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Gender differences in smallholders' socioeconomic networks and acquisition of seed of improved wheat varieties in Ethiopia

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Enhancing farmers' access to improved seeds is essential to increase productivity and ensure food security in the Global South. However, for many socially marginalized groups, seed access is constrained by the weak institutions governing the input supply chains and the dissemination of information. Using cross-sectional survey data collected from 1,088 farming households in three major wheat-growing regional states of Ethiopia in 2021, this paper assesses empirically how participation in different socioeconomic institutions by men and women farmers shapes their access to and acquisition of seed of improved wheat varieties. The results show that the seed market in the study area is largely informal, where the recycling of wheat seeds from the previous season is a common practice among both male- and female-headed households. However, a significant difference exists between male- and female-headed households regarding patterns of varietal use, with male farmers growing newer wheat varieties more frequently. Men are also more active than women in local social and economic institutions, and their participation is positively associated with the adoption of new wheat varieties. Thus, strengthening the local social and economic institutions and supporting equitable participation of both male- and female-headed households in these institutions could facilitate the diffusion of quality seeds of improved and recently released wheat varieties in countries where the informal seed system plays a major role in seed acquisition.

KEYWORDS

gender, socioeconomic institutions, seed acquisition, wheat, Ethiopia

1. Introduction

Research and innovations in developing improved crop varieties have contributed to the enhancement of agricultural production and better food and nutritional security for smallholder farmers in the developing world (Evenson and Gollin, 2003; Shiferaw et al., 2014; Arouna et al., 2017). Although research has generated several crop varieties adapted to a wide range of biotic and abiotic stresses related to climate change, their adoption by smallholder farmers is still minimal (Evenson and Gollin, 2003; Walker et al., 2015; Acevedo et al., 2020). The adoption of improved agricultural technologies, particularly improved crop varieties, is associated with various socioeconomic factors that affect smallholder farmers' decisions concerning varietal use (Fisher and Carr, 2015). Smallholder farmers are heterogeneous in several aspects, including their resource endowments, skills, knowledge, experience, market participation, access to financial and extension services, and influence in decision making, as well as the socioeconomic groups they belong to and the networks in which they participate (Barrett, 2010; Marenya et al., 2017). Such heterogeneity affects farmers' perception and their capacity to adopt and use improved agricultural technologies (Fisher and Carr, 2015; Ward et al., 2016).

In the context of smallholder agriculture in Ethiopia, male- and female-headed households differ in many aspects. These include access to productive resources (Gebre et al., 2021) and extension services (Ragasa et al., 2012; Buchy and Basaznew, 2017), participations in input and output markets (Holden and Bezabih, 2008; Marenya et al., 2017), agricultural research activities (Annet et al., 2019), and social and economic organizations (Tsige et al., 2020), as well as overall farmland productivity (Aguilar et al., 2014; Gebre et al., 2019). Literature shows that some of these differences directly affect the adoption of improved agricultural technologies (Alene et al., 2000). However, there is a dearth of information on how difference in participation in social and economic institutions between male- and female-headed household are associated with the uptake of improved agricultural technologies, and particularly seed of improved wheat varieties in countries dominated by informal seed systems. Thus, exploring the linkages between participation in socioeconomic networks and varietal uptake of female-headed households is important to generate lessons for further efforts in empowering women farmers to build their socioeconomic networks and supporting them to benefit from the associated information flow and knowledge sharing through these networks.

Clustering the underlying survey data into male- and female-headed households, this paper explains how the acquisition of improved wheat seed is affected by household and farm characteristics and the diversity of the socioeconomic networks in which wheat-producing smallholder farmers in Ethiopia participate. In the context of a strong presence of informal seed sources and limited outreach of the public extension system, we hypothesize that increasing male and female farmers' participation in socioeconomic networks enhances farmers' access to information on modern wheat varieties and increases the likelihood of their adoption (Boahene et al., 1999; Shiferaw et al., 2014; Thuo et al., 2014). Some of the local socioeconomic networks could enhance farmers' awareness on the potential benefits and availability of improved agricultural technologies whereas others could support farmers' access to these technologies through making them readily available and facilitating the transaction. Whether the intensity of participation in these socioeconomic networks could improve technology uptake of male- and female-headed households is subject to empirical testing. Moreover, understanding the links between engagement in socioeconomic networks, information flow, and uptake of agricultural technologies will help facilitate efficient seed-information systems and design different seed-delivery pathways to reach male and female farmers through better-functioning socioeconomic networks.

The paper is organized as follows: Section 2 reviews existing literature and gives a context to the analysis. Section 3 presents the empirical approaches followed in addressing the research question; Section 4 describes the survey data used for the analysis; Section 5 gives the results of the descriptive and empirical analysis; and Section 6 concludes the paper.

2. Literature review

Missing and imperfect markets in the developing world affect smallholder farmers' adoption of improved agricultural technologies (Ogada et al., 2014; Shiferaw et al., 2015). When markets fail or transaction costs are high due to market imperfections, smallholder farmers tend to use their existing socioeconomic networks to access information and agricultural inputs required to enhance their agricultural productivity and associated livelihoods (De Janvry et al., 1991; Renkow et al., 2004; Teklewold et al., 2013). However, smallholder farmers are heterogeneous in their resource endowment and social capital. Gender is one of the elements where this diversity emanates and creates unbalanced benefits from the dissemination of improved agricultural technologies (Doss, 2001; Ndiritu et al., 2014).

Literature suggests that access to productive resources such as land, agricultural extension services, inputs, and agricultural information (including information networks) is gendered and generally discriminatory against women (Doss and Morris, 2001; Quisumbing and Pandolfelli, 2010; Fisher and Carr, 2015; Lamontagne-Godwin et al., 2019; Ankrah et al., 2020). To address the differences in access to information and extension services, Lamontagne-Godwin et al. (2019) call

for acknowledgment of the importance of gender inequalities in access to agricultural information and suggest targeted initiatives centered around (lead) female farmers. Atsbeha and Gebre (2021) illustrate that household size, women's age, landholding, information on the specific innovation, number of visits from extension agents, and access to training are among the major factors that influence women's access to agricultural extension services. The social networks that men and women farmers associate with are important avenues for access to information, resources, and socioeconomic safety nets. Some studies show that social networks are more important than extension services in technology adoption (Ramirez, 2013; Ward and Pede, 2014), while others show how extension services supported by social networks increase the efficiency of farmers' adoption of agricultural technology (Wang et al., 2020).

Men and women farmers rely on different social networks to get information related to the availability and accessibility of improved agricultural technologies and practices, including improved crop varieties. They also engage in diverse economic networks that could affect their capacity to access improved technologies in their vicinity. Not all networks are equally important in facilitating the flow of information and enabling women farmers to access improved technologies. Some networks accommodate both men and women, whereas some are restricted either to men or to women. Though most social networks would serve as a forum for information exchange, there could be differences among social networks regarding their relevance for farmers in getting information related to improved agricultural technologies and practices. For instance, Bandiera and Rasul (2006) found that family ties and friendships were more important than religious networks in the uptake of agricultural technologies in Mozambique. In addition to type, the size of the social network in which farmers are involved in could also play an important role in facilitating the wider dissemination of information and the adoption of improved agricultural technologies and practices (Wossen et al., 2013). Other studies show mixed results concerning the role of social network factors on information acquisition and technology adoption (Thuo et al., 2014).

Socioeconomic networks are important for the uptake of improved crop varieties, particularly in areas where seed systems are less developed and for crops like wheat where farmers could use recycled seed from the previous production without much loss of genetic potential (Alemu and Bishaw, 2015). When there are limited commercial wheat seed production and marketing systems in place, farmers use informal seed sources like buying from relatives, friends, neighbors, etc. (Bishaw et al., 2010). The choice among different seed sources depends on several factors, among which are the availability of the desired variety at alternative seed suppliers, the bundle of services that seed suppliers provide to farmers in making improved seeds accessible to different farmer groups, the quality of seed supplied by the different sources, the promotion and marketing services provided, the affordability of seed prices at different sources, and the farm and household characteristics that affect a farmer's attitude toward risk and uncertainty. Choices of varieties and seed access channels may also be influenced by information from farmers' social and economic networks. Differences in the social and cultural settings of male and female farmers may affect their relative exposure to and control over information (Tatlonghari et al., 2012; Gupta et al., 2020). Depending on the social and economic networks in which male and female household heads are involved, decisions concerning the adoption of crop varieties and the acquisition of seed could also differ for the two household types (Abebaw and Haile, 2013).

3. Empirical approach

Farmers adopt improved agricultural technology when the expected benefit from adoption is better than without adoption (Gebru et al., 2021). The expected benefits from technology adoption could be increased yield of crops and/or livestock, reduced production costs, reduced risks, saving land, and/or labor resources, improved productivity of natural resources such as land and water, etc. Realizing these benefits through technology adoption is partly affected by the availability and accessibility of targeted technologies in the rural settings of the developing world (Shiferaw et al., 2008). In this regard, farmers' participation in local socioeconomic institutions could play a crucial role in supporting and facilitating smallholder farmers' access to improved agricultural technologies (Abebaw and Haile, 2013; Wossen et al., 2017). Understanding the relationship between agricultural technology uptake and a household's participation in socioeconomic networks could help design specific wheat seed delivery pathway(s) to different farmer groups based on their socioeconomic setup. This could potentially accelerate the dissemination and scaling up of improved technologies (wheat varieties in this case) to wider but targeted agroecologies and address the challenges that these technologies were developed for.

With the aim of assessing the role of socioeconomic institutions in facilitating the adoption of improved wheat varieties by male and female-headed households in Ethiopia, we performed the analysis at two levels: First, using a binary Probit model, we explored whether participation and extent of participation in socioeconomic networks could affect the likelihood of introducing new wheat variety to their portfolio of wheat production and using improved wheat varieties released since 2010. Second, using ordinary least square (OLS) model, we assessed the relationship between farmers' participation in socioeconomic networks and the age of wheat varieties farmers were growing during the survey season.

As the number of socioeconomic networks in which a household participates could be determined by observed and unobserved factors that also affect wheat seed acquisition,

TABLE 1 Distribution of sample farm households by gender of the head across administrative regions.

Household type	Region			Total
	Amhara	Oromia	SNNPR	
Female-headed household (FHHH)	20 (19.2)	71 (68.3)	13 (12.5)	104 (100.0)
Male-headed household (MHHH)	223 (22.7)	607 (61.7)	154 (15.7)	984 (100.0)
Total	243 (22.3)	678 (62.3)	167 (15.3)	1,088 (100.0)

Figures in parentheses show percentages to the row total.

the level of farmer engagement in socioeconomic networks is expected to be endogenous. To check for the prevalence of endogeneity, we used Hausman's 2SLS estimation procedure, where the number of socioeconomic networks in which a household head was involved was regressed on household and farm characteristics using a Poisson regression model. The predicted values generated by the model were inserted as explanatory variables in the probit models used to estimate the likelihood of acquiring improved seed. The test results showed no significant coefficient estimates for predicted residuals from the first stage. We concluded that we did not need to correct for endogeneity in the model specification. Thus, we used the numbers of the social and economic networks directly as specified in the original models.

In this context, we further analyzed associations between farmers' engagement in socioeconomic networks and sources of wheat-seed acquisition. As farmers may use wheat seed saved from their own production, considering a single season's decision about whether to purchase fresh seed might give a misleading picture about wheat varietal uptake by smallholder farmers. Thus, we considered a 6-year period (2015–2020) and asked men and women farmers if the household purchased or obtained new wheat variety(ies) from external sources during these specific years. This captured farmers' decisions about participating in the wheat seed market, regardless of the age of the wheat varieties they purchased or obtained from external sources. To further assess whether there was a difference between men and women farmers in the age of the wheat varieties that they grew, we clustered varieties into two groups—those released before 2010 and those released after 2010. We did this because in the 2010/2011 production season, a serious yellow rust epidemic devastated wheat production in Ethiopia. According to some estimates, one-third of the wheat area in the country was affected by the epidemic. Since then, in developing and releasing wheat varieties, major emphasis has been given to resistance to rust (yellow, stem, septoria, etc.) (Jaleta et al., 2019).

4. Data

In this analysis, we used survey data collected in 2021 from 1,088 households located in three major wheat-growing administrative regions in Ethiopia (Amhara, Oromia, and SNNPR). The samples were distributed proportionately across the four main wheat agroecological zones [tepid to cool humid mid-highlands (H2), tepid to cool sub-humid mid-highlands (SH2), tepid to cool moist mid-highlands (M2), and tepid to cool sub-moist mid-highlands (SM2)]. From these agroecological zones, 40 districts where wheat was produced on more than 2,000 ha were selected randomly and proportionally to the wheat area in each wheat agroecology. From these districts, 80 *kebeles*[1] were proportionally selected. From each kebele, 14–16 households on average were randomly selected for the interview. Of a total of 1,088 households, 104 (10%) were female-headed households. In male-headed households, the main decision-making woman in the household was also interviewed to capture potential divergence between men and women concerning wheat production objectives, participation in the wheat-production decision-making process, marketing, consumption, varietal choices, and seed acquisitions. The survey captured a wide range of data, including household and farm characteristics, wheat varieties used by farmers, wheat seed sources and acquisition mechanisms, household-level socioeconomic and biophysical constraints, access to improved wheat varieties, participation in social and economic networks, etc. Table 1 presents the distribution of sample households interviewed by region and household type.

5. Results

5.1. Household wheat varietal choice and seed sources

The respondent farmers reported 20 improved wheat varieties grown during the 2020/2021 production season. Among them, *Kakaba*, *Danda'a*, and *Ogolcho* were the most popular ones and were grown by 53.4% of the surveyed farmers. These three varieties are known for their resistance to rust and were released during and after 2010 (Abro et al., 2017). In response to the recurring wheat rust challenges, the national seed production system gave attention to the wider supply and dissemination of these varieties. However, the popularity of these

1 Kebele is the lowest administrative unit.

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TABLE 2 Wheat varieties grown by sample households in the 2020/2021 main cropping season.

Variety name	Year of release (varietal age, years, in 2020)	Percentage adoption based on number of HHs		
		FHHH ($n = 104$)	MHHH ($n = 984$)	Overall ($n = 1,088$)
Laketch	1967 (53)	0.0	0.1	0.1
Pavon	1982 (38)	8.7***	2.8	3.4
Dashen	1984 (36)	1.9	2.2	2.2
Kubsa	1994 (26)	5.8	4.6	4.7
Tusie	1997 (23)	1.0	0.8	0.8
Hawi	1999 (21)	2.9***	0.6	0.8
Digalu	2005 (15)	3.8	5.4	5.2
Obsa	2006 (14)	1.0	0.9	0.9
Danda'a	2010 (10)	12.5	13.1	13.1
Kakaba	2010 (10)	25.0	21.3	21.7
Shorima	2011 (9)	1.9	1.9	1.9
Hidassie	2012 (8)	1.9**	6.4	6.0
Huluka	2012 (8)	4.8	3.7	3.8
Mangudo	2012 (8)	0.0	0.4	0.4
Ogolcho	2012 (8)	10.6	14.8	14.4
Sanate	2014 (6)	0.0	0.1	0.1
Kingbird	2015 (5)	0.0	1.0	0.9
Liben	2015 (5)	1.9***	0.3	0.5
Lemu	2016 (4)	1.0	0.4	0.5
Wane	2016 (4)	2.9*	1.2	1.4
Unknown	–	12.5	13.1	13.1

Mangudo is a durum wheat variety, and the rest are bread wheat varieties.
***, **, * Difference from the MHHH category in the proportion test is statistically significant at 0.01, 0.05, and 0.10 levels, respectively.

three varieties in use by male- and female-headed household groups was not significantly different (Table 2). Difference in the levels of adoption and use by male- and female-headed households was observed for *Pavon*, *Hawi*, *Hidassie*, *Liben*, and *Wane* varieties. Except for *Hidassie*, the remaining four were grown by a relatively higher proportion of female-headed households. In total, 13% of the respondent farmers reported names of wheat varieties not known in the varietal registry. Thus, it is likely that these farmers were growing landraces or improved varieties with names adapted to local contexts.

The most popular wheat varieties grown by smallholder farmers were released in 2010 (*Kakaba* and *Danda'a*) and 2012 (*Ogolcho*, *Hidassie*, *Huluka,* and *Mangudo*). Varieties released during these 2 years (2010 and 2012) were grown by 35 and 25% of the sample farmers, respectively. There were a few farmers (0.1%) growing an old variety (*Laketch*) that was released 53 years ago. A few farmers were also growing varieties released more recently, in 2015 (*Liban* and *Kingbird, 1.4%*) and 2016 (*Lemu* and *Wane, 1.9%*). Although there were 13 bread wheat and seven durum wheat varieties released during 2017–2019 that could potentially have been used by farmers during the 2020/2021 production season, the youngest variety that farmers reported was released in 2016 (some 4 years before the survey season). This implies that there is a time gap between varietal release and actual use of these varieties by men and women farmers. Among other factors, the limited capacity of the formal seed systems in the production and promotion of more recently released wheat varieties could be the main reason for this Dixon et al. (2006) and Nazli and Smale (2016).

Taking the year 2010 as a cut-off point in varietal release, due to shifts in emphasis on rust resistance in wheat breeding, Table 3 gives the percentage distribution of households growing "recent" (released during and after 2010) and "old" (released before 2010) improved varieties. Among those households who reported growing improved wheat varieties in the 2020/2021 cropping season, 71 and 79% of the female- and male-headed

TABLE 3 Comparison of age of varieties used by male- and female-headed households.

Wheat variety types by age	Percentage of households adopting old/new varieties		
	FHHH	MHHH	Overall
Ten or <10 years (released during or after 2010)[a]	71.4**	79.9	79.1
Number of households with varieties identified[b]	91	855	946

[a]Year 2010 is considered as a cut-off point as most popular rust resistant varieties—which have high relevance in stabilizing the Ethiopian wheat production—were released after 2010.
[b]Variety names reported from 142 plots were not identified in reference to names in the national varietal registry, and hence excluded from this analysis.
**Difference from the MHHH category in the proportion test is statistically significant at 0.05 level.

households, respectively, were growing varieties released during the last 10 years (2010–2020). The proportion of female-headed households growing recently released wheat varieties was lower than the proportion of male-headed households.

Farmers rely on different seed sources to acquire improved wheat varieties (Supplementary Table A1). Seed sources also vary according to the age of the wheat varieties. Most recently released varieties might not be popular among farmers and are usually obtained either from formal sources (*cooperatives, seed enterprises, and government support)* or informal sources (*friends, relatives, neighbors, and local markets*). As the years go by, farmers adopt these varieties and save their own seeds. The survey data shows that, compared to the female-headed households (FHHHs), the male-headed households (MHHHs) were quicker to acquire seeds of recently released wheat varieties and save their own seeds for the next production season. Although the continuous use of own saved seed is not conducive to a quick varietal turnover, this practice is not unique to any household type. Many farmers in the survey data (56% of female-headed and 48% of male-headed households) still recycled their own saved seed from the previous production season. Similar findings were reported by Shiferaw et al. (2014) and Alemu and Bishaw (2015) on the importance of own-saved recycled wheat seed use in Ethiopia. For purchased seeds, local markets (seed purchases from traders or unknown farmers) were the main sources of improved wheat seed both for male- and female-headed households. While local markets generally do not supply large quantities of wheat seed, farmers rely on them to purchase good quality grain for seed. Farmers usually make their own visual inspection of grain quality before deciding to buy wheat grain for seed. In addition, when buying wheat grain from local markets for seed purposes, farmers rely on the varietal information they get from the sellers in these markets. Compared to women household heads, a greater proportion of male household heads obtained wheat seed from formal markets, such as government sources or farmer cooperatives. Seed purchased from government sources and cooperatives constituted about 15% for female-headed households and 24% for male-headed households. Study conducted in eastern Africa (Otieno et al., 2021) also confirm that, compared to men, women farmers are less connected to experts, and farmer groups that facilitate access to improved seed marketing and exchange.

5.2. Engagement in socioeconomic institutions and varietal use

Social and economic institutions are organized in an agrarian community either by farmers themselves on voluntary basis or through external (e.g., government, NGO, etc.) interventions to ease local governance and facilitate farmers' access to social and economic services and scarce resources. Local institutions like *Iddir*[2] and *Equb* (merry-go-round) are organized by Ethiopian farmers on a voluntary basis to support mutually on social and economic purposes (Tefera et al., 2017). Formal organizations like farmers' associations are introduced mostly by the government whereas institutions such as saving and credit groups, water use associations, seed production and marketing groups, and farmers' cooperative unions are established in a hybrid form where farmers come together on a voluntary basis with the local government's support to register as legal entities. Regardless of their objectives when established, rural socioeconomic institutions can be a platform where members exchange information and share knowledge (Katungi et al., 2008; Yami and Asten, 2018).

Farmers rely on local socioeconomic institutions to get information and a supply of agricultural inputs, especially in rural areas where formal and well-functioning agricultural input markets are missing (Shiferaw et al., 2011). Development agents use some of these institutional arrangements to channel information on the availability and accessibility of improved wheat seed. Farmers also discuss and share information on modern agricultural technologies and practices informally when gathering for different social events. Thus, the engagement of smallholder farmers in socioeconomic institutions could widen the scope of information sources (Husen et al., 2017; Gupta et al., 2020).

In the survey, men and women household heads and their respective spouses (women in male-headed households) were asked about their involvement in different socioeconomic institutions. It transpired that *Iddir* was the most common social institution in which men and women farmers in both male-and female-headed households participated (Table 4).

2 *Iddir* is a social institution where members support each other mainly for funerals.

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TABLE 4 Involvement of men and women from the MHHHs and FHHHs in social and economic institutions.

Institution types	Participation in institutions (% HH)			
	Household participation		Individual participation in MHHH	
	MHHH[a] ($n = 984$)	FHHH ($n = 104$)	Men ($n = 984$)	Women ($n = 984$)
Social institutions				
Local administration	5.2*	1.9	5.0***	0.4
Farmers' association	19.7***	9.6	19.7***	0.0
Women's association	3.9[b]**	7.7	NA	3.9
Religious congregation	46.4	46.2	44.4***	34.0
Government team	6.3**	1.0	6.1***	0.4
Iddir (Funeral and social support)	80.5	80.8	76.7***	65.1
Non-members of any of the above	14.9	14.4	17.1***	27.6
Economic institutions				
Farmer cooperatives/input supply	32.8***	17.3	32.1***	8.5
Seed producer and marketing group	1.9*	0.0	1.8***	0.2
Saving and credit group	12.9	11.5	10.8***	6.3
Water users' association	8.1**	2.9	7.9***	1.1
Equb (Merry-goes-round)	4.6	4.8	3.3	2.6
Non-members of any of the above	57.3***	72.1	58.5***	83.7

[a]Includes both men and women heads in male-headed households; [b]through their spouses. Here, na stands for "not applicable".
***, **, *Difference from the MHHH category in the proportion test is statistically significant at 0.01, 0.05, and 0.10 levels, respectively.

Above 80% of MHHHs and FHHHs were members of this social institution. In male-headed households, 77% of men and 65% of women farmers participated in *Iddir*. Targeting such popular social institutions for disseminating information on improved seed could help reach out to a large number of farm households. The two second most popular social institutions in which farmers were involved were religious congregations and farmers' associations. On the economic side, cooperatives and saving and credit groups were more popular than any other form of economic institution reported by the surveyed farmers. Compared to men, the proportion of women who did not participate in any of the social and economic institutions considered in this study was higher in both male- and female-headed households. Such male dominated participation in socioeconomic institutions could potentially limit women farmers' access to information and uptake of improved technologies and practices. In situations where social networks are gender-clustered, i.e., more women in women's network and more men in men's network, and men's networks are more likely connected to improved seed exchange, the function of social networks that women farmers participate in is more important than the size of these networks in increasing women farmers' access to improved seeds (Otieno et al., 2021).

Farmers' cooperatives are the most common sources of chemical fertilizer and formal seed delivery in rural Ethiopia (Abebaw and Haile, 2013; Abate, 2018; Tefera and Bijman, 2019). Chemical fertilizer and improved seeds are sold directly to farmers through cooperatives, with strong support from the government. However, in our survey data, only 32% of the male-headed households and 17% of the female-headed households were members of these socioeconomic institutions (Table 4). Taking a close look at the association between cooperative membership by men and women farmers in both male- and female-headed households and the acquisition of improved wheat seed, the mean comparison test in Table 5 shows that, in male-headed households, cooperative members were more likely to purchase fresh seed during the 2015–2020 period and to use more recently released wheat varieties. However, in female-headed households, there was no significant difference between members and non-members in purchasing fresh seed and in using seed of wheat varieties released since 2010. Although above 70% of both member and non-member female-headed households were using recently released wheat varieties, they might possibly have used other sources to acquire their seed.

In addition to the participation of male- and female-headed households specifically in farmers' cooperatives as discussed above, Table 6 presents the links between membership of several institutions and adoption of fresh wheat seed and recently released varieties. It shows that male-headed households who participated in a relatively greater number of

TABLE 5 Cooperative membership and seed acquisition by gender of the household head.

Variables	Overall ($n = 1,088$)		MHHH ($n = 984$)		FHHH ($n = 104$)	
	Members ($n = 334$)	Non-members ($n = 754$)	Member ($n = 323$)	Non-member ($n = 661$)	Member ($n = 18$)	Non-member ($n = 86$)
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
HH purchased fresh wheat seed during 2015–2020 (1 = yes)	0.59 (0.03)***	0.44 (0.02)	0.59 (0.03)***	0.43 (0.02)	0.44 (0.12)	0.55 (0.05)
HH grew wheat varieties released during 2010–2016 (1 = yes)[a]	0.82 (0.02)*	0.78 (0.02)	0.82 (0.02)***	0.79 (0.02)	0.77 (0.11)	0.70 (0.05)

*** and * are significantly different from the other group mean at the 1 and 10% level, respectively.
[a]Estimated only for households with variety names identified using the variety registry (n = 946).

TABLE 6 Linking institutional membership and technology adoption.

	Number of institutions in which the household participates					
	Overall ($n = 1,088$)		FHHHs ($n = 104$)		MHHHs ($n = 984$)	
	Social institutions	Economic institutions	Social institutions	Economic institutions	Social institutions	Economic institutions
Technology: fresh wheat seed during 2015–2020						
Adopters	1.6 (1.0)	0.62* (0.77)	1.3** (0.9)	0.33 (0.61)	1.6 (1.0)	0.66** (0.78)
Non-adopters	1.6 (1.1)	0.54 (0.87)	1.7 (1.0)	0.41 (0.67)	1.6 (1.1)	0.55 (0.88)
Technology: wheat variety released during or after 2010[a]						
Adopters	1.7** (1.0)	0.63*** (0.85)	1.6* (1.0)	0.45 (0.69)	1.7*** (1.0)	0.65*** (0.86)
Non-adopters	1.4 (0.9)	0.44 (0.69)	1.3 (0.8)	0.27 (0.53)	1.4 (0.9)	0.47 (0.71)

***, ** and * Statistically significant difference exists with the non-adopter category at 0.01, 0.05 and 0.10 levels, respectively.
[a]Estimated only for HHs with variety names match names in the variety registry (n = 946).

economic institutions were more likely to purchase fresh seed during the 2015–2020 period. For female-headed households, however, the average number of social institutions in which a household was involved was lower for those who purchased fresh wheat seed during the 2015–2020 period. Looking into the adoption of wheat varieties released during or after 2010, both by male-and female-headed households, the more social and economic institutions in which the household participated, the better the likelihood of adopting these recently released varieties. The participation of male- and female-headed households in socioeconomic institutions needs to be encouraged in order to facilitate households' access to and utilization of improved and more recently released wheat varieties.

Descriptive statistics and a mean comparison test for selected variables used in the empirical analysis are presented in Supplementary Table A2. The test results show that there is no statistically significant difference in the percentage of male- and female-headed households purchasing fresh seed from any external sources. However, male-headed households are to some extent more likely to grow recently released wheat varieties. Male household heads are relatively older than female household heads, and compared to female household heads, they are found to participate more in both social and economic networks. Similarly, the number of adult family members, the area under wheat production, and the number of phones owned per household are greater for male-headed households.

5.3. Results of the empirical analyses

In the survey questionnaire, farmers were asked if they had purchased any fresh seed of an improved wheat variety during the period 2015–2020; from which source they had procured seed; the quantity of seed procured; and whether they had maintained or changed the seed they had been growing since then. To understand men and women farmers' seed acquisition and maintenance behavior, we used econometric models in identifying farmer and farm characteristics to explain the likelihood that men and women farmers purchased improved seeds on a regular basis and bought seeds of recently released wheat varieties.

TABLE 7 Determinants of adoption of new wheat varieties.

Explanatory variables	Used new varieties during 2015-20 (probit model)			Used varieties released since 2010 (probit model)		
	Overall	FHHH	MHHH	Overall	FHHH	MHHH
MHHH (1 = yes)	0.172 (0.265)			−0.557* (0.321)		0.004 (0.005)
Marital status (married is a reference)						
Single (1 = yes)	−0.031 (0.393)	7.767 (878.626)	−0.235 (0.451)	−0.310 (0.465)	−8.651 (316.591)	−1.762*** (0.679)
Divorced (1 = yes)	0.326 (0.425)	0.475 (1.060)	–	−0.997** (0.425)	−0.769 (1.112)	−0.434 (0.496)
Widowed (1 = yes)	0.378 (0.278)	1.076 (0.860)	−0.393 (0.473)	−0.714** (0.325)	−0.647 (0.836)	0.136* (0.075)
No. of social institutions in which a HHH is participating	−0.023 (0.054)	−0.733** (0.290)	0.020 (0.057)	0.139* (0.072)	0.482 (0.385)	−0.029 (0.090)
No. of economic institutions in which a HHH is participating	0.285*** (0.067)	0.436 (0.347)	0.284*** (0.069)	−0.049 (0.087)	−0.137 (0.453)	0.054 (0.045)
No. of phones owned by the HH members	0.258*** (0.053)	−0.351 (0.354)	0.277*** (0.055)	0.099 (0.070)	0.670* (0.353)	−0.021 (0.046)
No. of plows owned by the HH	0.260*** (0.041)	0.299 (0.215)	0.263*** (0.044)	0.003 (0.043)	0.156 (0.172)	0.762** (0.320)
Administrative zones and other household variables included	Yes	Yes	Yes	Yes	Yes	Yes
Model intercept	−1.931*** (0.623)	0.669 (1.379)	−1.746*** (0.404)	0.496 (0.710)	−1.641 (1.711)	−0.569 (0.450)
Number of observations	1,088	91	980	891	74	808
Correct prediction (%)	71.43	79.31	71.15	81.18	81.63	81.7
LR chi^2 (28)	280.22	40.5	260.22	114.42	28.93	98.95
Prob > chi^2	0.00	0.01	0.00	0.00	0.05	0.00
Pseudo R^2	0.186	0.332	0.192	0.121	0.306	0.118

***, **, and * Coefficients are statistically significant at 0.01, 0.05, and 0.10 levels, respectively.

5.3.1. Purchase of fresh seed and use of recently released varieties

A binary probit model estimation on the likelihood of acquiring fresh seed of improved varieties is presented in Table 7. The table shows that the likelihood of introducing a new variety to the household's wheat production system is higher for male household heads who attended school above primary level, and for male and female household heads who engaged in a relatively large number of economic networks, whose household owned more plows (used as a proxy for farm capital), and whose members owned a greater number of mobile phones. There is zonal variation in the likelihood of introducing new wheat varieties into a household's wheat production system.

Households were asked what type of wheat varieties they grew during the 2020/2021 production season. For households who grew wheat on more than one plot during the main cropping season, one plot was randomly selected, and an assessment was made using this randomly selected plot. As most households grew wheat on a single plot, this did not lead to any loss of generality. The probit estimation results in Table 7 show that the likelihood that farm households grow recently released varieties (released since 2010) increases with a better level of education of male household heads and for male household heads engaged in several social networks. Several studies reported the role of farmers' education in agricultural technology adoption (Asfaw and Admassie, 2004; Shiferaw et al., 2008). In most of rural Ethiopia, male household heads are more educated than female household heads (Tiruneh et al., 2001). Thus, being male household head and having relatively better education could favor men farmers to adopt improved agricultural technologies. With better education, smallholder farmers could also assess the benefits of newly introduced technologies and associated risks in making their adoption decisions (Knight et al., 2003).

Both in the formal and informal seed systems, access to information on availability, and accessibility of improved wheat varieties and their seeds is crucial. These days, the wider coverage of mobile networks in rural areas could help

TABLE 8 Determinants of age of wheat varieties grown (OLS).

Explanatory variables	Household type		
	Overall	FHHH	MHHH
MHHH (1 = yes)	2.916* (1.557)		
Marital status (married is a reference)			
Single (1 = yes)	1.854 (2.253)	11.940 (9.978)	1.221 (2.502)
Divorced (1 = yes)	5.360** (2.345)	5.831 (5.516)	8.132** (3.772)
Widowed (1 = yes)	4.397*** (1.642)	2.588 (4.387)	3.545 (2.684)
No. of social institutions in which a HHH participates	−0.620* (0.330)	−1.019 (1.659)	−0.622* (0.339)
No. of economic institutions in which a HHH participates	0.326 (0.404)	1.604 (2.419)	0.154 (0.409)
No. of phones owned by the HH members	−0.329 (0.331)	−4.994** (2.195)	−0.231 (0.332)
No. of plows owned by the HH	−0.234 (0.223)	−0.396 (0.924)	−0.096 (0.234)
Administrative zones and other household variables included	Yes	Yes	Yes
Model intercept	9.324** (3.642)	20.213** (9.618)	14.685*** (2.374)
Number of observations	946[a]	91	855
$F_{(28,917)}$	4.88	1.51	3.95
Prob > F	0.00	0.09	0.00
Adj R-squared	0.103	0.129	0.085

***, **, and * Coefficients are statistically significant at 0.01, 0.05, and 0.10 levels, respectively.
[a]Sample farmers reported variety names in the varietal registry.

smallholder farmers to exchange information on agricultural inputs and related marketing (Haile et al., 2019). Like the result in this analysis, other studies also confirm the positive relationship between mobile phone ownership and the likelihood of adopting improved agricultural technologies (Nonvide, 2021).

5.3.2. Explaining the age of wheat variety grown

In addition to the binary classification of varieties into releases before and since 2010, we assessed how farmer participation in social and economic networks influenced the age of the wheat variety grown on the household's main wheat plot during the 2020/2021 main cropping season. Varietal age was computed by deducting the year a variety was released from the cropping year when the survey was conducted (2021). Table 8 shows that, among male-headed households, the average age of wheat variety grown decreased with an increase in the number of social networks in which the household head participated. Similar result was observed in Zambia where farmers participating in farmer organization were growing more recently released maize varieties (Manda et al., 2020). Compared to households headed by a married male farmer, divorced farmers, on average, were found to grow older varieties. For female-headed households, the most important variable that explained variations in the age of the wheat variety grown was the number of mobile phones owned by family members. With an increase in the number of mobile phones owned in female-headed households, the age of wheat varieties grown decreased.

6. Conclusions

The socioeconomic networks in which farmers are involved in could affect their access to different information usually used in making decisions about farming operations. Information shared through these networks usually includes availability of improved crop varieties, quality and performance of different farm inputs including seed, and farming practices to mitigate challenges related to biotic and abiotic risks in crop production. Using survey data collected in 2020/2021, different empirical approaches were applied to identify the role of socioeconomic networks in enhancing the utilization of improved wheat seed by men and women smallholder farmers in Ethiopia.

The empirical results show that household heads who are relatively better educated, own more farm capital and communication gadgets, and are involved in many economic networks are more likely to introduce new wheat varieties to their farm on a regular basis. Greater participation in social and economic institutions facilitates the uptake of recently released improved wheat varieties for both male- and female-headed households. Compared to male-headed households,

female-headed households are slightly less dependent on the formal wheat seed system (cooperatives and seed enterprises).

The results imply that designing strategies to enhance farmers' engagement in formal wheat seed systems in general, and paying particular attention to female-headed farm households, is crucial to facilitating farmers' quick access to improved and more recently released wheat varieties. In general, strengthening the social and economic institutes functioning in rural setups, facilitating men and women farmers' participation in these institutes, and linking information dissemination channels on agricultural innovations to these social and economic networks could help enhance the uptake of improved agricultural technologies. Though there are affirmative actions, constitutional law, policies, and strategies formulated and implemented in Ethiopia to foster women's social, economic, and political empowerment (Kumar and Quisumbing, 2015; Enyew and Mihrete, 2018), their participation in these domains is still minimal due to several factors including cultural norms (Zewde, 2019). Therefore, it is imperative to further strengthen the implementation of existing policies and strategies through coordinated efforts to improve women farmers' equitable access to resources (Ogato et al., 2009) and participation in social and economic institutions to benefit from the agricultural technology development and dissemination endeavors in the country.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The study was carried out in accordance with the Institutional Research Ethics Committee (IREC) guidelines set by the International Maize and Wheat Improvement Center (CIMMYT), as it is considered 'human subjects research' as per the institutional requirements. Data were collected using standard procedure after informed consent was registered from the survey participants before the actual interview.

Author contributions

MJ: conceptualization, data collection, data analysis, and writing manuscript. ME: conceptualization, data collection, and writing manuscript. HG and VK: conceptualization and writing manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.1080401/full#supplementary-material

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