicated the percentage of deprived households that were unable

Table 3. Crude deprivation rates of households by indicators (%)

Dimension	Indicator	Deprivation
Education	Years of Schooling	25.3
	Child school attendance	23.8
Health	Child Mortality	1.5
	Access of health facility	26.6
Living standard	Electricity	29.9
	Improved Sanitation	24.8
	Safe Drinking Water	27.1
	Roofing	2.0
Productive assets	Livestock index	32.7
	Durable asset	61.3

Source: own household survey.

to meet the minimum achievement set to the respective indicators. For example, about 61% of the sample households deprived in durable assets such as car, bajaj, motorbike, bicycle, cassette player, radio, mobile, hand insecticide pump or water pump. It is also explained that 32.7% of surveyed sample households did not have more than one item or two quantities in an item of the following livestock asset groups: beef cattle, milk cow, breeding bull, farm ox, goat, sheep and equine (donkey/horse/mule). Though 26.6% of sample households were lived without access to health facility or accessed after an hour trip from home, the proportion of deprived households in child mortality was smaller (1.5%). About 23.8% of households have school aged children who were not attending school. As compared to the finding of Ambel et al. (2015), the result shows that there is improvement in child school engagement because he found that the proportion of households with school aged child who were out of school was 58 percent in rural areas. The improvement in this regard is more dramatic in some areas of Ethiopia. For example, the finding of WIDE reported that nearly all 7 years old children were enrolled in school in the six study sites visited in Ethiopia in 2013 (Bevan et al., 2014). Even though school engagement was improved, about 25.3% of sample households had no family member who has completed 8 years of schooling. About 27% and 24.8% of households were leading their life without access to safe drinking water and without improved sanitation facility or can access safe drinking water after 30 minutes round trip from their home, respectively. The households which were deprived in improved sanitation facility were 24.8%. This indicates that the proportion of household deprivation in improved sanitation and safe drinking water of the study area is smaller than the average deprivation in Ethiopia, which were 45% and 59% in 2011, respectively (Ambel et al., 2015). Among the living standard indicators, only 2% of sample households were deprived in roofing. This illustrates that households at the study area could be able to have improved type of homes. Overall, the single deprivation analysis shows that as compared to previous studies there are deprivation improvements and there is deprivation difference among dimensions at the study area.

Households multidimensional poverty profile

The second cut-off in the AF methodology identifies the deprivation status of households in weighted indicators. As can be vividly indicated in Table 4, about 30.6% of surveyed households were deprived by at least 33.3% of the weighted indicators which were the identified poor (*H*) households at the study area. This is actually smaller than the national percentage of poor people that was 87% (OPHI, 2016). About 7% of the poor households were deprived in more than 50% of weighted indicators so that they are categorized as severely poor households. The poverty intensity rate (*A*) of the study area was 47% which indicates that the poor households were deprived by 47% of the average [weighted] number of dimensions or by 1.88 dimensions. The adjusted headcount ratio (*Mo*) shows that among the poor households, 14.4% were identified as multidimensional poor. This implies that

Table 4. Multidimensional poverty profile

Category	No. of households (%)
Non-poor households (MPI $\geq$ 33.3%)	69.4
Non-deprived households (MPI = 0)	10
Vulnerable to poverty (MPI $\geq$ 20-33.3%)	27.5
In severe poverty (MPI $\geq$ 50%)	7.3
poor households (H)	30.6 (0.02)
Poverty intensity (A)	47.1 (0.01)
Multidimensional poor households (MO) = ($H \times A$)	14.4 (0.01)

Source: own household survey. Note: values in parentheses are standard errors.

multidimensional poverty in the study area was estimated to be 14.4% and each MPI poor household has experienced simultaneous multiple deprivations. The contribution of productive asset dimension to (Mo), followed by education dimension, was quite high which is 39.5% and 24%, respectively. On the indicator level, durable asset had the highest contribution (23.5%) whereas the contribution of roofing was very low (0.4%), explaining that nearly all households at the study area were not living in grass thatched homes (Annex Table 1).

However, about 69.4% of the sample households were multidimensional non-poor. Out of them, 10% were not totally deprived in any indicator, but 59.4% were deprived in at least one indicator. Amongst the deprived non-poor households, 27.5% were deprived in range from 20% up to 33.2% of weighted indicators and hence, they are considered 'vulnerable to poverty' (Alkire & Foster, 2009; Ambel et al., 2015).

The result of the study is consistent with the finding of Ambel et al. (2015) who confirms that there have been significant reductions of deprivations in many dimensions, particularly in rural areas. Similarly, our finding reveals that the MPI of the study area is highly lower than both the national average and regional average which is 56.2% and 58.8%, respectively (OPHI, 2017). The area has also much smaller MPI than the estimated national rural MPI (63.7%) (OPHI, 2017).

Decomposition of MPI by irrigation use

Another useful trait of the MPI measure is that it can be applied to population subgroups and it is used to compare the progress of different groups and potentially identify those at risk of falling behind (Alkire et al., 2017). Accordingly, the study examines the distribution of poor people across irrigation households and non-irrigation households. It also evaluates whether progress of poverty reduction was evenly achieved across the two groups. Figure 2 presented below indicated that non-irrigator households were deprived by majorities of indicators. The MPI is also higher in the non-irrigator households (Annex Figure 1).

As clearly shown in Table 5, the incidence of poverty in non-irrigating households (44.6%) was higher than irrigating households (19.5%). Not surprisingly, there was much variation in the proportion of multidimensional poor by irrigator and non-irrigator households (Annex Figure 2). From the total MPI poor households, 21% were non-irrigation users and the remaining 9% were irrigator households. When we decompose MPI by *kebele* groups, there was a considerable variation among different community groups. Enashenifalen *kebele*, had greater proportion (64.6%) of multidimensional poor households, whereas Enguti *kebele* had the least proportion of MPI poor with a share of 4.3%. The former *kebele* uses irrigation but the later does not use and this also confirm MPI difference among irrigation users and non-users.

The result of the study highlights that poverty reduction is not equally progressed in irrigating and non-irrigating households and it varies in local administrative areas as well. Both the proportion of poor and MPI poor households were higher in non-irrigating households. Inline of this, the interview with KIDP office indicate that up on the operation of the project, the living standard and income of irrigation beneficiaries become improved.

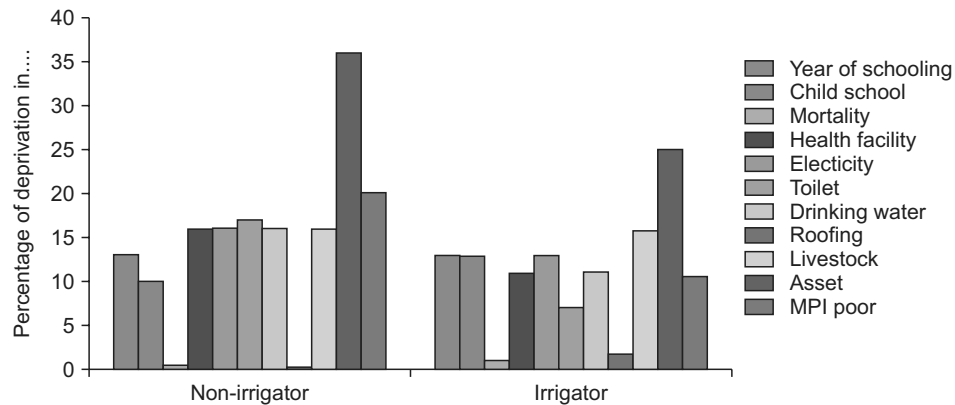


Fig. 2. Level of deprivation and proportion of MPI poor households across irrigation use.

Table 5. MPI decomposition by sub-groups

Subgroups	Categories	Pop. Share	H	Mo
Irrigation user	Non-irrigator	0.443	0.446	0.210
	Irrigator	0.557	0.195	0.092
Kebeles	Kudmi	13.9	32.7	14.5
	Enguti	10.6	9.5	4.5
	Amarit	19.5	24.7	12.3
	Tagel wodefit	11.6	4.3	1.8
	Kurit Bahir	10.1	47.5	24.5
	Enashenifalen	16.5	64.6	30.3
	Abiyotfana	17.7	24.3	10.4
Total		100	30.6	14.4

Source: own household survey.

They also believed that poverty in their context is low in irrigating households than rainfed farm households. This is consistent with the finding of Namara et al. (2008) who found that the depth of poverty for irrigators is less than those without access to irrigation. The result also suites to the idea of (De Neubourg et al., 2010; Dhongde & Haveman, 2015) which argued that poverty rates vary by geographic or administrative regions, degree of urbanization and technology adopting groups. Overall, it should be noted that the incidence of poverty among the sample households is still higher irrespective access to irrigation.

Even though the above discussion revealed that rainfed farm households were poorer than irrigator households, the key research question remaining is, whether irrigation adopters are better off than non-adopters as a result of the impact of irrigation. This fundamental question is therefore addressed by applying switching regression model in the following section.

The Impact of Irrigation on Household Multidimensional Poverty

Descriptive statistics of households' socio-economic characteristics

Summary statistics and statistical significance tests on the socio-economic profile of adopters and non-adopters for continuous and binary variables are presented in Table 6. There was no significant difference on gender of household heads and land covered by crop for irrigators and non-irrigators. This is attributable to the fact that both groups belong to the same population and the variables in question do not lend itself to change based on irrigation participation or otherwise. However, the average age of irrigator and non-irrigator households in-

Table 6. Descriptive summary of selected variables used in estimations

Variable	Non-Irrigators (N=175)	Irrigators (N=220)	t-test/x ² value
Outcome variable			
Multidimensional poverty index (MPI)	0.33	0.21	7.4***
Household characteristics variables			
Age of household head (years)	40.5	42.7	-1.8**
Gender of household head (1 = male)	0.30	0.38	0.78
Marital status of household head (1 = married)	0.43	0.51	-7.2***
Family size (number)	5.18	6	-4.1***
Length of residence at the area (years)	35.8	38.5	-1.9*
Education level of household head (years)	9.3	8.4	3.5***
Member of Edir (1 = yes)	0.41	0.47	4.6**
Household wealth variables and farm characteristics			
Household head farming experience (years)	20.7	22.9	-1.7*
Household farm income (Birr)	6,337.7	11,442.3	-5.8***
Total land size (ha)	2.2	2.8	-5.5***
Land covered by crop (ha)	0.88	0.89	-0.3
Own farm ox	1.4	1.7	-2.8***
Crop marketability (1 = yes)	0.35	0.37	11.2***
Growing crop type by expecting high yield (1 = yes)	0.41	0.54	6.9***
Crop resistance of climate change (1 = yes)	0.37	0.32	24.2***
Institutional and access related variables			
Input supply (1 = yes)	0.29	0.32	4.0**
Access to media (1 = own radio/tv/mobile)	0.28	0.42	6.7***

Note: ***, ** & * are significance levels at 1%, 5% & 10%; Standard errors in parentheses.

Source: own household survey.

indicated that there is statistical significance difference between the two groups. The average age for both groups suggests that the farmer population is younger and energetic with possibly switching to more lucrative ventures. The average family size in irrigating and non-irrigating households is 6 and 5, respectively and the difference is statistically significant. It is worthy that, larger size of household with high proportion of economically active labor is relevant for adoption of new technologies and household welfare security (Glewwe et al., 2000). Irrigation adopters do seem to have higher proportions of marital status, length of residence in the area and being a member of *edir*³, whereas they have lower proportion of education level.

Regarding to farm and economic characteristics, significant difference was observed on the farming experience of household heads between irrigators and non-irrigators (22.9 and 20.7 years, respectively). Significant difference was also noticed for variables such as average farming income, ownership of total land size, farm ox, access to information (own radio/mobile/TV), and agricultural input supply with higher mean levels for all of these variables in favor of irrigation participants. This suggests that these variables might be correlated with decision to irrigation adoption. However, the assumption of farmers about the marketability, high yield expectancy and climate change resistance capacity of crops they grow was higher in favor for non-irrigators.

Econometric results and discussion

The Differences in poverty outcome may not be due to irrigation adoption itself but unobserved ability and

³*Edir* is a traditional social/mutual aid association practiced in Ethiopia.

characteristics that could affect households' relative welfare. Hence, to check whether the arguments are correct, the full maximum likelihood estimation of endogenous switching model that can control for unobservable selection bias is presented in Table 7. The estimation consists of both irrigation participation/adoption model and outcome model for irrigators and non-irrigators. The determinant forces behind farmers' decisions to participate in irrigation use and poverty status of households are also presented where the dependent variable is dummy and the outcome variable is continuous (Annex Table 2).

Among model estimating variables, access to media/information (own radio/TV/mobile), used in the adoption equation is excluded from outcomes equation, to meet the condition of model identification (Asfaw et al., 2012; Kuwornu & Owusu, 2012; Nonvide, 2018). The hypothesis behind was that this variable affects the probability of irrigation adoption but does not influence multidimensional poverty. It is believed that a household that owns radio/mobile/TV have access of information. Accessibility to information is key to be aware on the contribution of adopting irrigation to reduce household poverty. Since irrigation adoption is an investment where farmers spend an extra capital, they might not adopt it unless they have clear idea about its profitability. However, access

Table 7. Full information maximum likelihood estimates of the switching regression model

Variables	Irrigation adoption model	Outcome model	
		Irrigating farmers	Non-irrigating farmers
Age of household head	0.037 (0.011)***	0.005 (0.002)***	0.001 (0.002)
Marital status household head	-0.84 (0.33)**	-0.077 (0.045)*	-0.047 (.075)
Length of residence at the area	-0.015 (0.007)**	-0.002 (0.001)*	-1.59e-06 (0.001)
Education level	-0.071 (0.027)**	0.004 (0.004)	-0.006 (0.006)
Member of edir	-0.32 (0.23)**	-0.08 (0.034)**	-0.09 (0.043)**
Household head farming experience	-0.011 (0.009)	-0.004 (0.002)**	-0.002 (0.002)
Log household farm income in birr	0.431 (0.08)***	0.023 (0.015)	-0.008 (0.012)
Total land size per ha	0.383 (0.108)***	0.036 (0.015)**	-0.037 (0.02)*
Land covered by crop per ha	-1.39 (0.245)***	-0.156 (0.036)***	0.07 (0.059)
Own farm ox	0.019 (0.083)	-0.048 (0.015)***	-0.05 (0.015)***
Crop marketability	-0.427 (0.189)**	-0.038 (0.03)	0.045 (0.038)
Growing a type of crop by expecting high yield	0.865 (0.439)**	0.087 (0.074)	0.205 (0.059)***
Crop resistance of climate change	-0.567 (0.16)***	-0.06 (0.026)**	-0.098 (0.04)***
Input supply	0.116 (0.155)	-0.031 (0.025)	.006 (0.026)
Access to media (radio/TV/mob.)	0.355 (0.115)***	-	-
_cons	-2.60 (0.82)***	0.086 (0.156)	0.53 (0.086)***
/lns1	-1.702 (0.062)***	-	-
/lns2	-1.954 (0.078)***	-	-
/r1	2.089 (0.387)***	-	-
/r2	0.398 (0.304)	-	-
sigma_1	0.182 (0.011)	-	-
sigma_2	0.141 (0.011)	-	-
rho_1	0.969 (0.022)***	-	-
rho_2	0.378 (0.26)	-	-
N	395	220	175

Log likelihood = 44.32; Wald chi2(14) = 69.57; Prob > chi² = 0.0000

Wald test of indep. eqns.: chi2(1) = 31.43; Prob > chi2 = 0.0000

Note: ***, ** & * are significance levels at 1%, 5% & 10%; Standard errors in parentheses.

Source: own household survey.

to information without adopting irrigation does not directly affect the multidimensional poverty.

Estimates of the endogenous switching model revealed that the model has a high fit with its explanatory variables. The Wald test of independence confirming the sample selection bias and was significant at 1%. This implies that at least one of the explanatory variables significantly explains the variation in household poverty. The correlation coefficient (Rho_1) between the equations of irrigation adoption and MPI was positive and significantly different from zero (at 1% significance level). According to Lokshin & Sajaia (2004), this suggests that the mean MPI of those who irrigate is higher than randomly selected households mean for irrigators, and those not using irrigation do no better or worse condition than a random individual for non-irrigators. This further implies that the irrigation adoption decision and MPI outcome are affected by observable and unobservable factors (Xie, 2000).

Determinants of irrigation adoption and MPI

The results of the adoption model given in the second column of Table 7 revealed that the coefficients of most of the variables hypothesized to influence participation in irrigation use have the expected signs. Variables such as age, marital status, length of residence, level of education, *edir*, farming income, total land size holding, land covered by crop, crop marketability, crop resistance to climate change, high yield expectancy from a growing crop and access to media are statistically significant in explaining the decision to participate in irrigation use. Of these determinant factors, age of a household head, income from farming, total land size owned by household and high yield expectancy are positively influenced households to be a member of the project.

It is indicated that a unit addition to age most likely improves the probability of participation. This attributes to the fact that older farmers might possess richer farming experience that could be easily harnessed for improved irrigation activity (Kuwornu & Owusu, 2012). A unit increase of income from farming agriculture and land size positively influences the probability of household participation in irrigation project. One possible explanation is that these assets eases the access of households to agricultural inputs and afford the costs so that they could adopt the technology. Those farmers who expect high yield from a selected type of growing crop are also more likely influenced to adopt irrigation. Consistent with the hypothesis of the study and the findings of Asfaw et al. (2012), the result shows that irrigation adoption is most likely determined by the proxies of access to information such as radio, TV and mobile. This implies that ownership of these assets eases the access of households to information. Hence, households who have access to information about irrigation are likely urged to adopt it. In connection to this The coefficients for variables such as, marital status, length of residence, education level, member of *edir*, cropped land size, crop marketability and perception of households on crops resistance to climate change are negative sign, but are statistically significant determinants of irrigation adoption.

The determinants of household's multidimensional poverty status in irrigated and non-irrigated households are also presented in Table 7. Variables such as total land size, member of *edir*, farm ox ownership and perception of households on crop's resistance to climate change significantly contributes for multidimensional poverty reduction in both irrigated and non-irrigated households. Holding of large land size and number of farm oxen are wealth proxies in the study area. Hence, it is not surprise that a unit increase of these assets play a significant role in household's effort to reduce poverty. Expectedly, the contribution of *edir* for poverty reduction in both groups is statistically significant because it is a traditional social/mutual aid association practiced in Ethiopia. Perception of households on crops resistance to climate change also negatively influences poverty (i.e., reduce poverty) in both groups. The explanation behind this result indicates that farmers are experienced and skilled in identifying and growing climate resilient types of crops. Selectively growing a type of crop by expecting more yield than other crops was the additional variable that significantly determines poverty in non-irrigator households. In other words, those farmers who perceived the type of crop they choose to grow provides high yield most likely lowers their MPI. In the irrigator households, age of household head, marital status, length of residence at the area, farming experience and size of land covered by crop significantly decreases multidimensional poverty. One possible explanation is that aged and long resident as well as experienced farmers might know the

local opportunities to reduce poverty such as agro-ecology, nature of the soil, type of crops suitable to the environment and feasible income generating activities.

Predicted impact of irrigation adoption on multidimensional poverty

The predicted MPI from endogenous switching regression model are used to examine the mean MPI gap between irrigators and if they had not irrigated. Table 8 presents the expected MPI under actual and counterfactual conditions for irrigator and non-irrigator households at the study area. Cases (a) and (b) are the expected MPI values observed in the sample which were 0.21 for the irrigators and 0.33 for the non-irrigator households. A t-test analysis ($t = -15.04$ significant at 1%) between the two groups indicated that irrigation households had significantly lower MPI with the difference being 11.5%. This illustrates that the expected multidimensional poverty of irrigators is lower than non-irrigators. However, it cannot be attributed to the use of irrigation alone (Asfaw et al., 2012; Nonvide, 2018). Therefore, based on this simple comparison, it can be misleading to attribute the different level of observed poverty to the use of irrigation.

As a result, the treatment effects report of irrigation adoption was used. Note that the negative/positive signs of TT and TU indicate the direction of poverty. For example, if irrigators are less poor than non-irrigators, the MPI mean value for irrigators should be smaller than their counter group and hence, when we subtract the result is negative and vice-versa. It is estimated that in the counterfactual case (c), the irrigator households MPI would have been 0.175 more if they did not adopt irrigation. This implies that if the irrigator households did not irrigate, they would be 17.5% more poor than what are today. The effect of irrigation on non-irrigator households in the counterfactual case (d) show that if the non-irrigator households had adopted irrigation, their MPI would be lowered by 0.375. The result reveals that if the non-irrigators adopted irrigation they would reduce poverty by 37.5%. The TH value in the table shows that the transitional heterogeneity effect was positive and significant (0.2) implying that the effect of using irrigation was significantly bigger for the non-irrigator households if they irrigate. If they did adopt irrigation, the non-irrigator households would be 20% less poor than irrigators. The heterogeneity effects reveal that the non-irrigator households would have been poorer than the irrigators in the counterfactual case (c), and case (d).

The findings of this study suggest that there is a positive relationship between irrigation adoption and household's multidimensional poverty reduction. Irrigating farm households could reduce their multidimensional poverty by 17.5%. This illustrates that the contribution of irrigation to reduce household multidimensional poverty at the study area was 17.5%. The result is consistent with previous findings of Nkhata (2014), Ayele et al. (2013) and Hussain & Wijerathna (2004) who reported that there are indicative patterns of farm households' poverty in large and medium-scale irrigation systems. Irrigation development has a profound direct impact on agriculture output levels. It boosts total farm output and hence, with unchanged prices, raises farm incomes thereby reduces poverty (Lipton et al., 2003). In 2002-2003, IWMI carried out detailed case studies on assessing impacts of irrigation on poverty alleviation in Bangladesh, China, India, Indonesia, Pakistan and Vietnam. The finding indicated that in most settings, poverty incidence is 20-30 percent higher in rain-fed settings than in irri-

Table 8. Average expected MPI for irrigating and non-irrigating households

Sample groups	Decision stage		Treatment effects
	Irrigate	Not irrigate	
Irrigators	(a) 0.219 (0.005)	(c) 0.394 (0.006)	TT = -0.175 (.007)***
Non-irrigators	(d) -0.042 (0.006)	(b) 0.333 (.006)	TU = -0.375 (.008)***
Heterogeneity effects	BH ₁ = 0.26 (.008)***	BH ₂ = 0.06 (0.008)***	TH = 0.2 (0.008)***

Note: *** is significance level at 1%; Standard errors in parentheses.

Source: own household survey.

gated settings (Hussain & Wijerathna, 2004). Irrigation also significantly contributes to reducing the worst kind of poverty, i.e., chronic poverty. The poverty incidence, depth and severity were also found to be lower among irrigation households than among non-irrigation household (Meliko & Oni, 2011).

However, the impacts of irrigation on poverty vary widely across and within irrigation systems and depend on a number of factors (Hussain & Wijerathna, 2004). Therefore, incidence, depth and severity of poverty is affected more by the intensity of irrigation use than mere access to irrigation (Namara et al., 2008). For example, Fitsum et al. (2009) found that due to improved efficiency and management, the bulk of the contribution to national economy comes from the smallholder managed irrigation schemes; most importantly from the traditional schemes.

Therefore, it is suggested that simple access to irrigation is not a sufficient condition to alleviate poverty in rural households who are dependent to a great extent on agriculture for their livelihoods. Besides, access to other production inputs and services, low cost of irrigation use and awareness on efficient utilization of the system are important to enhance benefits of irrigation for poverty alleviation.

Opinions and Perceptions of Key Informants on the Contribution of KIDP

Basically, the study has employed the key informant interviews to triangulate the findings of the econometric statistics and increase the validity of results. The main focus of the interview was to ascertain the extent to which the project has affected households' poverty status. Their personal opinions about the benefits of the project, their satisfaction level, poverty trend and the measures to be taken for better performance of the project were assessed. The KIDP project office and farmers (relocated and host) were the identified key informants. To illustrate the details of presentation and discussion, the following three cases have been chosen.

Case 1: Girmachew Amare

I am one of the former dwellers in this kebele at the command area. At the construction phase of the project we have heard that the project was established with big irrigation capacity. As a result, we have had big hope on the full adequacy of the service; unfortunately due to many reasons it is not satisfactorily adequate. However, with all the limitations, I am happy on the commencement of the project because it enables me to share the tips. Even if I am not rich in land holding, the irrigation service enables me to use my plot effectively. I am harvesting crops twice a year; especially market oriented cash crops such as head cabbage, potato, onion and garlic which are good sources of household income. In addition, I and my son make money from some off-farm activities to supplement our farm income. As a result, my income has improved and now I feel that I am in a better standard of living. When I compare my current level of poverty with before using the project, I can say that it is totally different on fever of my current life. Currently, I can easily afford the costs of children school, health and agricultural inputs. I thought that irrigation beneficiaries will be better off if the scheme has adapted good governance and use advanced water delivering technologies.

Case 2: Simegnew Takele

I am a new comer to Amarit Kebele dislocated from Sebehatie Kebele before six years. In the name of dam and canal construction, I lost my land and eucalyptus trees and then forced to resettle at this Kebele without appropriate compensation. Even so, I was happy to be a beneficiary of irrigation. It is good to see such technologies though it is not well managed. For example, due to tertiary canal problem, blocks do not equally share water which minimizes our satisfaction. Another big challenge for irrigation users is input cost. However, the benefits outweigh the challenges. The project enables me to produce fruit, vegetables and staple crops two times in a year. My production increases from time to time. In addition, my children have engaged in alternative jobs to support themselves. As a result, I sense it as I am in a good life. I found it difficult to compare my poverty level before and after I use irrigation. I thought this one is by far better than before. Of course, I am still poor, but better poor. For instance, solar light, mobile and bed with Kangaroo foam are my assets that I could purchase

by selling garlic and cabbage which I grow them using irrigation. I feel that I and my neighbors will enjoy more improved life if the water and input supply problems are addressed.

Case 3: Tewachew Abebe

So as to understand the improvement level of farming communities in the command area, *Ato Tewachew*, director of KIDP was interviewed. His demonstration about the life situation of irrigation beneficiaries was consistent with what farmers' explained. He stated:

Needless to say, the project has been playing incommensurable role in household poverty reduction. It enables farmers to utilize their land effectively. They could harvest highly marketable farm crops twice a year, rather than only once as they did before. In our production assessment reports we found that the trend of production improvement is continuous. Besides, farmers could be able to engage in alternative job opportunities to support their farm income. The community in the command area could also easily access road and transportation which they could not access if the project had not been commenced. Even though we did not study the exact poverty status of households, we observe that their living standard is improving. However, I want to note you that the system is providing the service within various ups and downs such as administrative ownership problem, water shortage and conflict of interest. In my opinion, the project will sustainably serve beneficiaries if it is administered by the community and adopt new irrigation technologies.

In a general view, the key informants were not fully satisfied by the provided service as much as they kept from the project. They thought as the project would make them more profitable than what it does today. However, they recognized that the project has played a significant role in enhancing their livelihoods and reducing poverty. They assured that their living standard has improved upon they started to be irrigation beneficiaries. They also could access infrastructural opportunities such as road and transportation, and they felt proud as if they would never be the divisible part of such development blessings if the project was not commenced. The result of the interview is consistent with Gebre et al. (2008) who argue that irrigation beneficiaries would increase their production capacity, access infrastructural opportunities and improve their living standards. Analogously, Fitsum et al. (2009) has found that irrigation farming generates more average income than rainfed farming. Furthermore, the result suites to the econometric model results of the study and hence it assured that the finding is valid.

CONCLUSIONS AND POLICY IMPLICATIONS

This study basically evaluates the impact of the *koga* irrigation development project on household poverty by employing endogenous switching regression model. The endogenous switching model controls for bias due to the observable and unobservable factors. Poverty was measured using multidimensional poverty index (MPI).

The study found the headcount ratio, multidimensional poverty index and poverty intensity of the study area were lower than the national, rural and regional average estimates of 2017. This indicated that there is a trend of poverty reduction, but the result confirmed that poverty reduction was not equally progressed in irrigating and non-irrigating households. The proportion of poor and MPI poor non-irrigator households were higher than irrigators. The outputs of the endogenous switching model and the key informant interview proved that irrigation adoption has positive influence on household multidimensional poverty reduction. Irrigators were less poor than their counterparts. The contribution of irrigation in multidimensional household poverty reduction at the study was 17.5%. However, it should be noted that the incidence of poverty among the sample households is still higher regardless of access to irrigation. This implies that while irrigation is essential for household poverty reduction there is a need for complementary services, updated technologies, infrastructure, policies, and institutions for greater impacts on welfare outcomes.

Therefore, the study recommends that access to irrigation should be accompanied by the provision of institutional support services, modern technologies and complementary production inputs. For example, creating

awareness for farmers on effective and efficient utilization of the scheme, access of modern irrigating technologies, credit and farm inputs such as improved seed, fertilizer and insecticide are of great importance to reduce poverty. It is also recommended that so as to excel the impact of irrigation on rural poverty reduction the government should expand the technology over non-irrigated areas.

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Annex Table 1. Contribution of dimensions and indicators to overall multidimensional poverty in %

Dimension	<i>Mo</i>	Indicator	<i>Mo</i>
Education	24.8	Years of Schooling	14
		Child school attendance	10.8
Health	15.8	Child Mortality	1.3
		Access of health facility	14.5
Living standard	20	Electricity	6.8
		Improved Sanitation	6.9
		Safe Drinking Water	5.7
		Roofing	0.4
Productive assets	39.5	Livestock index	16
		Durable asset	23.5

Source: own household survey.

Annex Table 2. Full information maximum likelihood estimates of the switching regression model

Fitting initial values.....

Iteration 0: log likelihood = 37.467027

Iteration 1: log likelihood = 43.233392

Iteration 2: log likelihood = 44.273567

Iteration 3: log likelihood = 44.325711

Iteration 4: log likelihood = 44.326147

Iteration 5: log likelihood = 44.326147

Endogenous switching regression model Number of obs = 395

Wald chi (14) = 69.57

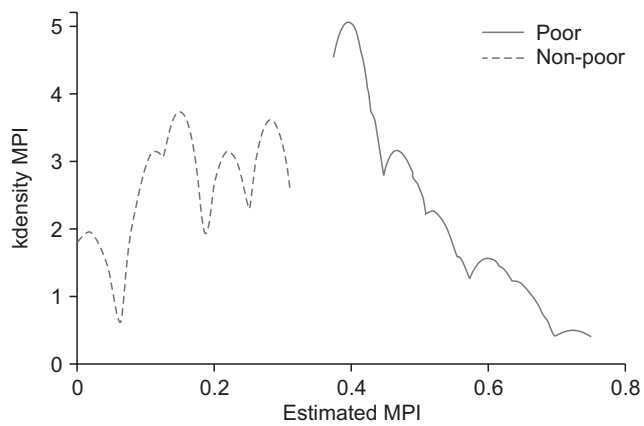
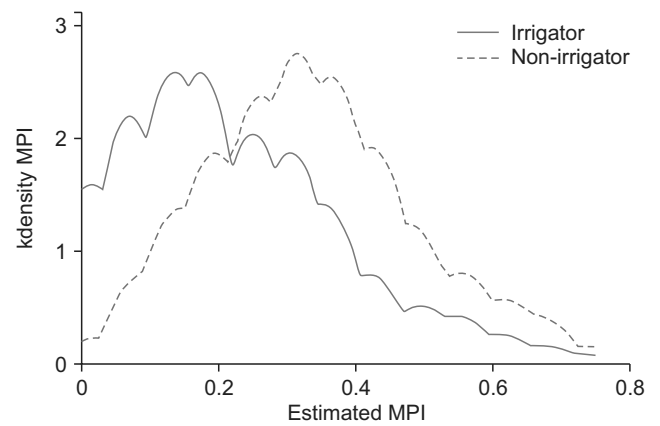
Log likelihood = 44.326147 Prob > chi2 = 0.0000

	Coef.	Std. Err.	Z	P>z	[95% Conf. Interval]	
MPI_1						
farmox	-.0482838	.0150236	-3.21	0.001	-.0777294	-.0188381
experience	-.0037799	.0016295	-2.32	0.020	-.0069738	-.0005861
expctcy	.0868865	.0738159	1.18	0.239	-.05779	.231563
AGE	.0054714	.0019197	2.85	0.004	.0017089	.0092339
Mar_dumy	-.0772848	.0446742	-1.73	0.084	-.1648446	.0102749
CROPLAND	-.1558971	.0359667	-4.33	0.000	-.2263905	-.0854038
logfarminc	.0229254	.0146396	1.57	0.117	-.0057676	.0516184
EDIR	-.0806838	.0339506	-2.38	0.017	-.1472257	-.0141418
educlevel	.0041053	.0040175	1.02	0.307	-.0037688	.0119795
mrktable_dumy	-.0377248	.0288909	-1.31	0.192	-.09435	.0189004
TLANDSIZE	.0356568	.0149058	2.39	0.017	.0064419	.0648717
rcc	-.0597849	.0259509	-2.30	0.021	-.1106476	-.0089221
inputsup	-.0309387	.0248619	-1.24	0.213	-.0796671	.0177897
LENGTHRES	-.0024479	.0012954	-1.89	0.059	-.0049869	.0000911
_cons	.0864968	.1557398	0.56	0.579	-.2187477	.3917412
MPI_0						
farmox	-.0311462	.0118953	-2.62	0.009	-.0544606	-.0078318
experience	-.0020794	.0015136	-1.37	0.169	-.005046	.0008872
expctcy	.205156	.0588635	3.49	0.000	.0897857	.3205263
AGE	.0007856	.0018628	0.42	0.673	-.0028655	.0044368
Mar_dumy	-.0465705	.0750037	-0.62	0.535	-.193575	.100434
CROPLAND	.0702021	.0598437	1.17	0.241	-.0470894	.1874937
logfarminc	-.007601	.0121159	-0.63	0.530	-.0313478	.0161458
EDIR	-.0877891	.0428315	-2.05	0.040	-.1717373	-.0038408
educlevel	-.0056107	.0055475	-1.01	0.312	-.0164836	.0052621
mrktable_dumy	.0448362	.0384814	1.17	0.244	-.030586	.1202583
TLANDSIZE	-.0374916	.0232526	-1.61	0.107	-.0830658	.0080826
rcc	-.0978589	.037295	-2.62	0.009	-.1709559	-.024762
inputsup	.0064018	.026241	0.24	0.807	-.0450296	.0578333
LENGTHRES	-1.59e-06	.0012066	-0.00	0.999	-.0023665	.0023633
_cons	.5312997	.085957	6.18	0.000	.3628271	.6997722
IRRIUSE						
experience	-.0111831	.0099365	-1.13	0.260	-.0306584	.0082922
AGE	.036792	.0114513	3.21	0.001	.0143479	.0592361
CROPLAND	-1.393873	.2457959	-5.67	0.000	-1.875624	-.9121221

Annex Table 2. Continued

	Coef.	Std. Err.	Z	P>z	[95% Conf. Interval]	
educlevel	-.0719508	.0266974	-2.70	0.007	-.1242769	-.0196248
mrktable_dumy	-.4268198	.1891735	-2.26	0.024	-.797593	-.0560466
TLANDSIZE	.3836364	.1080548	3.55	0.000	.1718529	.5954198
rcc	-.5665021	.1632181	-3.47	0.001	-.8864037	-.2466005
inputsup	-.1168556	.1554647	-0.75	0.452	-.4215607	.1878495
LENGTHRES	-.0154648	.0074171	-2.09	0.037	-.030002	-.0009276
farmox	.018847	.0833975	0.23	0.821	-.1446091	.182303
expctcy	.8652409	.4391376	1.97	0.049	.0045471	1.725935
Mar_dumy	-.8362728	.3314378	-2.52	0.012	-1.485879	-.1866665
logfarminc	.4313043	.0808198	5.34	0.000	.2729004	.5897082
EDIR	-.3187198	.2288532	-1.39	0.164	-.7672638	.1298242
info_ratvm	.3557732	.1152672	3.09	0.002	.1298536	.5816929
_cons	-2.603573	.8208134	-3.17	0.002	-4.212337	-.994808
/lns1	-1.702707	.0622347	-27.36	0.000	-1.824685	-1.580729
/lns2	-1.95388	.0781985	-24.99	0.000	-2.107147	-1.800614
/r1	2.089572	.386723	5.40	0.000	1.331609	2.847535
/r2	.3981885	.3044852	1.31	0.191	-.1985916	.9949685
sigma_1	.1821897	.0113385			.1612685	.205825
sigma_2	.1417231	.0110825			.1215844	.1651974
rho_1	.9698386	.0229764			.869642	.9932975
rho_2	.3783979	.2608875			-.1960214	.759473
LR test of indep. eqns.: chi2(1) = 16.09 Prob > chi2 = 0.0001						

Source: own household survey.

**Annex Fig. 1.** MPI poverty cut-offs.**Annex Fig. 2.** MPI score distribution of irrigators and non-irrigators.