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Structural and Institutional Heterogeneity among Agricultural Cooperatives in Ethiopia: Does It Matter for Farmers' Welfare?

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This paper analyzes how structural and institutional heterogeneity among irrigation cooperatives shapes the impact of membership on farmers' welfare in northern Ethiopia, using a novel heteroskedasticity-based identification strategy. More specifically, we estimate how cooperative characteristics influence members' income and poverty level. We find that stricter water use regulations have income-enhancing and poverty-reducing effects for farmers. We also find that farmers benefit more from membership in larger, younger, and bottom-up cooperatives initiated through grassroots collective action. Our findings have implications for irrigation development in Ethiopia and call for a better deliberation of organizational heterogeneity in cooperative impact studies

Key words: heteroskedasticity-based identification, household welfare, irrigation, organizational heterogeneity

Introduction

Agricultural cooperatives are seen as an important institutional tool for poverty reduction and rural income growth in low- and middle-income countries (Verhofstadt and Maertens, 2015). Cooperative membership enables small farmers to capture the benefits of scale economies, reduce transaction costs in purchasing inputs and marketing outputs, and improve access to extension, credit, and other services (Soboh et al., 2009; Ito, Bao, and Su, 2012; Saitone, Sexton, and Malan, 2018). Various studies from around the world show that membership in cooperatives has a positive impact on smallholder farmers in the form of producer prices, market participation, technology adoption, productivity, farm income, and poverty reduction (Fischer and Qaim, 2012; Ito, Bao, and Su, 2012; Abebaw and Haile, 2013; Vandeplas, Minten, and Swinnen, 2013; Verhofstadt and Maertens, 2014, 2015; Chagwiza, Muradian, and Ruben, 2016; Ma and Abdulai, 2016; Ma, Abdulai, and Goetz, 2018; Mojo, Fischer, and Degefa, 2017; Wossen et al., 2017).

In a recent review of 56 empirical studies on farmer cooperatives, Grashuis and Su (2019) conclude that cooperative membership generally has a positive impact on farmers. This literature

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largely investigates the average impact of cooperative membership by comparing the performance of members and nonmembers. Some studies go beyond this and analyze heterogeneous impacts across farmers (Bernard, Taffesse, and Gabre-Madhin, 2008; Fischer and Qaim, 2012; Ito, Bao, and Su, 2012; Abebaw and Haile, 2013; Verhofstadt and Maertens, 2015). Grashuis and Su's review concludes that benefits are unequally distributed between small and larger farmers. Various studies point to heterogeneity in the organizational characteristics of cooperatives (e.g., Sykuta and Cook, 2001; Markelova et al., 2009), and some studies analyze the implications of these differences for the performance at the cooperative level (e.g., Gezahegn et al., 2019, 2020). Yet, with a few exceptions (e.g., Francesconi and Heerink, 2011; Fischer and Qaim, 2012; Verhofstadt and Maertens, 2014; Zhang et al., 2013), studies analyzing the impact of cooperative membership largely ignore the heterogeneity in cooperative organizational characteristics.

The objective of this paper is to understand how differences in organizational (structural and institutional) characteristics of irrigation cooperatives shape the impact of cooperative membership on farmers' welfare in northern Ethiopia. We use survey data from 509 farmers in 40 cooperatives and a novel heteroskedasticity-based identification strategy (based on Lewbel, 2012) to estimate how cooperative characteristics influence members' income and poverty level. Our study complements the few previous studies that analyze how cooperative characteristics shape the impact on members (e.g., Francesconi and Heerink, 2011; Fischer and Qaim, 2012; Zhang et al., 2013; Verhofstadt and Maertens, 2014). However, our focus and approach are innovative in multiple ways. First, our study only concentrates on irrigation cooperatives (IRCs) and includes 40 IRCs that were specifically selected from a larger cooperative survey based on their organizational characteristics in a stratified random way. The other studies include a smaller number and a mixture of cooperative types, implying less variability in cooperative characteristics. For example, Verhofstadt and Maertens (2014) deal with horticulture and maize cooperatives (16 in total) and cannot disentangle the effect of organizational characteristics from the effect of the particular sector in which the cooperatives operate. Our approach makes it possible to better single out the influence of structural and institutional characteristics.

Second, we look at the impact of multiple cooperative characteristics related to its structure (size, age, and formation initiative) and institutional design (water use regulations and type of joint activities). While our set of cooperative characteristics is still limited, according to availability of information and variation in the data, it goes much beyond the focus on cooperative heterogeneity in other studies: Verhofstadt and Maertens (2014) only focus on joint activities and type of payment system; Fischer and Qaim (2012) only investigate the impact of cooperative age; Francesconi and Heerink (2011) only distinguish between two types of cooperatives (marketing vs. livelihood cooperatives and open vs. closed cooperatives); and Zhang et al. (2013) only deal with cooperative size.[1] Our paper provides a more comprehensive analysis of cooperative heterogeneity.

Third, while impact studies mostly compare cooperative members and nonmembers, our analysis only includes cooperative members. This reduces potential bias from endogeneity problems related to farmers' self-selection into a cooperative, though it does not eliminate bias from selection into a cooperative with specific characteristics, which we address using Lewbel's (2012) heteroskedasticity-based identification strategy, which is useful in the absence of good instruments for a set of potentially endogenous variables. In addition, our approach allows for a statistically more straightforward interpretation of the impact of cooperative characteristics on farmers' welfare and avoids the pitfall associated with interpreting a difference in significance level as a significant difference. For example, Fischer and Qaim (2012) find a statistically significant effect on income for old cooperatives but an insignificant effect for young cooperatives, but this does not necessarily imply that members of older cooperatives have a significantly larger income than members of younger cooperatives, because the difference between a significant and an insignificant effect may itself not be statistically significant (Gelman and Stern, 2006).

[1] Zhang et al. (2013) focus on group size, group leadership, endowment heterogeneity, interest homogeneity, and poverty level. Only group size is a cooperative-level characteristic; the others relate to farmer-level characteristics.

The focus on cooperative heterogeneity in Ethiopia is particularly relevant. Cooperatives are very widespread in the country, covering 98% of villages in the Tigray region, and the landscape is very diverse, with the remains of the pre-1991 government-controlled cooperative system and new post-1991 bottom-up collective action (Bernard, Abate, and Leman, 2013; Gezahegn et al., 2019) and donor-driven initiatives. The question in Ethiopia has, therefore, moved from whether cooperative membership improves farmers' welfare to which cooperative characteristics improve farmers' welfare most, which is what we address in this paper. Our focus on the welfare implications of IRCs is also particularly relevant given the emphasis the Ethiopian government puts on investment in small-scale irrigation as a key poverty-reduction strategy (Tilahun et al., 2011).

Background

The government of Ethiopia recognizes the importance of cooperatives for improving the socioeconomic conditions of the rural poor. Starting from 1994, the government has designed various policies to strengthen the development of cooperatives (Bernard et al., 2010). A Federal Cooperative Agency—which plays a crucial role in promoting, registration, legalization, auditing, certifying, and monitoring cooperatives (Ethiopian Ministry of Finance and Economic Development, 2006)—was established in 2002. The Ethiopian Agricultural Transformation Agency (ATA) and many non-governmental organizations (NGOs) also promote and support cooperatives (Ethiopian Agricultural Transformation Agency, 2012). Agricultural cooperatives are very important in distributing agricultural inputs, especially seeds and fertilizer, to farmers in Ethiopia and support farmers to obtain access to improved agricultural technologies, extension services, and training (Gezahegn et al., 2020). In Ethiopia, high dependence on rain-fed agriculture is a major cause of poverty and food insecurity (Bacha et al., 2011). Uncertainty about rainfall causes high risk in farming and the application of modern farm inputs in particular (Zewdie et al., 2019). Access to irrigation can induce farmers to use yield-enhancing modern technologies (Amede, 2015) and to switch crops and/or cropping systems. Several studies document a positive impact of irrigation projects on agricultural productivity and rural livelihoods (e.g., Aseyehegu, Yirga, and Rajan, 2011; Bacha et al., 2011; Dillon, 2011) and on farmers' yields and revenues (Olayide, Tetteh, and Popoola, 2016; Zewdie et al., 2019).

Small-scale irrigation (SSI) schemes, with a command area of less than 200 hectares (ha), have been developed in Ethiopia since the mid-1980s, and the government emphasizes continued investment in such irrigation projects as a key poverty-reduction strategy (Tilahun et al., 2011). Of the total 4.25 million ha of land suitable for irrigation in the country, only 5%–6% is actually irrigated (Gebregziabher, Namara, and Holden, 2012). In Tigray, the regional government embarked on a massive irrigation development program, especially after the establishment of Co-SAERT in 1995.[2] NGOs, such as REST (Relief Society of Tigray), and international organizations, such as IFAD (International Fund for Agricultural Development), have also invested in irrigation projects in Tigray (Gebregziabher, Namara, and Holden, 2009). By the end of 2003, 54 micro-dams had been constructed (Haregeweyn et al., 2006). The total irrigated land increased from 4,000 ha in 2004 to 83,000 ha in 2009 (Yohannes et al., 2017). River diversion, rainwater harvesting, dams, natural ponds and rivers, and groundwater pumping are common sources to irrigate plots.

Managing common resources, such as irrigation water, is often hindered by state and market failures. Collective action is often a more efficient and equitable way of doing so because of communities' high level of social capital (Agrawal, 2003). In Ethiopia, water users' associations (WUAs) are formed to regulate water use and administer irrigation water sustainably, equitably, and efficiently. Traditionally, farmers built small-scale schemes on their own collective initiative and managed them through their own WUAs (Ethiopian Ministry of Water Resources, 2002). WUAs can also be initiated by the government or by NGOs and be organized as top-down rather than

[2] Co-SAERT: Commission for Sustainable Agriculture and Environmental Rehabilitation of Tigray.

collective action institutions. WUAs get legal status as registered irrigation cooperatives (IRCs) with more formal management structures. The main purpose of IRCs is to manage, operate, and maintain an irrigation system within their command areas and distribute water equitably to members for agricultural purposes. They also train their members in farming and water-saving technologies and may jointly purchase (sell) farm inputs (outputs). In Tigray, about 980 IRCs serve more than 45,000 members, with a capital of over 23 million ETB (Tigray Cooperative Promotion and Market Development Agency, 2017).[3] Government- and NGO-constructed irrigation schemes, including dams and river diversions, are usually handed over to IRCs for management, operation, and maintenance. IRCs are typically led by a committee of five members, including a chairman, a vice chairman, a secretary, a treasurer, and a cashier. The organizational structure of most IRCs includes elected *Abo-mayat*, literally "water fathers," who are in charge of water administration and distribution. Farmers with plots in a given irrigation command area become members of an IRC by paying registration fees and buying at least one share and are required to abide by subsequent irrigation canal cleaning and maintenance duties.

Methods

Sampling Strategy and Data Collection

We combine data from a cooperative-level survey conducted in 2017 and a farm-household survey conducted in 2019. For the cooperative-level survey, 511 cooperatives were selected using a multistage random sampling technique. In the first stage, 12 *woredas* (districts) were randomly selected from four zones (Eastern, Central, South and Southeastern, and West and Northwestern zones), three from each zone (Figure 1). In the second stage, 223 *tabias* (the smallest administrative unit) were randomly selected in the selected district proportional to the number of cooperatives. Finally, 511 cooperatives, including 111 IRCs, were randomly sampled from the selected *tabias* proportional to the number of cooperative types. For the household survey, we selected 40 IRCs from the cooperative-level sample, 10 from each of the four zones. We first classified the 111 IRCs in 10 strata on the basis of five characteristics: (i) input purchase arrangement (joint vs. independent); (ii) output marketing arrangement (joint vs. independent); (iii) formation initiative (bottom-up vs. top-down);[4] (iv) cooperative size (small vs. large); and (v) cooperative age (young vs. old). For each zone, we randomly selected 10 IRCs, one from each stratum, in such a way that three IRCs are selected from each of the two districts in a zone and four in the district with the highest number of IRCs. Finally, we randomly selected 509 farmers from the 40 sampled IRCs proportional to the size of the cooperative.[5]

The cooperative survey was conducted between April and August 2017 and the household survey between January and March 2019. Both surveys were implemented by trained enumerators who speak Tigrigna, the local language, using a structured questionnaire and Qualtrics, a computer-assisted personal interviewing software program. Both surveys used comprehensive questionnaires, including various modules on different topics. Farmers in the sample produce cereals, legumes, fruit, and vegetables on irrigated land and sell their produce at the farm gate or at nearby town markets or use it for their own consumption. Land is mostly individually owned and cultivated by the farmers and irrigated under IRC arrangements. Depending on the cooperative arrangements on joint versus independent marketing, produce from irrigated plots is either sold jointly through the cooperative or individually by the farmers. The same holds for purchase of farm inputs. Farmers might or might not

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[3] ETB is the Ethiopian currency: 1 ETB $\approx$ 0.03 USD at the time of the survey.

[4] Formation initiative refers to whether a cooperative was initiated bottom-up by the members or top-down by the government or an NGO. Throughout the paper, we use bottom-up and self-initiated interchangeably and top-down and externally initiated interchangeably.

[5] Five of the 40 originally selected IRCs could not be accessed for the household survey. These were replaced by five other IRCs in the same district from the sample of cooperatives.

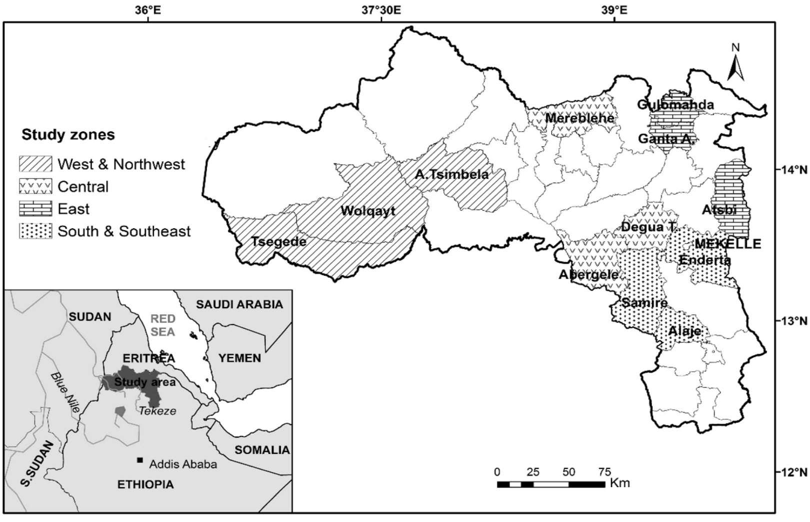

Figure 1. Location of the Study Woredas (districts) in Tigray Region, Ethiopia
Source: Authors' design.

have other plots of nonirrigated land that they cultivate and might or might not engage in livestock rearing and off-farm activities.

Model Specification

To assess the impact of cooperative structure (size, age, and formation initiative) and institutional design (water use regulations and joint activities) on household welfare (income and poverty level), we estimate the following model:

$$H_{ij} = \beta_0 + C_{Sj}^{'}\beta_1 + C_{Ij}^{'}\beta_2 + X_{ij}^{'}\beta_3 + \varepsilon_{ij},\ \varepsilon_{ij} = \alpha u_j + e_{ij}; \quad (1)$$

$$C_{Oj} = \gamma_0 + X_{ij}^{'}\gamma_1 + \omega_j,\ \omega_j = u_j + v_j. \quad (2)$$

We estimate separate models for farm income, total income, income per adult equivalent, and poverty gap as welfare outcomes H_{ij} of household i in cooperative j; C_{Oj} denotes IRC organizational characteristics, including structural characteristics C_{Sj} and institutional characteristics C_{Ij}; C_{Sj} is a vector of the size (number of members),[6] age (years since establishment), and formation initiative (bottom-up vs. top-down) of cooperative j; C_{Ij} is a vector of water use schedule (whether members use irrigation water on a turn basis or simultaneously), water division rule (whether water is allocated among members equally or based on land area), and farm input purchase and output marketing arrangements (joint vs. independent); X_{ij} is a vector of household control variables, including gender, education, age of the household head, household size, total cultivated area including the irrigated plot, livestock ownership, agricultural assets, home-market distance, and district dummies; $\alpha,\ \beta,\ \gamma$ are parameters to be estimated; u_j is cooperative-level unobserved heterogeneity; and e_{ij} and v_j are idiosyncratic errors. The effect of IRC characteristics on farmers' welfare outcomes may vary with the values of certain household control variables. For example, the effect of joint input purchases on farm income is unlikely to be additive with that of market distance. We capture this potential nonlinear effect by including interaction terms in the model.

Standard OLS estimation of equation (1) may result in endogeneity bias if the unobserved heterogeneity, u_j, is correlated with both the cooperative characteristics, C_{Oj}, and the outcome

[6] As members join the cooperative with their own individual land, membership size has a direct implication for the size of irrigated land affiliated to an IRC.

variables, H_{ij}. The most common approach to reduce endogeneity bias is an instrumental variable (IV) estimation (Angrist and Pischke, 2008), but finding good instruments is a challenge. As we have a large set of potentially endogenous variables in C_{Sj} and C_{Ij} and cannot find good instruments for all of these, we rely on another approach. We use an innovative, heteroskedasticity-based identification strategy, proposed by Lewbel (2012) for cases in which traditional instruments are weak or not available. In equation (2), we explicitly model the potentially endogenous variables, C_{Oj}, with u_j representing a vector of omitted or unobserved factors that may directly influence both H_{ij} and C_{Oj}, which underlies the correlation of errors across the two equations. For example, u_j may capture an IRC's unobserved environment, including its members' unobserved characteristics.

Besides the standard exogeneity assumptions $E[X\varepsilon] = 0$ and $E[X\omega] = 0$, and nonsingularity of $E\left(XX'\right)$, the key additional assumptions required for applying this estimator are $cov[X, \varepsilon\omega] = 0$ and $cov\left(X, \omega^2\right) \neq 0$. The model is identified using estimates of $[X - E(X)]\,\omega$ as instruments,[7] where $E(X)$ is the expected value of X. The strategy can also be combined with (one or more) external instruments to increase estimation efficiency. The only nonstandard assumption needed for identification is that the error ω should be heteroskedastic (i.e., $cov\left(X, \omega^2\right) \neq 0$) (Lewbel, 2012). In our case, there is no reason to believe that ω would be homoskedastic, because equation (2) is just the linear projection of C_{Oj} on X_{ij} and not a structural model motivated by economic theory. A number of recent studies (e.g., Le Moglie, Mencarini, and Rapallini, 2015; Mishra and Smyth, 2015; Ivanov, Santos, and Vo, 2016; Awaworyi Churchill, Valenzuela, and Sablah, 2017; Lin, Weldemicael, and Wang, 2017; Bauer, Schiller, and Schreckenberger, 2020; Awaworyi Churchill, Appau, and Farrell, 2019) apply this method as a main model or a robustness check, and they report results close to those obtained using good instruments. Other researchers (Sabia, 2007; Kelly and Markowitz, 2009; Emran and Hou, 2013; Zhao, 2015) apply this identification strategy to a variety of settings in which instruments are either weak or difficult to obtain.

For each welfare outcome, we estimate three models: (i) simple OLS and Tobit—the latter for the censored poverty gap variable; (ii) Lewbel estimation, using only the internally generated instruments $[X - \bar{X}]\,\hat{\omega}$; and (iii) Lewbel+Z, combining $[X - \bar{X}]\,\hat{\omega}$ with an external instrument Z. In the latter, we use IRC's average distance to village or district markets as an external instrument. An IRC's distance to a market may influence its characteristics C_{Oj}. But given that home-market distance is controlled for in X_{ij}, IRC-market distance likely does not influence an individual farmer's welfare outcome directly, except through its effect on the performance of the IRC. We estimate the Lewbel and Lewbel+Z models using the GMM (generalized method of moments) estimator. As the hierarchical structure of our data (members nested within IRCs) might introduce serial correlation in the residuals across members of a given IRC, we cluster over cooperatives during estimation.

Results

Descriptive Statistics

Table 1 reports descriptive statistics at the household level. Farm income—calculated as the net revenue from crop production, including nonmarketed crops valued at market prices and dividends from the IRC—averages about 21,000 ETB. Total household income—including income from crop production, livestock rearing, off-farm self-employment, wages, forest products, land rental, and remittance—averages 36,000 ETB. Income per adult equivalent—calculated based on the OECD modified adult equivalence scale (Organisation for Economic Co-operation and Development, 2012)[8]—is on average 13,000 ETB. Variability in income is large in the sample, but on average more

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[7] The estimate of $[X - E(X)]\,\omega$ is $[X - \bar{X}]\,\hat{\omega}$, where $\bar{X}$ and $\hat{\omega}$ are the sample estimates of the population parameters $E(X)$ and ω, respectively.

[8] The scale assigns a value of 1 to the household head, 0.5 to each additional adult ($\geq$ 14 years), and 0.3 to each child (<14 years).

Table 1. Descriptive Statistics of Welfare Outcomes and Household Characteristics

Variable Name	Description (unit)	Mean
Welfare outcomes		
Farm income	Value of crops produced (including non-marketed crops valued at market prices) minus variable production costs; dividends received from IRC minus contribution to IRC (1,000 ETB)	21.37 (33.89)
Total household income	Income from crop and livestock production, off-farm self-employment, wages, forest products, land rental, and remittances (1,000 ETB)	36.05 (41.95)
Income per adult equivalent	Total household income over the number of adult equivalent members in the household (1,000 ETB)	13.48 (18.64)
Poverty gap	Difference between estimated national poverty line and income per adult equivalent for households below the poverty line (1,000 ETB)	4.52 (2.50)
Human capital		
Male HH	Household head (HH) is male (yes=1)	0.93
Education of HH	Years of schooling of the household head (number)	3.69 (3.38)
Age of HH	Age of household head (years)	48.28 (12.43)
Family size	Number of members of a household (number)	6.27 (2.02)
Adult equivalent	Family size in adult equivalent (number)	3.01 (0.87)
Physical capital		
Cultivated area	Total area of land cultivated by a household (hectares)	1.07 (0.94)
Share irrigated	Ratio of irrigated area of land to total cultivated area	0.40 (0.26)
Livestock	Number of livestock owned in tropical livestock unit (TLU)	5.43 (3.52)
Value of assets	Monetary value of agricultural assets owned (1,000 ETB)	7.10 (11.20)
Location		
Market distance	Average distance of a farmer's home from village or district markets (walking minutes)	113.41 (97.35)

Notes: Numbers in parentheses are standard deviations.

than half of the household income is derived from crop production. The poverty gap is on average 4,5000 ETB and is measured as the difference between the 2018 national poverty line of 8,427 ETB and the income per adult equivalent. The former is derived from the 2015/16 national poverty line of 7,184 ETB (of Finance and Economic Development, 2017), converted to real prices using consumer price indices (Ethiopian Central Statistics Agency, 2019). Human and physical capital variables show that the sampled households are rather large (on average 6.27 members), with a low level of education (3.69 years on average) and small landholdings (1.07 ha on average). On average, 40% of the farmers' land is irrigated. Farmers live, on average, about 2 hours' walking distance from a village or district market, but variability in remoteness is large in the sample.

Table 2 reports descriptive statistics at the cooperative level. The sampled IRCs have, on average, 115 members and are 7.93 years old, but there is a lot of variation in the sample. About one-third of the IRCs are initiated through bottom-up collective action of the farmers and communities themselves; the remainder are initiated top-down through government or NGO actions. Most of the self-initiated IRCs started as traditional water users' associations and changed their legal status into a

Table 2. Cooperative Characteristics

Variable Name	Description (unit)	Mean
Structural and institutional characteristics		
Cooperative size	Number of members of the IRC (number)	115
		(124)
Cooperative age	Years since the establishment of the IRC (number)	7.93
		(6.22)
Self-initiated	Bottom-up initiated IRC (yes = 1)	0.32
Water schedule	Use of irrigation water is on turn basis (yes = 1)	0.45
Water division	Water division is based on land size in the IRC (yes = 1)	0.35
Joint purchase	IRC with joint input purchase arrangement (yes = 1)	0.45
Joint marketing	IRC with joint output marketing arrangement (yes = 1)	0.62
Location		
IRC-distance	Distance of the IRC to village or woreda markets (walking minutes)	112.30
		(85.06)
Eastern zone	IRC location in the Eastern zone (yes = 1)	0.40
Central zone	IRC location in the Central zone (yes = 1)	0.26
SSE zone	IRC location in the South & Southeastern zone (SSE) (yes = 1)	0.18
WNW zone	IRC location in the West & Northwestern zone (WNW) (yes = 1)	0.16

Notes: Numbers in parentheses are standard deviations.

cooperative. Only 45% of the IRCs regulate the use of irrigation water on a turn basis, specifying the length of time a farmer is allowed to apply irrigation water to the IRC-affiliated land; the remainder do not regulate water use at all. Additionally, 35% divide water based on the size of farmers' IRC-affiliated land, with varying water use times per farmer; 45% of the sampled IRCs jointly purchase inputs for the members—mostly fertilizer, pesticides, seeds, etc.—and 62% collectively market the output from members' IRC-affiliated land.

Econometric Results

Table 3 presents the Lewbel and Lewbel+Z estimates. We initially generated OLS and Tobit (for the censored outcome variable, poverty gap) estimates, but to save space we are only presenting the Lewbel and Lewbel+Z results. The OLS and Tobit estimates are given in the Online Supplement (available online at www.jareonline.org). Due to log-transformation and missing data for a number of variables, the sample size drops to 486 (487) for farm income (total income, income per adult equivalent, and poverty gap).[9] Statistical tests with regard to instrument relevance and validity perform well. The Kleibergen–Paap LM statistics (instrument-relevance tests) reject the null hypotheses that the instruments are not correlated with the endogenous regressors. The Hansen J statistics fail to reject the joint null hypotheses that the instruments are uncorrelated with the error term for all models, and C statistics fail to reject the null hypotheses that the external instrument Z is exogenous. Moreover, Breusch–Pagan tests for heteroskedasticity of the error terms in the first-stage regressions (not reported) are significant, meeting the requirement to apply the Lewbel identification

[9] Some values for farm income, total income, and income per adult equivalent are negative so that log-transformation leads to missing values. We drop from poverty gap (not log-transformed) observations with missing values for total income in order to use the same sample size.

Table 3. Lewbel and Lewbel+Z Estimates: farm income, total income, income pae, and poverty gap

	Ln Farm income		Ln Total income		Ln Income pae		Poverty gap (1,000 ETB)	
Variables	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**
Structural and institutional characteristics								
Cooperative size	0.133**	0.120**	0.099**	0.100**	0.098**	0.099**	−0.506***	−0.503***
	(0.054)	(0.053)	(0.047)	(0.047)	(0.047)	(0.047)	(0.135)	(0.135)
Cooperative age	−0.044***	−0.040***	−0.038***	−0.037***	−0.039***	−0.038***	0.079***	0.070***
	(0.011)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.024)	(0.023)
Self-initiated	0.254***	0.230**	0.250***	0.248***	0.275***	0.273***	−0.650***	−0.603***
	(0.098)	(0.096)	(0.084)	(0.084)	(0.083)	(0.083)	(0.230)	(0.228)
Water schedule	0.263**	0.189	0.227*	0.182*	0.213*	0.169	−0.567*	−0.354
	(0.128)	(0.116)	(0.124)	(0.106)	(0.123)	(0.106)	(0.333)	(0.288)
Water division	0.051	0.022	0.094	0.089	0.086	0.080	−0.509*	−0.514*
	(0.117)	(0.114)	(0.101)	(0.100)	(0.100)	(0.100)	(0.294)	(0.292)
Joint purchase	0.368**	0.388***	0.352***	0.365***	0.346***	0.360***	−0.859***	−0.891***
	(0.144)	(0.143)	(0.115)	(0.113)	(0.114)	(0.112)	(0.327)	(0.325)
Joint marketing	−0.262*	−0.298**	−0.197*	−0.208*	−0.204*	−0.216*	0.582*	0.633**
	(0.144)	(0.141)	(0.115)	(0.114)	(0.115)	(0.113)	(0.322)	(0.312)
Human capital								
Male HH	0.351**	0.327**	0.290**	0.272**	0.248*	0.228*	−0.287	−0.307
	(0.139)	(0.138)	(0.133)	(0.129)	(0.128)	(0.124)	(0.397)	(0.394)
Education of HH	0.045***	0.047***	0.044***	0.043***	0.045***	0.044***	−0.074**	−0.067**
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.030)	(0.029)
Age of HH	0.002	0.003	−0.003	−0.004	−0.007**	−0.007**	0.019**	0.021**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.008)	(0.008)
Family size	−0.078***	−0.075***	−0.048**	−0.048**	−0.183***	−0.182***	0.362***	0.364***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.045)	(0.045)
Physical capital								
Cultivated area	0.233***	0.246***	0.147***	0.151***	0.143***	0.148***	−0.207**	−0.212**
	(0.058)	(0.057)	(0.046)	(0.045)	(0.045)	(0.044)	(0.094)	(0.095)
Share irrigated	0.522***	0.508***	0.422***	0.416***	0.454***	0.448***	−0.544	−0.545
	(0.159)	(0.159)	(0.151)	(0.151)	(0.150)	(0.150)	(0.380)	(0.377)
Livestock	0.075***	0.073***	0.102***	0.101***	0.101***	0.100***	−0.237***	−0.236***
	(0.013)	(0.013)	(0.011)	(0.011)	(0.011)	(0.011)	(0.028)	(0.028)
Ln Value-assets	0.145***	0.144***	0.138***	0.136***	0.136***	0.134***	−0.460***	−0.459***
	(0.025)	(0.025)	(0.020)	(0.020)	(0.020)	(0.020)	(0.053)	(0.053)
Location								
Ln Market distance	−0.175**	−0.135*	−0.264***	−0.246***	−0.257***	−0.241***	0.842***	0.762***
	(0.078)	(0.071)	(0.069)	(0.064)	(0.068)	(0.063)	(0.178)	(0.164)
Eastern zone	−0.504***	−0.538***	−0.096	−0.098	−0.116	−0.117	0.439	0.502
	(0.146)	(0.143)	(0.129)	(0.129)	(0.129)	(0.129)	(0.339)	(0.333)
Central zone	−0.295***	−0.300***	−0.006	−0.006	−0.018	−0.017	0.047	0.081
	(0.109)	(0.108)	(0.102)	(0.102)	(0.102)	(0.102)	(0.292)	(0.288)
SSE zone	0.392***	0.406***	0.451***	0.460***	0.432***	0.442***	−0.863***	−0.848***
	(0.126)	(0.126)	(0.120)	(0.120)	(0.121)	(0.120)	(0.297)	(0.295)
Constant	7.234***	7.284***	7.832***	7.901***	7.795***	7.866***	5.453***	5.178***
	(0.316)	(0.315)	(0.296)	(0.275)	(0.298)	(0.279)	(0.800)	(0.775)

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Table 3. – continued from previous page

	Ln Farm income		Ln Total income		Ln Income pae		Poverty gap (1,000 ETB)	
Variables	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**
No. of obs.	486	486	487	487	487	487	487	487
Instrument relevance test (*p*-value)	0.050	0.052	0.049	0.044	0.049	0.044	0.056	0.033
Instrument validity test (*p*-value)	0.615	0.600	0.446	0.469	0.443	0.461	0.682	0.700
Exogeneity of external IV (*p*-value)	–	0.220	–	0.564	–	0.503	–	0.601

Notes: Robust standard errors in parentheses. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. Estimates are based on Lewbel (2012) using Stata's ivreg2h command. Cooperative size is measured in 100 members.

strategy. In general, our estimates are robust across the different models. The signs of the estimates of all models are consistent per outcome variable. The Lewbel and Lewbel+Z estimates are very similar to each other in sign and magnitude. There is some variation in magnitude and significance level between the OLS and Tobit estimates (see Tables S1 and S2 in the Online Supplement) on the one hand and the Lewbel and Lewbel+Z estimates on the other, which may be attributed to the potential endogeneity bias in the former.

Findings show that the organizational heterogeneity of the IRCs contributes substantially to explaining the differences in household welfare. We find a positive welfare effect of cooperative size: An increase of 100 members in IRC size increases farm income by 12%–13%, total household income and per adult equivalent income by about 10% and decreases the poverty gap by 500 ETB.[10] We find a negative effect of cooperative age: A 1-year increase in the age of an IRC is associated with a decrease of about 3%–4% in farm income, total household income, and income per adult equivalent and an increase in the poverty gap of 70–163 ETB. Members of self-initiated IRCs have farm, total, and per adult equivalent incomes that are 23%–28% higher, with a 603–1645 ETB lower poverty gap than members of the government- or NGO-initiated IRCs. Further, we find that members of IRCs with a water schedule have about 20% higher farm, total, and per adult equivalent incomes and a lower poverty gap (with significance levels varying somewhat across the models); members of IRCs with area-based water division practices have a poverty gap that is about 500 ETB lower. We find a positive effect of joint purchase on farm, total, and per adult equivalent incomes and a negative effect on poverty gap; the effects are reversed for joint marketing. Members of joint-purchase IRCs have incomes that are about 35% higher and a poverty gap that is 859–891 ETB lower, while members of joint-marketing IRCs have incomes that are about 20% lower and a poverty gap that is 582–633 ETB higher.

The estimated coefficients of the control variables are largely consistent with expectations. We find significantly higher farm, total, and per adult equivalent incomes and a lower poverty gap among smaller households with a better educated household head and more land, livestock, and other productive assets. Male-headed households have a significantly higher income, and households with older household head have a lower per adult equivalent income and a higher poverty gap. A higher share of irrigated land increases farm, total, and per adult equivalent incomes but has no significant effect on the poverty gap. The result that the farm and total household incomes decrease with household size relates to a higher dependency ratio in larger households (correlation coefficient = 0.56), leading to a lower availability of labor on the farm due, perhaps, to an increased need to take care of the dependents. Additionally, location influences income and poverty, with households

[10] Cooperative size is measured in 100 members in the regressions.

closer to the market and in the South and Southeastern zone having higher farm, total, and per adult equivalent incomes and a lower poverty gap. Farmers in the Eastern and Central zones have a lower farm income, but this does not translate into a lower total or per adult equivalent income or a higher poverty gap. Differences across zones might relate to land quality, which is generally better in the western and southern parts of the region.

Table 4 summarizes the results from models with interaction terms of joint purchase, joint marketing, and formation initiative with market distance and land size. We find that the positive welfare effect of being a member of a self-initiated IRC significantly decreases with farmers' distance to the market and significantly increases with their cultivated area. The heterogeneity in effects is rather large, with a 1% increase in the market distance resulting in a 33%–41% reduction of the positive income effect, and a 1 ha increase in land size in a 11%–18% increase of the positive income effect. The positive income effect of joint purchase reduces with farmers' land size but does not significantly change with market distance. The poverty-reducing effect of joint purchase is stronger for smaller farms and farmers farther from the market. The negative effect of joint marketing on income does not change much with market distance; at a large distance, joint marketing lowers the poverty gap. The adverse welfare effects of joint marketing intensify with farmers' land size.

Discussion

Our results show that structural and institutional characteristics of IRCs in northern Ethiopia affect farmers' welfare substantially. We find that membership in larger, younger, and self-initiated cooperatives results in significantly higher incomes for farmers. First, the positive effect of cooperative size likely relates to economies of scale and is in line with findings from cooperative-level studies reporting a lower cost of service delivery in larger cooperatives (e.g., Gezahegn et al., 2019). Our results contradict the finding of Zhang et al. (2013), who report a negative effect of group size on members' water productivity in irrigation cooperatives in China and relate this to an intensified free-riding problem in larger cooperatives, which may be alleviated by reducing group size (Giannakas, Fulton, and Sesmero, 2016). The average cooperative size in Zhang et al. is more than double the average size in our sample, which could partially explain the differences in findings and could imply that an optimal cooperative size exists.

Second, the negative effect of cooperative age contradicts the finding of Fischer and Qaim (2012), who find a positive welfare effect of cooperative membership only for older cooperatives. A difference in age of the sampled cooperatives, 7.93 years in our study versus 3 years in Fischer and Qaim on average, may again explain differences in findings. The negative effect of cooperative age can relate to a declining goal congruence and more heterogeneous interests among new and elder members of older cooperatives—as Hind (1999) argues. In addition, aging irrigation infrastructure and declining external support from the government or NGOs, as older cooperatives are supposed to be more self-reliant, could explain the effect.

Third, we find a positive welfare effect of self-initiation, which is consistent with the argument that bottom-up and collective action organizations are more effective in creating benefits for their members (Deininger, 1995) due to better social norms and values, such as reciprocity, trust, and fairness (Vandersypen et al., 2008) and historical community relationships (Burney and Naylor, 2012). The affiliation and commitment of members in top-down cooperatives might be lower and only endure as long as external benefits exist. Our result is in line with Pritchard (2013), who reports top-down cooperatives in Rwanda to be problematic, and with Gezahegn et al. (2020), who report higher technical efficiency among bottom-up cooperatives in Ethiopia. We find that membership in self-initiated IRCs benefits farmers closer to the market and larger farms more. This may relate to less government and NGO support for more remote self-initiated cooperatives, which can result in lower access to inputs and services for cooperative members. The higher benefit of self-initiated IRCs for larger farmers may point to possible reinforcing effects between scale economies and a higher goal congruence among their members.

Table 4. Heterogeneous Effect of Institutional Characteristics on Welfare Outcomes by Market Distance and Area Cultivated

	Ln Farm income		Ln Total income		Ln Income pae		Poverty gap (1,000 ETB)	
Variables	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**	**Lewbel**	**Lewbel+Z**
SIN	0.097	0.086	0.197***	0.187**	0.218***	0.209***	−0.591***	−0.572***
(self-initiated)	(0.091)	(0.089)	(0.074)	(0.073)	(0.074)	(0.074)	(0.198)	(0.198)
Ln Market	−0.051	−0.040	−0.064	−0.052	−0.071	−0.061	0.581***	0.550***
distance	(0.078)	(0.078)	(0.072)	(0.070)	(0.072)	(0.070)	(0.171)	(0.168)
SIN × Ln Market	−0.347***	−0.340***	−0.414***	−0.410***	−0.399***	−0.396***	0.301	0.280
distance	(0.087)	(0.088)	(0.080)	(0.079)	(0.079)	(0.078)	(0.229)	(0.223)
SIN	0.174*	0.159*	0.167**	0.167**	0.194***	0.195***	−0.620***	−0.607***
(self-initiated)	(0.090)	(0.089)	(0.075)	(0.075)	(0.075)	(0.075)	(0.201)	(0.200)
Cultivated area	0.185***	0.192***	0.115**	0.118**	0.117**	0.119***	−0.135	−0.134
	(0.066)	(0.066)	(0.047)	(0.046)	(0.046)	(0.045)	(0.097)	(0.098)
SIN × Cultivated	0.181**	0.184**	0.115*	0.114*	0.105*	0.105*	−0.042	−0.047
area	(0.086)	(0.086)	(0.063)	(0.063)	(0.063)	(0.063)	(0.168)	(0.167)
JP (Joint	0.249*	0.252*	0.276***	0.276***	0.271***	0.273***	−0.693**	−0.709**
purchase)	(0.132)	(0.130)	(0.105)	(0.103)	(0.104)	(0.102)	(0.308)	(0.307)
Ln Market	−0.177**	−0.177**	−0.189**	−0.192**	−0.186**	−0.189**	1.045***	0.973***
distance	(0.082)	(0.081)	(0.089)	(0.085)	(0.089)	(0.086)	(0.235)	(0.224)
JP × Ln Market	0.185	0.186	−0.038	−0.040	−0.034	−0.036	−0.570**	−0.537**
distance	(0.113)	(0.113)	(0.092)	(0.091)	(0.092)	(0.091)	(0.265)	(0.263)
JP (Joint	0.372***	0.384***	0.323***	0.335***	0.324***	0.338***	−0.655**	−0.689**
purchase)	(0.142)	(0.141)	(0.100)	(0.098)	(0.100)	(0.098)	(0.293)	(0.290)
Cultivated area	0.426***	0.435***	0.298***	0.301***	0.305***	0.308***	−0.796***	−0.783***
	(0.077)	(0.076)	(0.061)	(0.061)	(0.061)	(0.060)	(0.172)	(0.169)
JP × Cultivated	−0.251***	−0.251***	−0.221***	−0.222***	−0.228***	−0.230***	0.781***	0.763***
area	(0.078)	(0.078)	(0.061)	(0.061)	(0.059)	(0.059)	(0.177)	(0.175)
JM (Joint	−0.192	−0.190	−0.193*	−0.195*	−0.203*	−0.205*	0.410	0.441
marketing)	(0.136)	(0.136)	(0.111)	(0.111)	(0.110)	(0.110)	(0.306)	(0.302)
Ln Market	−0.16	−0.163*	−0.174*	−0.167*	−0.172*	−0.169*	0.908***	0.870***
distance	(0.097)	(0.097)	(0.101)	(0.101)	(0.101)	(0.101)	(0.240)	(0.233)
JM × Ln Market	0.194*	0.202*	−0.059	−0.042	−0.055	−0.037	−0.481*	−0.472*
distance	(0.115)	(0.114)	(0.108)	(0.107)	(0.109)	(0.107)	(0.253)	(0.253)
JM (Joint	−0.373***	−0.392***	−0.310***	−0.321***	−0.309***	−0.319***	0.694**	0.747***
marketing)	(0.126)	(0.124)	(0.103)	(0.101)	(0.102)	(0.101)	(0.289)	(0.281)
Cultivated area	0.489***	0.501***	0.396***	0.397***	0.399***	0.399***	−0.933***	−0.945***
	(0.081)	(0.080)	(0.074)	(0.074)	(0.074)	(0.074)	(0.190)	(0.191)
JM × Cultivated	−0.310***	−0.310***	−0.315***	−0.314***	−0.320***	−0.317***	0.890***	0.902***
area	(0.081)	(0.081)	(0.074)	(0.074)	(0.074)	(0.074)	(0.183)	(0.183)

Notes: Home-market distance and cultivated area are mean-centered in order to reduce multicollinearity and improve the interpretability of regression coefficients as it is not meaningful to consider an observation with a 0 value for these variables. Single, double, and triple aserisks indicate significance at the 10%, 5%, and 1% level, respectively.

We find that stricter water use regulation in IRCs contributes to farmers' welfare, as it may prevent a free-rider problem and result in a fairer and more efficient distribution of the irrigation water. Water allocation arrangements play a role in coping with the risk of water shortage (Juárez-Torres, Sánchez-Aragón, and Vedenov, 2017). For example, a water use schedule may avoid destructive competition and conflicts over water use (Dessalegn and Merrey, 2014). Water use regulations may also ration water consumption toward socially optimal levels and address scarcity (Ifft, Bigelow, and Savage, 2018). Given that there are no irrigation water prices to induce optimal water use in the study area, the poverty-reducing effect of area-based water allocation may incentivize rational farmers to stick to such a regulation, thereby playing a role in alleviating resource abuse. Moreover, a fair allocation of available water resources has been shown to be linked to the long-term stability of cooperative ventures (Aadland and Kolpin, 2011). Water use schedules may be particularly beneficial to female household heads who are labor-constrained due, mainly, to a double responsibility—domestic and farm, as they cannot show up on the farm as early as their male counterparts to compete for the scarce irrigation water in the absence of a water schedule. In Tigray, Yohannes et al. (2017) report a case in which a female household head had to offer her land to sharecroppers because she could not get water at the "right" time as a member of her water users' association, which had a first-come-first-served policy. We also find that joint input purchasing arrangements in the IRCs positively affect farmers' welfare while joint output marketing arrangements have an overall adverse effect. Both buying inputs and selling outputs collectively are expected to reduce transaction costs and increase farmers' bargaining power vis-à-vis suppliers and buyers (Verhofstadt and Maertens, 2014). The estimated effects of joint purchase, including the heterogeneous effects that its welfare-enhancing effect decreases with farm size and increases to some extent with market distance, are in line with this transaction cost argument. Joint input purchase improves the welfare of larger farmers less because these farmers already have more bargaining power than smaller farmers in individual market transactions. Joint input purchase is more poverty reducing in more remote areas because reducing transaction costs is more important in such areas.

The adverse welfare effect of joint marketing implies that collective selling does not necessarily result in better prices for farmers. This result is not in line with the transaction cost argument and might be very specific to the study area. Members of joint-marketing IRCs mainly produce fruit and fresh vegetables and sell larger volumes, attracting itinerant traders to the farm gate during the harvest season. As the lack of village-level market connectivity in the area may result in harvest-time price slumps (Burney and Naylor, 2012), farmers who sell their produce independently may be better off because they are more likely to sell at nearby markets and/or use their harvest for home consumption, since their small output quantities may not attract farm-gate buyers during the harvest season. While joint marketing may result in lower transaction costs, selling at the farm gate during the peak season is less remunerative (Fafchamps and Hill, 2005). The negative effect of joint marketing is stronger for larger farms, implying that selling collectively at the farm gate penalizes larger farms more strongly, as they could attract higher prices and have lower transaction costs (Sigei, Bett, and Kibet, 2014) when selling independently in nearby markets. In very remote areas, however, we find a poverty-reducing effect of joint marketing, which could relate to larger transaction cost reductions in these areas. There is a parallel between our finding and that of Francesconi and Heerink (2011) who show a 10%–14% lower degree of commercialization for members of livelihood (as opposed to market-oriented) cooperatives compared to independent farmers in Ethiopia. One might wonder why farmers engage in a detrimental joint marketing arrangement. An important insight from Leathers (2006) may explain this apparent contradiction:[11] while joint marketing arrangement is unfavorable, farmers may find it a better option as it may be difficult for them to find buyers unilaterally.

[11] Leathers (2006) argues that farmers may join a marketing cooperative even though their transaction costs would be lower without the cooperative since it becomes more difficult for nonmembers to find buyers.

Conclusion

In this article, we analyze the impact of organizational heterogeneity among irrigation cooperatives on the income and poverty of smallholder farmers using a combination of household- and cooperative-level survey data and an innovative, heteroskedasticity-based identification strategy in northern Ethiopia. We find that farmers benefit most from membership in larger, younger, and self-initiated irrigation cooperatives established through bottom-up collective action rather than those initiated by government or donor actions. Stricter water use regulations in irrigation cooperatives and collective input purchasing among cooperative members have income-enhancing and poverty-reducing effects for farmers—joint input purchase is especially beneficial for smaller and farther farmers. Yet the collective marketing—usually at the farm gate—of mainly horticultural products from irrigated fields through the irrigation cooperatives is not beneficial for farmers, particularly for larger farms and farmers located closer to markets.

Our findings have implications for cooperative management and irrigation development in Ethiopia. Small-scale irrigation schemes might be more successful if supported through bottom-up cooperatives that are initiated within communities by farmers themselves. In this sense, our findings support the current policy of transforming existing bottom-up water users' associations into cooperatives but do not support the policy of heavy government and donor interference in the formation, management, and operation of cooperatives. The Ethiopian government puts a lot of emphasis on the role of cooperatives in irrigation expansion, rural development, and poverty reduction. Yet, too-heavy top-down involvement in cooperative formation might be counterproductive, as it is often claimed to discourage member involvement (Dunn, 1988; Gezahegn et al., 2020). However, top-down cooperative formation can potentially be a solution in settings where social capital is too low to allow for the grassroots emergence of cooperatives (Kurakin and Visser, 2017) and when the formation of IRCs is bound to fail because of farmers' inability to bear the initial transaction costs (Patibandla and Tripathy, 2004).

In addition, policies that favor larger and younger IRCs could be beneficial for upward income mobility and poverty reduction in Tigray. The formation of new, smaller cooperatives through splitting up existing larger cooperatives—a common practice in Tigray (Gezahegn et al., 2019)—might be less conducive. Our results also imply that IRCs can benefit from applying rather strict water-access regulations to avoid free-riding problems that cause inefficient water use. However, IRCs, as they stand, should be careful in expanding their activities and services beyond maintenance of irrigation infrastructure and water use regulations, as not all collective activities are beneficial for farmers. Finally, our results document that cooperative heterogeneity is important and support a call for considering organizational heterogeneity in cooperative impact studies. A fruitful area of future research would be to shift focus from whether cooperative membership improves farmers' welfare to whether organizational characteristics matter for farmers' welfare.

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Online Supplement: Structural and Institutional Heterogeneity among Agricultural Cooperatives in Ethiopia: Does It Matter for Farmers' Welfare?

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Table S1. OLS and Tobit Estimates: farm income, total income, income pae, and poverty gap

Explanatory Variables	Ln Farm income	Ln Total income	Ln Income pae	Poverty gap (1,000 ETB)
Structural and institutional characteristics				
Cooperative size	0.048	0.054	0.053	−0.343
	(0.064)	(0.059)	(0.059)	(0.247)
Cooperative age	−0.016	−0.031***	−0.031***	0.163***
	(0.013)	(0.011)	(0.012)	(0.047)
Self-initiated	0.098	0.267**	0.281**	−1.645***
	(0.129)	(0.116)	(0.116)	(0.556)
Water use	−0.099	0.012	0.002	−0.447
	(0.173)	(0.152)	(0.152)	(0.631)
Water division	−0.116	−0.073	−0.072	−0.146
	(0.141)	(0.125)	(0.125)	(0.525)
Joint purchase	0.240	0.337***	0.340***	−1.010
	(0.159)	(0.130)	(0.130)	(0.645)
Joint marketing	−0.179	−0.276**	−0.290**	1.341*
	(0.170)	(0.139)	(0.139)	(0.723)
Human capital				
Male household head (HH)	0.353	0.357	0.320	−0.540
	(0.223)	(0.237)	(0.239)	(0.835)
Education of HH	0.038**	0.043***	0.044***	−0.106
	(0.018)	(0.015)	(0.015)	(0.068)
Age of HH	−0.003	−0.006	−0.009*	0.048**
	(0.005)	(0.005)	(0.005)	(0.020)
Family size	−0.077***	−0.055**	−0.190***	0.709***
	(0.029)	(0.026)	(0.026)	(0.112)
Physical capital				
Cultivated area	0.230**	0.134*	0.136**	−0.543*
	(0.113)	(0.070)	(0.067)	(0.327)
Share-irrigated	0.349	0.431*	0.466**	−1.103
	(0.272)	(0.225)	(0.225)	(0.912)
Livestock	0.063***	0.090***	0.088***	−0.560***
	(0.019)	(0.014)	(0.014)	(0.089)
Ln Value-assets	0.098***	0.119***	0.118***	−0.699***
	(0.037)	(0.031)	(0.031)	(0.141)
Location				
Ln Market distance	0.026	−0.146	−0.143	0.877*
	(0.111)	(0.101)	(0.102)	(0.454)
Eastern zone	−0.529***	−0.256	−0.276	0.970
	(0.201)	(0.193)	(0.194)	(0.841)
Central zone	−0.426**	−0.184	−0.189	0.167
	(0.168)	(0.150)	(0.152)	(0.676)
SSE zone	0.338*	0.307*	0.287	−1.720**
	(0.180)	(0.182)	(0.183)	(0.768)
Constant	8.179***	8.364***	8.326***	4.837***
	(0.477)	(0.448)	(0.452)	(1.789)
No. of obs.	486	487	487	487

Table S2. Heterogeneous Effect of Institutional Characteristics on Welfare Outcomes by Market Distance and Area Cultivated

Variables	Ln Farm income	Ln Total income	Ln Income pae	Poverty gap (1000 ETB)
SIN (Self-initiated)	0.088	0.257**	0.271**	−1.712***
	(0.129)	(0.117)	(0.117)	(0.531)
Ln Market distance	0.118	−0.052	−0.050	0.587
	(0.124)	(0.121)	(0.123)	(0.469)
SIN × Ln Market distance	−0.332**	−0.342**	−0.334**	1.055
	(0.154)	(0.140)	(0.140)	(0.747)
SIN (Self-initiated)	0.071	0.251**	0.265**	−1.827***
	(0.131)	(0.118)	(0.119)	(0.529)
Cultivated area	0.176	0.101	0.104	−0.354
	(0.112)	(0.069)	(0.067)	(0.244)
SIN × Cultivated area	0.201	0.124	0.119	−1.853***
	(0.134)	(0.099)	(0.097)	(0.697)
JP (Joint purchase)	0.238	0.336***	0.339***	−1.001
	(0.159)	(0.130)	(0.130)	(0.644)
Ln Market distance	−0.117	−0.160	−0.159	1.067*
	(0.144)	(0.149)	(0.150)	(0.595)
JP × Ln Market distance	0.270	0.026	0.031	−0.380
	(0.170)	(0.161)	(0.161)	(0.750)
JP (Joint purchase)	0.214	0.315**	0.317**	−0.928
	(0.160)	(0.131)	(0.131)	(0.656)
Cultivated area	0.482***	0.357***	0.363***	−1.285**
	(0.127)	(0.106)	(0.106)	(0.497)
JP × Cultivated area	−0.314**	−0.277***	−0.283***	0.962*
	(0.146)	(0.106)	(0.106)	(0.524)
JM (Joint marketing)	−0.134	−0.267*	−0.280*	1.222*
	(0.176)	(0.145)	(0.145)	(0.734)
Ln Market distance	−0.086	−0.168	−0.166	1.288**
	(0.152)	(0.162)	(0.163)	(0.629)
JM × Ln Market distance	0.189	0.038	0.040	−0.746
	(0.167)	(0.166)	(0.166)	(0.716)
JM (Joint marketing)	−0.189	−0.287**	−0.301**	1.378*
	(0.169)	(0.137)	(0.137)	(0.716)
Cultivated area	0.476***	0.413***	0.418***	−1.402**
	(0.158)	(0.130)	(0.131)	(0.566)
JM × Cultivated area	−0.291	−0.330**	−0.333**	1.038*
	(0.179)	(0.133)	(0.134)	(0.606)

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