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Impact of membership of seed-producer cooperatives on commercialisation among smallholder farmers in the central highlands of Ethiopia

Abera Gemechu*
Debrezeit Agricultural Research Center, Bishoftu, Ethiopia; College of Agriculture and Environmental Sciences, School of Agricultural Economics and Agribusiness, Haramaya University, Ethiopia. E-mail: agemechu16@gmail.com

Moti Jaleta
International Maize and Wheat Improvement Center (CIMMYT), Addis Ababa, Ethiopia. E-mail: m.jaleta@cgiar.org

Lemma Zemedu
Debrezeit Agricultural Research Center, Bishoftu, Ethiopia. E-mail: zemedul@gmail.com

Fekadu Beyene
College of Agriculture and Environmental Sciences, School of Agricultural Economics and Agribusiness, Haramaya University, Ethiopia. E-mail: keneefbk@gmail.com

* Corresponding author

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Abstract

Low agricultural commercialisation due to low productivity and a lack of access to and use of improved seeds are common features of smallholders in the Ethiopian highlands. Seed-producer cooperatives (SPCs) were established and strengthened in these highlands to facilitate smallholders' access to improved seed. Using survey data collected from 425 randomly selected smallholders, a full-information maximum likelihood endogenous switching regression (ESR) model and a propensity score-matching (PSM) technique were employed to estimate the impact of membership of seed-producer cooperatives on the output and input commercialisation of members and non-members. The results show that farm size, availability of extension services, household size, farm income, participation in other farmers' organisations, access to training, and education of the household head are key factors associated with cooperative membership. The results from the ESR and PSM models are consistent and show that being a member had a positive and statistically significant impact on tef and wheat farmers' output and input commercialisation. Non-members' status in output and input commercialisation would have been improved if they had been members of seed-producer cooperatives. The results indicate that joining seed-producer cooperatives has proven to be a beneficial approach for farmers, as it minimises transaction costs and facilitates farmers' access to input and output markets for tef and wheat crops. The results show that, if farmers were not part of SPCs, the commercialisation of their tef and wheat output would have decreased by 43 and 31 percentage points, respectively. Furthermore, if non-members had joined the seed cooperatives, their *tef and wheat output commercialisation levels would have increased by 19.5 and 13.3 percentage points, respectively. The findings imply that governments and development partners should deliver training for SPC members on quality seed production and management in their farm operations and assist SPCs in setting up seed storage facilities and acquiring winnowing machines.*

Key words: commercialisation, cooperative, impact, improved seed, Ethiopia

1. Introduction

The development of Ethiopia's economy is closely tied to the success of its agricultural sector, which contributes approximately 33.3% to the country's gross domestic product (GDP) and employs 80% of the population (Agricultural Transformation Agency [ATA] 2021). Moreover, agriculture plays a pivotal role by supplying 70% of the inputs to industry, meeting 85% of the food supply, and contributing 81% of foreign income (National Bank of Ethiopia [NBE] 2022). Similarly, crop production makes up 72.7% of the agricultural GDP (National Planning Commission of Ethiopia [NPC] 2021). However, despite its significant contribution to the economy, the agricultural sector has not met expectations. In particular, the production and marketing of cereal crops, such as tef and wheat, face numerous challenges, including limited input supply, diseases and pests, inadequate infrastructure, weak institutional services, and subpar product quality. More importantly, the seed sector in Ethiopia is currently facing significant obstacles that impede access to improved tef and wheat seeds. The exorbitant prices set by suppliers make it unaffordable for farmers, forcing them to rely on their own saved seeds instead of purchasing new ones (Bishaw & Atilaw 2016; Sisay *et al*. 2017).

In addition, smallholder farmers are confronted with myriad challenges in acquiring improved seeds and accessing markets, which ultimately lead to low crop productivity and low levels of commercialisation. These challenges encompass limited access to quality seeds and markets, insufficient information and knowledge, limited credit and financial services, lack of market linkages, climate change and environmental degradation, and limited access to extension services (Dey & Bezabih 2021). Moreover, smallholder farmers in the country face various obstacles within agricultural cooperatives and commercialisation, such as ineffective and unsustainable marketing strategies, limited land ownership, and limited market access (Sisay *et al*. 2017; Mulesa, 2021). These challenges result in cereal crops such as tef and wheat having lower productivity levels compared to the potential yields observed in research stations at the national, regional and local level (Bekele & Shiberu 2014; Food and Agriculture Organization of the United Nations [FAO] 2020a).

To mitigate the poor performance of the agricultural sector, the Ethiopian government formulated and put into practice an economic transformation plan based on the framework of agricultural development-led industrialisation (ADLI), with consecutive five-year growth and transformation plans (GTP I and GTP II) aimed at enhancing the livelihoods of rural smallholders (Bernard *et al*. 2013; NPC 2018). To effectively carry out this strategy, agricultural cooperatives have been tasked by the government to enhance smallholder productivity and commercialisation (Bezabeh 2018). The GTP II plan presumed seed-producer cooperatives (SPCs) to be key stakeholders and seeds to be crucial contributors to Ethiopia's agricultural development (NPC 2018).

Nevertheless, despite the diligent endeavours, the overall crop production, particularly in the cereal sub-sector, continues to be characterised by a subsistence production system due to its inadequate productivity (Urgessa 2015). Moreover, the level of commercialisation for both output and inputs remains significantly low. For example, based on the 2019/2020 estimate, an average of only 23% of the grain crops produced by smallholders were sold in the market (Central Statistical Agency [CSA]

2020). Moreover, the effectiveness of cooperatives in marketing agricultural output for the benefit of their members is limited. Therefore, there is a significant challenge in enhancing the role of cooperatives in an inclusive manner to improve the commercialisation of smallholder farmers' produce (Alemu 2011). Pender and Alemu (2007) and Gebremedhin and Jaleta (2010) estimated the market share of cereal grains to be around 24% to 25%. Among the major staple crops, the commercialisation level of tef was only 24%, while that of wheat was 20% (Anteneh & Asrat 2020).

In recent times, tef has gained global recognition for its gluten-free and nutrient-rich composition, making it a valuable source of income for Ethiopian farmers due to increased production (Hailu *et al*. 2015; Lee 2018). Tef is grown in Ethiopia on approximately three million hectares of land by six million farm households (Bachewe *et al*. 2015a). The low tef yield, of 1.9 tons per hectare, can be attributed to a number of factors, including limited utilisation of modern agricultural inputs, reliance on traditional sowing methods, inadequate access to market information, absence of high-yielding varieties, and imperfect output and input markets (Bachewe *et al*. 2015a, 2015b; CSA 2019).

In addition, smallholder farmers have a lower level of commercialisation for tef, at 24 %, which hampers the realisation of its potential as an export commodity, particularly in the context of its globalisation (Alemu & Berhanu 2018). Moreover, Ethiopia has identified wheat as a key crop in its efforts to achieve national food self-sufficiency. It is not only an important commodity in the market, but also a major source of income for smallholder farmers in the country (CSA 2015). The country produces approximately 3.9 million tons of wheat on 1.6 million hectares, involving 4.7 million farmers, and achieves an average productivity of 3.1 tons per hectare (Ethiopian Statistics Service [ESS] 2022). However, despite its immense potential, smallholder farmers primarily grow wheat for subsistence rather than commercial purposes, resulting in limited economic benefits (Shikur 2022).

Despite the emphasis on tef and wheat production as strategic crops for food security, small-scale farmers face challenges in meeting the demand for improved seeds through public-based institutions. One way for farmers to overcome these challenges and achieve economies of scale is through the utilisation of cooperatives. By doing so, they can benefit from reduced unit costs of inputs and services, improved product and service quality, minimised risks, and the collective ability to address shared challenges, including exploring new market opportunities (Bernard & Spielman 2009; Fischer & Qaim 2012). Farmers' cooperatives provide numerous benefits to their members, such as improving the commercialisation and productivity levels of farmers (Ochieng *et al*. 2020). As a result, policymakers and development practitioners have shown significant interest in collective action mechanisms, such as seed-producer cooperatives, to address improved seed supply gaps faced by smallholders (ATA 2021; FAO 2020b).

Improved crop varieties that have been developed by the Ethiopian Institute of Agricultural Research have been distributed to farmers through the research-extension wing of the institute, as well as public and private seed producers. However, the research-extension wing has limited capabilities, and public and private seed producers focus mainly on a small number of cereal crops and vegetables, meeting only a fraction of the overall seed requirement (Bishaw & Atilaw 2016). As a result, self-help seed-producer cooperatives were established by rural farmers in different regions of Ethiopia, with support from the government and practitioners (NPC 2021). These cooperatives aim to bridge the significant gap between the demand and supply of improved seeds, thereby promoting the commercialisation of staple cereal crops in terms of input and output (Sisay *et al*. 2017).

Bernard *et al*. (2008) examined the impact of cooperatives on smallholders' commercialisation behaviour in Ethiopia using propensity score matching (PSM) and showed that cooperatives had a limited influence on access to credit and infrastructure for their members due to the weak capacity of farmers' cooperative management and the lack of availability of financial resources. They did this by comparing households that are members of cooperatives to similar households in comparable areas without cooperatives. The results are somewhat sobering in that, when looking at the aggregate of the households in the sample, cooperative membership had no impact on the average decision on how much to sell for those who did participate.

Moreover, Bernard and Spielman (2009) examined the role of rural producer organisations in supporting smallholder commercialisation, and the extent to which the principles of an inclusive, bottom-up approach relate to marketing the performance of cooperatives in Ethiopia. They found that poorer farmers tend not to participate in rural producer organisations, although they may benefit from them indirectly. In contrast to the aforementioned findings, Hailu *et al*. (2015) and Shumeta and D'Haese (2018), who conducted research on the impact of rural organisations on agricultural technologies and the impact of coffee cooperatives on member household coffee production performance in Ethiopia respectively, showed that cooperative membership had no statistically significant effects on the outcomes of smallholder farmers.

The empirical studies mentioned above have highlighted several gaps in the existing studies. Firstly, there is a dearth of studies on how being a member of seed-producer cooperatives influences the commercialisation behaviour of smallholder farmers. Secondly, the existing research findings show that the impact of cooperatives on small-scale farmers differs. Some studies suggest that joining a cooperative results in a positive impact on the commercialisation of smallholders' output (e.g. Bernard & Spielman 2009; Francesconi & Heerink 2011; Shiferaw & Muricho 2015; Chagwiza *et al*. 2016), whereas others found no significant economic effects on small-scale farmers (Bernard *et al*. 2008; Shumeta & D'Haese 2018). Thirdly, the previous empirical studies conducted in Ethiopia on the impact of cooperatives on smallholder commercialisation by Bernard *et al*. (2008), Bernard and Spielman (2009), Francesconi and Heerink (2011) and Chagwiza *et al*. (2016) are outdated and suffer from methodological shortcomings. These studies employed a propensity score-matching (PSM) model, which may not adequately address selection bias stemming from both observed and unobserved differences. As a result, the studies fail to account for biases that may arise from unobservable variables, thereby not providing substantial evidence for policymakers and stakeholders (Bekele & Shiberu 2014; White & Raitzer 2018). Consequently, the findings of these studies may either underestimate or overestimate the actual impact (Zeng *et al*. 2015). Therefore, the current study took into consideration both the observable and unobservable characteristics of farmers using both the PSM and ESR models to obtain a consistent and unbiased estimate for policymaking.

Furthermore, the structure and functioning of the cooperatives examined vary significantly. It therefore is important to note that there is a scarcity of empirical findings on how membership of seed-producer cooperatives impacts the level of commercialisation of outputs and inputs among smallholder tef and wheat farmers in the central highlands of Ethiopia. The objective of this article hence was to address these gaps by identifying factors that influence farmers' decisions to join SPCs and to analyse the effect of membership of seed-producer cooperatives on the levels of commercialisation of tef and wheat output and input in Ethiopia. The structure of this paper is as follows: Section 2 outlines the research methodology, while Section 3 discusses the findings. Finally, Section 4 concludes.

2. Data and empirical methods

2.1 Description of the study areas

The study was conducted in Adea and Lume districts of the East Shewa Zone in the Oromia National Regional State of Ethiopia. Adea district is located at a latitude of 8.52629 and a longitude of 39.46609, with an elevation of 1 880 metres above sea level. The district is renowned nationally for its production of tef and wheat, which are the dominant crops in the agricultural system of the area. In addition, there are 21 primary seed-producer cooperatives (hereafter referred to as SPCs) and 63 farmers' service cooperatives registered in the Adea district. On the other hand, Lume district is located at a latitude of 8.6106 and a longitude of 39.2328, with an elevation of 1 500 to 2 300 metres above sea level. Tef, wheat and vegetables are the primary cash crops and subsistence crops in the district. The district has 14 primary SPCs involved in the production of various crop varieties, along with 12 irrigation cooperatives, 25 forest conservation cooperatives, seven marketing cooperatives, three fishery cooperatives, two dairy cooperatives and 97 service cooperatives.

2.2 Sampling procedure and determination of sample size

To draw a representative sample for this study, a multistage purposive and stratified random sampling technique was used. First, the East Shewa Zone of Ethiopia was purposively selected due to the availability of SPCs. Second, Adea and Lume districts were purposively selected based on the functionality and existence of SPCs and private limited seed-producer companies that had been focused on cereal seed production for the preceding 10 years, in consultation with the zonal cooperative promotion office. Third, kebeles (wards) in the districts were stratified into SPCs and independent farmers (control) who produce tef and wheat while serving the private seed-producer companies operating in the districts as out-growers of seeds. Fourth, a sample of eight kebeles, four from each district, were randomly selected based on the availability of mature SPCs to create a sampling frame containing the lists of households with SPCs and independent farmers living in the same kebele. Finally, from the two strata, 425 representatives of sample households, 212 members of SPCs and 213 independent farmers who produced tef and wheat seeds under privately owned companies were randomly selected for the survey.

2.3 Data

The primary data used in this study came from a household survey conducted across two districts selected from the East Shewa Zone of Oromia, Ethiopia. Personnel holding first degrees in economics and statistics were recruited and trained before embarking on the actual data collection. Structured and semi-structured questionnaires were pre-tested on non-sampled households to check for non-response and inconsistency. The primary data was collected from the household heads of the sample of SPC members and non-members under the supervision of the principal researcher. The household survey was carried out between February and April in 2023. An extensive collection of secondary data was collected alongside the primary data. The secondary data was obtained from a variety of sources, such as the annual reports of district cooperative promotion offices, zonal cooperative promotion offices, the Oromia region cooperative agency, the Ethiopian cooperative commission, as well as published and unpublished journal articles.

2.4 Analytical framework

To answer the research questions, the researchers followed the counterfactual approach of causality (Heckman *et al*. 1998). Each farmer faces two regimes: The observed (actual) and the unobserved (counterfactual). For example, the treatment indicator (D_i) equals 1 if an individual (i) receives treatment, and 0 otherwise. The individual who receives treatment has a Y_{1i} outcome (observed) and a Y_{0i} outcome (unobserved – what would have happened to the individual if the same individual had not received the treatment). To mitigate the problem of missing data, the researchers applied both the PSM technique and the endogenous switching regression (ESR) model. The random utility framework states that farmers choose to be SPC members when the net benefits of joining SPCs are greater than not joining SPCs. The utility gain of membership could be expressed as a function of observed covariates in the latent variable model, as follows:

$$D_i^* = \beta Z_i + \vartheta_i, \text{ with } D_i = \begin{cases} 1 \; if \; D_i^* > 0 \\ 0 \;\; otherwise \end{cases}, \quad (1)$$

where D_i^* is an indicator of the latent SPC membership, β is a vector of parameters to be estimated, and ϑ_i is the error term that explains the unobserved benefits of an individual i. The observed dependent variable, viz. membership status (D_i), where D_i = 1 for members and D_i = 0 for non-members, is also related to D_i^*, as indicated in Equation (1).

2.4.1 Specification of propensity score-matching model (PSM)

Following previous studies (Henrich *et al*. 2010; Abebaw & Haile 2013; Rosenbaum & Rubin 1983), the researchers implemented PSM using three matching algorithms: five-nearest neighbour, kernel and radius matching. Finally, after checking for the fulfilment of the assumptions of the common support and balancing property, the average treatment effects on the treated (ATT) were computed by restricting the matches to the households with propensity scores that fell in the area of common support, as follows:

$$\text{ATT} = \text{E}\,(Y_1 - Y_0 | D_i = 1) = \text{E}\,(Y_1 | D_i = 1) - \text{E}\,(Y_0 | D_i = 1), \quad (2)$$

where Y_1 is the outcome (level of commercialisation of tef output and input) in the treated condition; Y_0 is the outcome in the control condition; and the D_i indicator variable (treatment status) denotes membership of a seed-producer cooperative. It is generally supposed that matching is a good method to estimate the average treatment effect in observational studies. However, PSM controls only for observable selection biases.

2.4.2 Specification of the endogenous switching regression model (ESRM)

Following previous empirical studies, such as those of Di Falco *et al*. (2011), Shiferaw and Muricho (2015) and Mojo *et al*. (2017a), the researchers utilised the ESR method to consider both observable and unobservable biases. ESR constitutes the selection Equation (1) and tries to account for the endogeneity of the membership decision by estimating a simultaneous equations model of the outcome variables with endogenous switching. Let us assume that a farmer has two outcome functions where the farmer faces two regimes, (i) to be a member and (ii) not to be a member. These can be represented as follows:

$$\text{Regime 1: } Y_{1i} = \gamma_1 X_{1i} + \varepsilon_{1i} \quad if \;\; D_i = 1 \quad (3a)$$

$$\text{Regime 2: } Y_{2i} = \gamma_2 X_{2i} + \varepsilon_{2i} \quad if \;\; D_i = 0, \quad (3b)$$

where Y_{1i} and Y_{2i} are outcome variables representing the household tef and wheat output commercialisation index, $HCOI_i = \left[\frac{Gross\ value\ of\ tef\ or\ wheat\ output\ sale_{hhi\ yeari}}{Gross\ value\ of\ tef\ or\ wheat\ production_{hhi\ Year\ j}}\right] * 100$, expressed in Ethiopian birr in the 2022 production season. On the input side, the household crop input commercialisation index (HCICI) $= \left[\frac{The\ total\ value\ of\ purchased\ inputs\ for\ tef\ and\ wheat}{The\ total\ value\ of\ tef\ and\ wheat\ crops\ produced}\right] * 100$ under regimes 1 and 2, while X_i represents a vector of covariates included in Z_i. γ is a vector of the estimated parameters and ε_i is the error term of the outcome variable. Therefore, in the first stage, we estimated the probability of membership to model the treatment effect. According to Di Falco *et al*. (2011), the key assumption in ESR is that the error terms in equations (1), (3a) and (3b) have a trivariate normal distribution, with a zero mean and covariance matrix Ώ, in the following form:

$$\mathbf{cov}\ (\vartheta_i, \varepsilon_{1i}, \varepsilon_{2i}) = Ώ = \begin{bmatrix} \sigma_\vartheta^2 & \sigma_{12} & \sigma_{1\vartheta} \\ \sigma_{12\vartheta} & \sigma_1^2 & \sigma_{2\vartheta} \\ \sigma_{1\vartheta} & \sigma_{2\vartheta} & \sigma_2^2 \end{bmatrix},$$

where σ_ϑ^2 is the variance of the error term in the membership Equation (1), σ_1^2 and σ_2^2 are the variances of the error terms in the outcome (household's output commercialisation index and input commercialisation index) (equations 3a and 3b), σ_{12} is the covariance of (ε_{1i}, ε_{2i}); $\sigma_{1\vartheta}$ denotes the covariance of ($\varepsilon_{1i}, \vartheta_i$); and $\sigma_{2\vartheta}$ is the covariance of ($\varepsilon_{2i}, \vartheta_i$). The covariance between ε_{1i} and ε_{2i} is not defined, as Y_{1i} and Y_{2i} cannot be observed simultaneously. Moreover, the correlation between the error term of the selection equation and the outcome equation in (3a) and (3b) is not zero (i.e. cov ($\vartheta_i, \varepsilon_1$) # 0 and cov ($\vartheta_{i,}, \varepsilon_2$) # 0), which creates selection bias. Sample selection occurs when factors not observed by the researcher but known to the farmer affect both membership choice and outcomes (Fuglie & Bosch 1995). The expected values of $\in_{1i}$ and $\in_{2i}$, conditional on sample selection, are non-zero and can be represented as follows:

$$E[\varepsilon_{1i}|D_i = 1] = \sigma_{1\vartheta}\ \frac{\phi(Z_{i\alpha})}{\Phi(Z_{i\alpha})} = \sigma_{1\vartheta}\ \lambda_{1i} \tag{4a}$$

$$E[\varepsilon_{2i}|D_i = 0] = \sigma_{2\vartheta}\ \frac{\phi(Z_{i\alpha})}{1-\Phi(Z_{i\alpha})} = \sigma_{2\vartheta}\ \lambda_{2i} \tag{4b}$$

Here, ϕ (.) is the standard normal probability density function, Φ (.) is the standard normal cumulative density function, and $\lambda_{1i} = \frac{\phi(Z_{i\alpha})}{\Phi(Z_{i\alpha})}$ and $\lambda_{2i} = \frac{\phi(Z_{i\alpha})}{1-\Phi(Z_{i\alpha})}$, where λ_{1i} and λ_{2i} are the inverse Mills ratios (MIR) computed from Equation (1) and included in equations (3a) and (3b) to correct for selection biases in the ESR. If the estimated covariances, $\hat{\sigma}1\vartheta_i$ and $\hat{\sigma}2\vartheta_i$, are statistically significant, then the membership decision and the output and input commercialisation index are correlated, implying the presence of endogenous switching and suggesting that the null hypothesis – that sample selection bias is absent – can be rejected. Lokshin and Sajaia (2004) found that full information maximum likelihood (FIML) allows for the simultaneous estimation of the selection equation and outcome equations (Equation (1) and equations (3a) and (3b), respectively), resulting in consistent standard errors. Given the previous assumptions regarding the distribution of the error terms, the logarithmic likelihood function of FIML was adopted from Di Falco and Yesuf (2011) and expressed as:

$$\ln L_i = \sum_{i=0}^{n} D_i \left[\ln \phi\left(\frac{\varepsilon_{1i}}{\sigma_1}\right) - \ln \sigma_1 + \ln \Phi(\theta_{1i})\right] + (1 - D_i)\left[\ln \phi\left(\frac{\varepsilon_{2i}}{\sigma_2}\right)\right] - \ln \sigma_1 + \ln \Phi(\theta_{2i}), \tag{5}$$

where $\frac{\left(Z_{i\alpha} + \rho_j\, \varepsilon_{ji/\sigma_j}\right)}{\sqrt{1-\rho_j^2}}$ j = 1, 2, with ρj denoting the correlation coefficient between the error term ϑ_i of the selection Equation (1) (latent variable) and the error term εji of equations (3a) and (3b), respectively. This relationship can be expressed by $corr$ (corr (ϑ_i , ε_i) =ρ. The signs of the correlation terms have an important economic interpretation (Abdulai & Huffman 2014). If ρ_A < 0, it implies positive selection bias, which suggests that farmers with above-average commercialised output and commercialised input are more likely to be a member of an SPC. On the other hand, if ρ_N > 0, it implies a negative selection bias. To identify the ESR model, the researchers utilised the presence of SPCs in the village of residence of the households and the SPC membership of their relatives (through peer influence) as a potential instrument that does not have a direct influence on the outcome variables, but has a direct influence on their membership of SPCs (Shiferaw *et al*. 2014). Hence, four comparable expected outcomes were computed using equations (6a), (6b), (6c) and (6d), as follows: the actual expected household crop output commercialisation index/household input commercialisation index for SPC members (Equation 6a) and non-members (Equation 6b), and the household crop output commercialisation index/household input commercialisation index in counterfactual scenarios, i.e. outcomes for members if they had not been a member (Equation 6c) and outcomes for non-members if they had been a member (Equation 6d). The conditional expectations for the household crop output commercialisation index or household crop input commercialisation index in the four cases are defined as follows:

$$E(Y_{1i}\,|D_i = 1) \;=\; \gamma_1\, X_{1i} + \sigma_{1\vartheta}\, \lambda_{1i} \tag{6a}$$

$$EY_{2i\,|}|D_i = 0) \;=\; \gamma_2\, X_{2i} + \sigma_{2\vartheta}\, \lambda_{2i} \tag{6b}$$

$$E(Y_{2i}|D_i = 1) \;=\; \gamma_2\, X_{2i} + \sigma_{2\vartheta}\, \lambda_{2i} \tag{6c}$$

$$EY_{1i\,|}|D_i = 0) \;=\; \gamma_1\, X_{1i} + \sigma_{1\vartheta}\, \lambda_{1i} \tag{6d}$$

Following Di Falco *et al*. (2011), the researchers also calculated the average impact of the treatment on the treated (ATT) – the mean effect that SPC membership has on members' output and input commercialisation as the difference between Equation (6a) and Equation (6c), and the average effect of treatment on non-members (untreated) (ATU) as the difference between Equation (6d) and Equation (6b).

$$\text{ATT} = E(Y_{1i}\,|D_i = 1) - E(Y_{2i}|D_i = 1) \tag{7a}$$

$$\text{TU} = EY_{1i\,|}|D_i = 0) - EY_{2i\,|}|D_i = 0) \tag{7b}$$

The heterogeneity effects for the collective of households being members and those not being members were also calculated, specifically as differences between Equation (6a) and Equation (6d) (i.e. H_1), and between Equation (6c) and Equation (6b) (i.e. H_2), respectively. Finally, the researchers again followed Di Falco *et al*. (2011) to investigate the 'transitional heterogeneity' (H_3).

3. Results and discussion

This section presents and discusses both the descriptive and econometric results. The descriptive results consist of percentages, t-tests and chi-square tests for doing simple comparisons between members and non-members of SPCs. Next, the researchers present the results dealing with the determinants of membership of SPCs (logistic regression model), and then the results from the propensity score matching and full information maximum likelihood endogenous switching regression models for assessing the impact of membership of SPCs on the output and input commercialisation of smallholder tef and wheat farmers.

3.1 Descriptive results

The results reveal that 49.9% of households were affiliated with SPCs, while the remaining 50.1% were not associated with SPCs. The results also show that, of the respondents who were members of SPCs, 93.8% were from male-headed households and 6.1% from female-headed households. Similarly, among the non-members of SPCs, about 92.5% were male farmers and 7.5% were female. The sex difference in membership of SPCs could be due to male-headed farming households having better access to farmer organisations compared to their female counterparts. The difference in membership of SPCs between male-headed and female-headed households is influenced by socioeconomic factors, resulting in notable distinctions between the two groups. The results of the mean t-test reveal that male-headed households had larger farm sizes, higher levels of education, and greater farm income in comparison to female-headed households. These disparities are statistically significant at the levels of $P < 0.01$ and 0.05 respectively. The issue of land rights predominantly being held by men in the country contributes to limited land access for female farmers, particularly in cases of widowhood, which is a crucial requirement for joining seed-producer cooperatives. Furthermore, low-income female farmers in agricultural communities encounter difficulties in accessing agricultural resources, impeding their participation in farmer organisations.

The household survey showed that members of SPCs had an educational attainment of 4.65 school years, while non-members had an educational attainment of 3.57 school years. Furthermore, there was a statistically significant difference between SPC members and non-members in terms of the level of education of the head of the household, at $P < 0.001$, with members of SPCs having a relatively higher level of education. Furthermore, the findings indicate that the average size of farmland holdings differed between members and non-members of SPCs. Specifically, SPC members had an average farmland holding of approximately 1.74 hectares, whereas non-members had an average farmland holding of 1.03 hectares. The mean difference in farm landholding size between members of SPCs and non-members was approximately 0.70 hectares, and this difference was statistically significant at $P < 0.001$.

The mean livestock ownership per household with SPC members was higher (8.4) compared to households that were not members of SPCs (5.8), and the differences were significant at $P < 0.05$. This indicates that livestock is one of the asset outcomes of the commercialisation of tef and wheat farmers' involvement in SPCs. Income generated from the sale of livestock and its products helps to mitigate the liquidity problem of farmers when participating in the input market. This finding is consistent with Hailu and Fana (2017), who found that farmers who owned livestock participated in the purchase of chemical fertilisers, improved seeds and herbicides. However, the findings contrast with those of Gebremedhin and Jaleta (2010), who found that owning livestock decreases the likelihood of engaging in the crop market. This is because livestock provides an alternative source of cash income, resulting in a negative correlation between livestock ownership and crop commercialisation.

The average household commercialisation index (HCI) for tef output for the sample was 0.55, indicating that, on average, farmers sell more than half of their tef produce. Interestingly, the tef output commercialisation index differs significantly between SPC members (0.58) and non-members (0.50). This implies that the SPC members had a higher level of commercialisation for their tef output compared to non-members ($p < 0.001$). The average household wheat output commercialisation index

(HCI) for the sample was 0.54, suggesting that, on average, farmers sell more than half of their wheat produce. There is a notable difference in the wheat output commercialisation index between members of SPCs (0.56) and non-members, for whom it is around 0.51. The wheat output commercialisation index for SPC members is significantly greater than that of non-members ($p < 0.001$).

On the contrary, the findings indicate that the tef seed commercialisation index for SPC members is considerably higher than that for non-members ($p < 0.001$). Furthermore, the results suggest that farmers who belong to SPCs are more actively involved in the wheat seed market compared to those who are not members. The findings furthermore suggest that there is a significant disparity in the fertiliser commercialisation index between SPC members, at 0.16, and non-members, for whom it stands at approximately 0.10. This implies that the use of fertilisers plays a crucial role in enhancing productivity. Consequently, the anticipation of increased yields may influence the fertiliser market participation decisions of tef and wheat farmers in the study areas. Table 1 presents the summary statistics of the sample households.

Table 1: Descriptive statistics of sample households by membership status of seed cooperatives

Variables and their description	Total sample (N = 425)	Members (N = 212)	Non-members (N = 213)	Mean difference	t-test/ chi-square
Age of household head, in years	46.73	50	43.4	-6.5***	5.4
Sex of household head (dummy, 1 = male)	0.93	0.938	0.92	0.013	0.56
Household size, in adult equivalents	4.59	4.91	4.28	-0 .63***	3.49
Education of household head, in years of schooling	4.11	4.65	3.57	-1.07***	2.88
Total land holding cultivated, in hectares	1.38	1.7	1.03	-0. 70***	7.05
Improved tef land covered, in hectares	1.24	1.2	0.82	0.44***	6.65
Improved wheat land coverage, in hectares	0.72	0.86	0.57	0.29***	5.21
Livestock ownership (TLU)	7.62	8.5	5.8	2.6**	7.7
Contact with development agent, in days per year	2.57	3.53	1.62	-1.91***	-5.99
Tef yield, in quintal per hectare	17.05	21.24	12.86	8.38***	7.79
Wheat yield, in quintal per hectare	20.3	25.6	15	10.6***	5.04
Distance to nearest market, in minutes	45.56	43.98	47.13	3.15	0.80
Distance to district market, in minutes	117	114.5	119.60	5	0.71
Distance to seed-producer cooperatives, in minutes	28.8	26.8	30.8	4	1.3
Total income from tef sales, per household	64 537.6	88 605.75	40 582.44	48 023.30***	8.64
Total income from wheat sales, per household	41 136.94	55 013.7	27 325.35	27 688.3***	5.83
Off-farm income per household	3 762.02	4 261.9	3 266.77	995.17	0.84
Tef output commercialisation index	0.55	0. 58	0.50	0.082***	4.83
Wheat output commercialisation index	0.54	0.56	0.51	0.052***	3.12
Tef seed commercialisation index	0.68	0.80	0. 55	0.255***	4.21
Wheat seed commercialisation index	0.38	0.52	0.35	0.17**	1.87
Fertiliser commercialisation index	0.13	0.16	0.10	0.06**	2.15
Herbicide commercialisation index	0.98	0.57	0.14	0.43	0.88
Fungicide commercialisation index	0.11	0.112	0.102	0.01	0.30
Market access (dummy, 1 = yes)	0.48	0.92	0.051	0.87***	36.8
Adea _dummy (1 = yes)	0.67	0.60	0.73	0.123***	2.73
Lume_dummy (1 = yes)	0.34	0.41	0.27	0.133***	2.91

Source: Results from own survey in 2023
Notes: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively

3.2 Determinants of membership of seed producer cooperatives

The researchers estimated the propensity score using binary logistic regression to match SPC members with non-members based on observed characteristics of the households surveyed. The dependent variable in the logit model is coded as 1 if the sampled household head is a member of an SPCs, and as 0 if the household head is not a member. The goodness-of-fit tests show that the selected covariates provide good estimates of the conditional membership density. The explanatory variables are jointly statistically significant, as are the explanatory variables ($LR\ \chi 2$ (15) = 328.44; Prob > Chi^2 = 0.000) and the pseudo R^2 (0.28). The results from the model output reveal that 10 variables out of 15 were statistically significant at different levels of probability, as indicated in Table 2.

Table 2: Logit model results of the determinants of membership of a seed producer cooperative

Variable	Logit estimates		Marginal effects	
	Coef.	Std Err	Coef.	Std Err
Age	0.027*	0. 016	0.003*	0. 002
Age squared	0.002	0.007	0.0021	0.009
Sex	0.424	0. 231	-0.079	0.050
Household size	0.112**	0.056	0.022**	0.010
Educational level	0.106**	0. 046	0.010**	0.004
Ln total income	1.51***	0.264	0.139***	0.021
Ln tef farmland size	0. 96 ***	0.193	0.190***	0.034
Ln wheat farmland size	0.49***	0.093	0.162***	0.06
Access to training	3.22***	0.345	0.298***	0.018
Frequency of extension contacts	0.121**	0.059	0.013**	0.007
Membership of other farmers' organisations	2.76**	1.19	0.256**	0.104
Distance from the SPC office	-0.98***	0.004	-0.013***	0.001
Off-farm income	0.009	0.001	0.0019	0.0001
Adea (dummy: 1 = yes)	0.95	1.6	0.090	0.16
Lume (dummy: 1 = yes)	0.42	0.68	0.13	0.15
Constant	-6.73			
Observations	425			
LR chi^2(14)	328.44			
Prob > chi^2	0.000			
Log likelihood	-129.66			
Pseudo R^2	*0. 2802*			

Notes: Binary outcomes indicating discrete changes from 0 to 1; *** and ** indicate significance at the 1% and 5% levels, respectively.

The results show that total farm income, farmland size and access to training had a positive and statistically significant effect on the smallholders' decisions to join SPCs (P < 0.001). The results of the study are consistent with the findings of Mojo *et al*. (2015), who indicated that farmers with larger landholdings are more likely to join cooperatives. Moreover, the frequency of extension contacts, household size, membership of other farmers' organisations and educational level of the household head had a positive and statistically significant effect on the smallholders' decisions to join SPCs, at P < 0.05. This result is consistent with the findings of Abate *et al*. (2014) and Mojo *et al*. (2015), who indicated that a household with a higher education level had a higher probability of participation in a cooperative. In addition, the age of the household head had a positive and statistically significant effect on a farmer's decision to join a seed cooperative. The findings of other studies (Bernard *et al*. 2008; Bernard & Spielman 2009; Abebaw & Haile 2013; Abate *et al*. 2014; Mojo *et al*. 2015) are consistent with the age difference between the two groups.

The results suggest that smallholder farmers with larger plots of tef and wheat have greater access to extension services, have larger household sizes, higher total farm income, belong to other cooperatives, have received training on improved seed production and marketing, and are more likely to join SPCs. In addition, access to agricultural extension services plays a role in influencing farmers' decisions to join SPCs, as informed agents are more likely to discuss the benefits of membership with farmers. Conversely, the proximity of the SPC office is inversely correlated with the likelihood of farmers joining the cooperatives ($P < 0.001$). This can be attributed to the fact that, when the cooperative office is located near the farmer's residence, the cost of communication with cooperative officers is reduced. As farmers reside closer to the SPC office, they have greater opportunities to acquire knowledge and skills regarding the advantages of joining SPCs**.**

3.3 Impact of membership of SPC on commercialisation of tef and wheat output and input

This section presents and discusses the impacts of membership of SPCs on the commercialisation of tef and wheat outputs, as well as the commercialisation of inputs such as seeds, fertiliser, herbicides and fungicides, by using the PSM and ESR models. The first section provides an analysis of the results obtained through the PSM technique, followed by the results from the ESR model. The propensity scores estimated for the entire sample range from 0.001 to 0.998, with an average score of 0.498. The propensity scores for non-members of SPCs range between 0.001 and 0.996, while they range from 0.015 to 0.998 for members. Thus, the common support region can be identified within the minimum value of treated individuals (members of SPCs) and the maximum value of comparison groups (non-members of SPCs), which falls within the range of 0.0146 to 0.998.

Based on the results, it is evident that there is no statistically significant difference between the two groups after matching. This indicates that both groups have similar characteristics, unlike what is shown in Table 1 (unmatched sample), where there is a statistically significant difference between the two groups in relation to several variables. In addition, the standardised differences (% bias) in the means of the covariates between members and non-members are all below 20%, demonstrating that the balancing requirement has been met adequately. Furthermore, out of the total number of 425 sample observations, 209 treated and 193 untreated individuals were found within the support region, indicating that suitable matches had been found for the member group. However, 20 untreated and three treated samples were outside the support group and were dropped from the sample, since their propensity scores fell outside the common support propensity score range.

Farmers in the member group who were unable to find a suitable match were categorised as having received treatment. In contrast, individuals who were not affiliated with seed-producer cooperatives were classified as untreated. The ATT estimation was based on a sample size of 402, consisting of 209 members and 193 non-members. Table 3 provides a summary of the quality-matching tests conducted using nearest neighbour, kernel and radius-matching algorithms. The results indicate that there is no statistically significant difference between the two groups after the matching process. Furthermore, Table 3 shows that the pseudo-R-square initially was higher, but decreased significantly across all algorithms after matching, suggesting no systematic difference in the distribution of the covariates.

Table 3: Summary of the quality-matching test for selected algorithms

Algorithms	Sample	Pseudo-squared	Wald chi-square (p-value)	Mean standardised bias	Median standardised bias
Nearest neighbour	Unmatched	0.56	334.08 (0.000)	66.80	32.7
	Matched	0.083	7.76 (0.440)	12.30	6.3
Kernel	Unmatched	0.568	334.08 (0.000)	66.8	32.7
	Matched	0.088	5.14 (0.170)	14.1	12.5
Radius	Unmatched	0.568	334.08 (0.000)	66.8	32.7
	Matched	0.071	14.60 (0.480)	18.8	12.9

Furthermore, the Wald chi-square on the joint significance before matching was not rejected (P = 0.000). However, it was rejected for all selected algorithms after matching, indicating that the matching was successful between members and non-members of SPCs (Caliendo & Kopeinig 2008). The algorithms exhibit a mean standardised bias that is less than 20%, indicating that the balancing requirement has been met. The PSM quality test demonstrates successful balancing through the relatively low pseudo-R square, low mean standardised bias, and the insignificance of joint covariates after matching. Furthermore, Figure 1 visually confirms the satisfaction of the common support condition by displaying the estimated PSM scores.

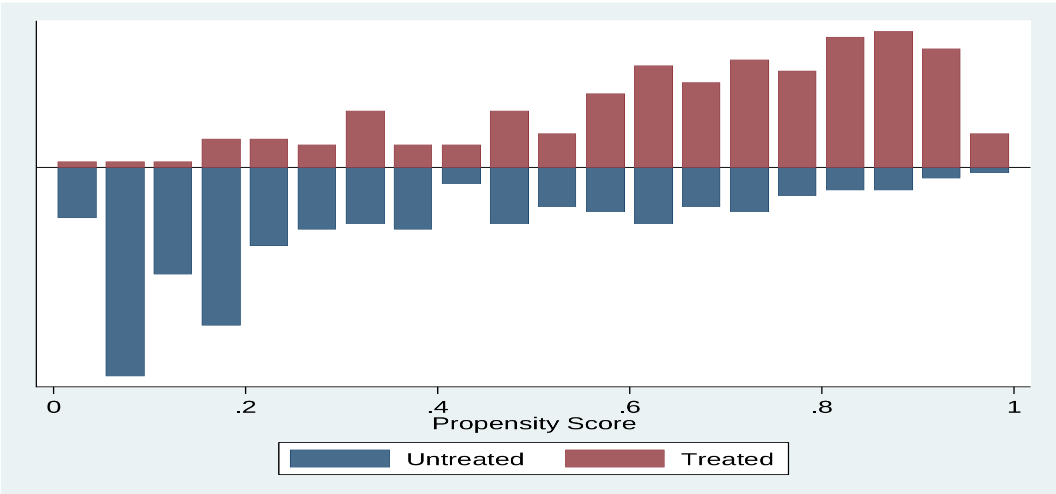

Figure 2: Propensity score distribution and common support for propensity score estimation

The PSM was subsequently employed to assess the impacts of membership of SPCs on the commercialisation of tef and wheat crop output on smallholder farmers engaged in their production in the central highlands of Ethiopia, as well as the effects of the commercialisation of essential inputs like seeds, fertiliser, herbicides and fungicides. The findings presented in Table 4 demonstrate that the estimation outcomes for the average treatment effect on the treated (ATT) of the outcome variables remain consistent across various matching algorithms, indicating the robustness of the estimates.

Table 4: PSM-based average treatment effects of membership of SPCs on outcome variables

Matching algorithm	Outcome variables	Treated	Control	ATT	SE	t-value
Nearest neighbour matching	Tef output market commercialisation	0.585	0.413	0.172***	0.048	3.58
	Wheat output market commercialisation	0.568	0.4433	0.125***	0.029	4.31
	Input commercialisation					
	Tef seed commercialisation	0.579	0.439	0.14***	0.031	4.51
	Wheat seed commercialisation	0.134	0.1032	0.031***	0.012	2.58
	Fertiliser commercialisation	0.163	0.102	0.061***	0.011	5.54
	Herbicide commercialisation	0.143	0.047	0.096***	0.009	10.6
	Fungicide commercialisation	0.09	0.02	0.07***	0.023	3.04
Kernel matching	Tef output market commercialisation	0.585	0.446	0.134***	0.035	3.82
	Wheat output market commercialisation	0.568	0.436	0.132***	0.024	5.5
	Input commercialisation					
	Tef seed commercialisation	0.192	0.055	0.14***	0.048	2.91
	Wheat seed commercialisation	0.13	0.101	0.029***	0.009	3.2
	Fertiliser commercialisation	0.127	0.103	0.024***	0.073	3.28
	Herbicide commercialisation	0.144	0.046	0.098***	0.009	10.8
	Fungicide commercialisation	0.09	0.04	0.05**	0.024	2.08
Radius matching	Tef output market commercialisation	0.579	0.439	0.14***	0.031	4.51
	Wheat output market commercialisation	0.564	0.420	0.141***	0.015	9.4
	Input commercialisation					
	Tef seed commercialisation	0.113	0.028	0.085***	0.03	2.83
	Wheat seed commercialisation	0.15	0.103	0.047***	0.008	5.87
	Fertiliser commercialisation	0.148	0.103	0.045***	0.048	4.4
	Herbicide commercialisation	0.153	0.0046	0.15**	0.07	2.12
	Fungicide commercialisation	0.09	0.048	0.043*	0.024	1.79

Source: Results from own survey in 2023
Note: *** and ** indicate significance at the 1% and 5% levels, respectively

Table 4 presents the average impact of the treatment effect on households, taking into account various pre-intervention characteristics of member and non-member households. The results provide compelling evidence of the substantial impact of membership of SPCs on the level of commercialisation of both outputs and inputs among the surveyed households. All outcome variables, such as tef and wheat output, as well as inputs like fertiliser, herbicides and fungicides, showed statistically significant results. Specifically, the level of commercialisation of tef and wheat output increased from 23% to 29% and 22% to 25%, respectively among member households.

In addition, the level of commercialisation of tef and wheat seed increased from 24% to 75% and 22% to 31%, respectively, compared to the case in non-member households. Moreover, being a part of SPCs led to a significant rise in the commercialisation of fertiliser, herbicide and fungicide – by 19% to 37.4%, 30.4% to 68%, and 48% to 77%, respectively, compared to non-member households. The findings presented herein demonstrate that, among the surveyed individuals, being a member of an SPC positively impacted the level of commercialisation of both tef and wheat crop output and input. The impacts of membership of SPCs on the outcome variables were robust for the matching techniques, and were consistent with the idea that collective action can increase output and input commercialisation for smallholders. This finding is in line with the results of Ito *et al*. (2012) and Verhofstadt and Maertens (2015), who studied the role of agricultural cooperatives in poverty reduction.

3.3.1 Endogenous switching regression estimates of output commercialisation

In order to verify the robustness of the outcomes obtained from PSM, the researchers employed a full information maximum likelihood estimate of the ESR model, which has the ability to manage endogenous selection bias. The model estimated both the decision to become a member of SPCs and the outcome equations jointly. The likelihood ratio tests of independence revealed significant results at a 1% probability level, rejecting the hypothesis that the three equations are jointly independent and demonstrating that the equations are dependent. The estimated coefficients of the selection equations for the commercialisation levels of the tef and wheat crop output are significantly different from zero. This suggests that both observed and unobserved factors influenced the farmers' decisions to join SPCs. This supported the researchers' decision to choose an endogenous switching model, since it handles the problem of endogeneity. The likelihood-ratio tests for the joint independence of the three equations are presented in the last row of Table A1 and Table A2 in the Appendix. The results show significant correlations, with (χ^2 - 157.45, P < 0.002) for Table A1 and (χ^2 - 141.33, P < 0.0000) for Table A2. The tests indicate a relationship between the error term in the selection equation and the error terms in the outcome equations.

The correlation coefficients (ρ1 and ρ2) between membership of SPCs and the levels of commercialisation for tef and wheat crop output (outcome variables) were found to be negative and statistically significant at P < 0.001. This confirms the presence of a selectivity bias in the decision to become a member of an SPC. The negative sign suggests that there is a positive selection bias, meaning that individuals who choose to be SPC members who are tef and wheat farmers tend to have higher levels of output commercialisation compared to similar farmers who are non-members of SPCs. It also suggests that farmers opt to join SPCs due to the comparative advantage they perceive. Members of these cooperatives have higher levels of commercialisation in crop output compared to non-members, who have lower levels of commercialisation. On the other hand, the estimate of the correlation coefficients for non-members of SPCs is statistically insignificant, implying that, without SPC membership, there would be no notable disparity in the average commercialisation level of tef and wheat output between the two categories of farmers. The necessary conditions for consistency are met as well, as rho1 < rho2, indicating that SPC members tend to commercialise crop output more than non-members who are not participating in SPCs (Lokshin & Sajaia 2004).

The results in Tables A1 and A2 in the Appendix show that the age of the household head had a negative and significant influence on the level of commercialisation of tef and wheat output of SPC members, while age squared had a positive and significant influence on the commercialisation of the tef and wheat output of farmers who were SPC members. This suggests that household age has an increasing impact on the commercialisation of tef and wheat output of SPC members, as older households gain more experience in improved agricultural activities and have the necessary resources required for SPC membership than younger households, which have less experience and resources. This result contradicts the findings of Abu (2015), who found that age squared is negatively associated with the quantity of groundnut sales, implying that older farmers sell less groundnut compared to younger farmers.

Total farm income positively influences the quantity of tef and wheat output sold. Higher farm household income presents the opportunity for cultivating large farm sizes via renting and purchasing productivity-enhancing inputs, leading to high output and then large marketable surpluses. The quantity of crop output produced is associated with a higher level of tef and wheat output sales. This is consistent with the work of Abu (2015), who found that household farm income is positively associated with the commercialisation of groundnut output. The finding is also in agreement with the findings of Gebremedhin and Jaleta (2010). The findings also indicate that possessing livestock has a significant impact on the commercialisation of tef and wheat output among member households. This implies that member households have a greater quantity of livestock, such as oxen, and actively participate in the commercialisation of tef and wheat output. Consequently, they are able to allocate resources to enhancing their crop productivity through improved inputs for crop production. This is consistent with the finding of Gebremedhin *et al*. (2009) and Ademe *et al*. (2017), who found that livestock size has a positive impact on the decision to participate in markets.

Furthermore, the size of tef and wheat farmland owned by farmers had a significant and positive impact on the commercialisation of tef and wheat output. With each increment in farm size, the level of commercialisation of tef and wheat output also increased. Given the circumstances in the study areas, expanding the cultivated land is not feasible, hence the only viable solution is to enhance crop productivity through intensified farming methods. This result is consistent with the findings of Bernard *et al*. (2008) and Gebremedhin and Jaleta (2010), who showed that land holding positively affects the share of production that is commercialised by a household. On the other hand, the size of the household exerted a significant and negative effect on the level of commercialisation of the tef and wheat output of member households. The presence of a negative sign implies that, as the household size increases, the quantity of tef and wheat output sold in the market diminishes due to the fact that households tend to utilise the outputs for their own consumption. This finding is contrary to the finding of Dube and Guveya (2016), who found that household size significantly and positively influenced commercialisation at the 5% level of significance.

The positive and statistically significant education level of the head of a farm household indicates that those with higher education are more likely to engage in the commercialisation of tef and wheat output. This finding aligns with the belief that education plays a crucial role in assisting farmers to make informed decisions regarding the adoption of new innovations, technologies and social networks (Abdulai & Huffman 2014). Furthermore, it is consistent with the research conducted by Gebremedhin and Jaleta (2010), who found that an increase in the education level of the household head leads to a 6% average increase in the proportion of output sold, and a 7% increase in the likelihood of participating in the output market as a seller.

The results indicate that regular contact with extension services and access to training on improved tef and wheat seed production, management and marketing have been found to have a positive and significant impact on the level of commercialisation of tef and wheat output among members of SPCs. This suggests that farmers who receive frequent extension visits and participate in training are more likely to engage in the commercialisation of tef and wheat output. This finding aligns with the research conducted by Abdulai and Huffman (2014), which highlighted the role of agricultural extension services in providing farmers with valuable information on improved technologies. On the other hand, the distance to the offices of SPCs had a significant negative impact on the commercialisation of tef and wheat output ($p < 0.1$). Households residing at distant locations from the SPC office were less inclined to become members of SPCs, resulting in lower participation in the commercialisation of tef and wheat output, likely due to higher transaction costs. This finding aligns with previous studies conducted by Bekele and Alemu (2015) and Gebremedhin and Jaleta (2010), which highlighted that distance to market hinders participation in crop output markets by increasing marketing costs.

Tables A1 and A2 in the Appendix present the results of the effect of membership of SPCs on the commercialisation of tef and wheat output for smallholder farmers. Columns 4 and 5 and 6 and 7 represent the results for members and non-members, respectively. The estimates indicate the impact of SPC membership on the levels of commercialisation of tef and wheat output. As mentioned earlier, the model requires the inclusion of at least one variable in the selection equation or SPC membership equation that is not present in the outcome equations. In the specification of the commercialisation levels of tef and wheat output, the presence of an SPC in the household’s residential village, and membership of the sampled household’s relatives in seed cooperatives (peer influence) were used as identification instruments. These variables influenced membership decisions, but did not have an impact on the commercialisation levels of tef and wheat output.

3.3.2 Endogenous switching regression estimates of input commercialisation

Tables A3, A4, A5, A6 and A7 in the Appendix display the impact of membership of an SPC on the outcome variables, including improved tef and wheat seeds, as well as the levels of commercialisation of fertilisers, herbicides and fungicides. The results are presented in columns 4 and 5 for SPC members, and in columns 6 and 7 for non-members. The estimates reveal the impact of membership of SPCs on members and non-members. The signs and significance of the correlation coefficients ($\rho1$ and $\rho2$) between membership of SPCs and the outcome variables demonstrate that self-selection occurred in relation to SPC membership. This implies that SPC membership may not have the same impact on non-members if they opt to be members (Abdulai & Huffman 2014). The necessary conditions for consistency are also met, as rho1 < rho2 suggests that SPC members achieve higher levels of input commercialisation compared to non-members of SPCs if they did not become a member of an SPC (Lokshin & Sajaia 2004).

The findings indicate that the size of farmland holdings of the household, the availability of training opportunities, ownership of livestock, total income generated and membership of other farmers' organisations were key factors in promoting the commercialisation of tef seeds among members of SPCs. In addition, the size of the household, educational attainment of the head of the farming household, and frequency of extension contact had a positive and significant impact on the commercialisation of tef seeds for both members and non-members of SPCs.

In the same vein, the commercialisation of wheat seeds was found to be positively and significantly influenced among members of SPCs by factors such as the size of the household, educational level of the head of the farm household, livestock ownership, and total income earned. Furthermore, access to training and frequency of extension contact were also found to have a positive and significant impact on the commercialisation of wheat seeds, regardless of whether individuals were members or non-members of SPCs. In contrast, the distance from the SPC office was found to have a negative and significant effect on the level of commercialisation of tef and wheat seeds.

The findings reveal that age squared and the access to training had a positive and statistically significant influence on the commercialisation of inorganic fertilisers, including urea and NPS (nitrogen, phosphorus and sulfur), for members of SPCs. The size of the household, the educational attainment of the household head, the overall income generated from farming by the household head, the total land area managed by the household head, as well as the participation in other agricultural associations like agricultural cooperatives had a positive and significant influence on the commercialisation of inorganic fertilisers for both members and non-members of SPCs. This suggests that, as farmers grow older, they gain expertise in utilising inorganic fertilisers to enhance the efficiency of their farming practices, as well as have financial capital to afford the acquisition of inorganic fertilisers. In addition, they can leverage the knowledge of development agents to effectively utilise improved inputs and increase the productivity of their farming endeavours. The results also imply that, as household size increases, farming households are compelled to use inorganic fertilisers to enhance productivity and meet both market and personal consumption needs. The finding aligns with the research conducted by Ademe *et al*. (2017), which revealed that the degree of involvement of farm households in the annual crop fertiliser market as purchasers is influenced by the size of the cultivated land. Conversely, the commercialisation of fertiliser by non-members of SPCs who produce tef and wheat is influenced by the frequency of extension contact. Table A5 in the

Appendix presents the impact of SPC membership on the marketing of inorganic fertilisers to smallholder tef and wheat farmers.

The findings also indicate that several factors had a positive and significant influence on the participation of tef and wheat farmers who were members of SPCs in the herbicide market. These factors include the education level of the household head, ownership of livestock, total farm income, and contact with extension services. These variables were found to have a positive and significant impact on farmers' decisions to purchase herbicides for weed control, with a level of significance of $P < 0.001$. The findings imply that farm households with higher levels of education, a substantial number of livestock for both draft and income purposes, and stronger financial capabilities were more likely to engage in the use of herbicides for weed control in their tef and wheat production, as well as in the production of high-quality seeds for the market. In addition, the size of land owned by the farm household, membership of agricultural cooperatives and farming experience also played a crucial role in farmers' herbicide purchases. These factors had a positive and statistically significant effect on both members and non-members of SPCs ($P < 0.001$). The impact of SPC membership on the commercialisation of herbicides among smallholder tef and wheat farmers is shown in Table A2 in the Appendix, specifically in columns 4 and 5 for members and columns 6 and 7 for non-members.

The findings of the study indicate that various factors had a significant impact on market participation in the purchase of fungicide by members and non-members of seed cooperatives. For members of SPCs, factors such as membership of other farmers' organisations, farm size, extension services provided by extension personnel, and farming experience in tef and wheat production were positively and significantly associated with fungicide commercialisation. On the other hand, factors such as household size, access to training and teff and what production, and ownership of livestock positively and significantly influenced the commercialisation of fungicides for non-members of SPCs. The results imply that being a member of an agricultural cooperative increases access to fungicide purchases at a reasonable price. In addition, extension agents play a crucial role in helping farmers acquire the necessary skills to use fungicides effectively, thereby increasing their participation in the market as fungicide purchasers. Furthermore, an increase in farm size also increases the probability of fungicide purchase. This finding is consistent with a previous study conducted by Ahmed and Mesfin (2017) in Ethiopia, which found a positive and significant association between farm size, farming group membership, and the adoption of improved technologies. Table A3 in the Appendix presents the impact of membership of SPCs on the commercialisation of fungicides among smallholder tef and wheat farmers. This impact can be observed in columns 4 and 5 for members and columns 6 and 7 for non-members.

3.4 Endogenous switching regression model impacts estimate results

Table 5 displays the findings from the full information maximum likelihood (FIML) endogenous switching-regression analysis. The results include the average effects on the treated (ATT), the average treatment effects on the untreated (ATU), the heterogeneity effects, and the transitional heterogeneity. The treatment effect, presented in the second-last column, illustrates the effect of membership of SPCs on both members and non-members (i.e. ATT and ATU). In addition, the transitional heterogeneity (TH) is found to be positive, except for wheat seed and fungicide, indicating that the impact of SPC membership on tef and wheat output, as well as input commercialisation (such as tef seed, inorganic fertiliser and herbicide), is significantly greater for farmers who are members compared to non-members. Furthermore, the base heterogeneity effect (BH1) demonstrates the influence of inherent characteristics of farm households on the commercialisation levels of crop output and input. On the other hand, BH2 reveals that SPC members would experience better outcomes even if they had not been members, suggesting the presence of some heterogeneity that allows commercialisation of tef and wheat output and inputs in the market compared to non-members.

Table 5: Expected conditional and average treatment effects of SPC membership on the commercialisation of tef and wheat output and inputs

Outcomes variables	Sub-samples	Decision stages		Treatment effect	t-value
		To be member	Not to be member		
Commercialisation of tef output	**Members**	0.8976139 (a)	0.5110779 (c)	0.3865 (ATT)	35.49***
	Non-members	0.592279 (d)	0.495774 (b)	0.0965 (ATU)	13.04***
	Heterogeneity effect	0.30533 (H1)	0.015304 (H2)	0.290026 (TH)	
Commercialisation of wheat output	**Members**	0.79448 (a)	0.55188 (c)	0.2426 (ATT)	12.06***
	Non-members	0.58815 (d)	0.51926 (b)	0.0688 (ATU)	6.203***
	Heterogeneity effect	0.20633 (H1)	0.03262 (H2)	0.17371 (TH)	
Commercialisation of inputs					
Commercialisation of tef seed	Members	0.38444 (a)	0.05501 (c)	0.329432 (ATT)	8.6***
	Non-members	0.25357 (d)	0.04701 (b)	0.20656 (ATU)	7.05***
	Heterogeneity effect	0.130874	0.007997	0.206555 (ATT)	
Commercialisation of wheat seed	**Members**	0.12402 (a)	0.04177 (c)	0.08225	5.23***
	Non-members	0.11418 (d)	0.01343 (b)	0.100756 (ATU)	3.94***
	Heterogeneity effect	0.009838	0.028343	-0.018506	
Commercialisation of fertiliser	**Members**	0.1616144 (a)	0.106768 (c)	0.054846	4.66***
	Non-members	0.1568019 (d)	0.1029885 (b)	0.053813	9.78***
	Heterogeneity effect	0.004813	0.00378	0.001033	
Commercialisation of herbicides	**Members**	0.11144 (a)	0.01061 (c)	0.100835	4.28***
	Non-members	0.02015 (d)	0.0066 (b)	0.013546	3.21***
	Heterogeneity effect	0.091294	0.004004	0.08729	
Commercialisation of fungicides	**Members**	0.03022 (a)	0.02166 (c)	0.008564	3.89***
	Non-members	0.02607 (d)	0.01519 (b)	0.010879	4.10***
	Heterogeneity effect	0.004149 (BH_1)	0.006465 (BH_2)	-0.0023 (TH)	

Notes: (a) and (b) denote observed outcomes (commercialisation levels of crop output and inputs); (c) and (d) denote counterfactual outcomes (commercialisation levels of crop output and inputs).

The findings indicate that SPC membership had a significant impact on the commercialisation levels of tef and wheat output for member households, with 89.8 and 79.5 percentage points respectively. On the other hand, the commercialisation levels were about 49.6 and 51.9 percentage points for non-members if they chose to become members of SPCs. Regarding the commercialisation levels of inputs such as tef and wheat seeds, fertiliser, herbicide and fungicide, the causal effects for SPC members were measured at 38.4, 12.4, 16.2, 11.1 and three percentage points respectively. However, if non-members decided to become members, the impact was about 4.7, 1.3, 10.3, 0.66 and 1.5 percentage points respectively. It is important to note that this straightforward comparison can be deceptive, as it might give the impression that households that joined SPCs experienced a 40.2 percentage point increase in commercialisation levels of tef output and a 27.5 percentage point increase in commercialisation levels of wheat output compared to non-member households.

However, the findings on the average treatment effect indicate that the commercialisation level of tef and wheat output for households that are members of SPCs (Equation 6a) would have commercialised by 38.7 and 24.3 percentage points respectively (i.e. had SPC members not participated in the seed cooperative, their average commercialisation levels of tef and wheat output would have decreased by 43 and 31 percentage points respectively (Equation 6c)). This is an average treatment effect on the treated (ATT), or a difference between members in tef and wheat output commercialisation levels if they had not been members. On the other hand, households that are not actually members (6b) would have had tef and wheat output commercialisation levels of about 9.7 and 6.9 percentage points (i.e.

about 19.5 and 13.3 percentage points higher commercialisation levels of tef and wheat output respectively if they had been cooperative members (7d), i.e. the average treatment effect on the untreated (ATU)). In contrast, the commercialisation levels of tef and wheat seeds for members of SPCs (6a) would have been 33 and 8.2 percentage points respectively (i.e. had SPC members not participated in seed cooperatives, their average commercialisation levels of tef and wheat seeds would have decreased by 85.7 and 66.3 percentage points respectively (6c)). Similarly, households that were not actually members (6b) would have had tef and wheat seed commercialisation levels of about 21% and 10% (i.e. about 439% and 750% higher levels of tef and wheat seed commercialisation respectively if they had been cooperative members (7d), i.e. the average treatment effect on the untreated (ATU)). Similar interpretations can also be made for the results of other inputs, such as fertiliser, herbicide and fungicide.

Similar to the findings of the PSM, the ESR model indicates a positive relationship between membership of SPCs and the commercialisation of smallholder tef and wheat farmers' output and inputs. Hence, the results imply that joining SPCs substantially enhances the level of commercialisation of both household output and inputs in tef and wheat farming. These findings are similar to the findings of Mwaura *et al*. (2020), Kanburi Bidzakin *et al*. (2019), Mojo *et al*. (2017b), Kirui and Njiraini (2013) and McCarthy and Essam (2009), who found that cooperative membership had a significant influence on household welfare, smallholder agricultural commercialisation and income, household income and assets, farm performance and rural household welfare through increased household income respectively.

4. Conclusions and recommendations

Aside from minor variations in the extent of impact between the PSM and ESR estimates, membership of seed producer cooperatives had a positive impact on the commercialisation of tef and wheat output, as well as the commercialisation of inputs such as improved seeds, fertiliser, herbicide and fungicide. This implies that the findings have the potential to enhance the existing knowledge on the impact of SPCs on the commercialisation of output and inputs in Ethiopia. It was observed that farmers have the opportunity to become members of seed producer cooperatives, provided they fulfil the requirements set by the SPCs. Nevertheless, it is of the utmost importance to handle the membership process with caution so as not to impede the ability of seed-producer cooperatives to generate top-notch seeds and achieve significant levels of commercialisation. The findings show that capacity-building initiatives for members of seed-producer cooperatives are a crucial factor in improving the commercialisation levels of crop output and inputs. In addition, it was noted that investing in agricultural machines would significantly elevate the overall standard of seed production and commercialisation. These measures would not only improve the livelihoods of rural households by increasing their level of commercialisation, but also contribute to bolstering food security – both within the study area and across the potential tef- and wheat-production areas in the country. Hence, it can be inferred that SPCs have a significant impact on transforming smallholders from subsistence farming to a more commercially focused approach in tef and wheat production, which has the potential to uplift farmers from poverty.

The study further highlights the positive impact of seed-producer cooperatives in enhancing the commercialisation of farmers' output and inputs, as well as their provision of marketing services. However, there are certain limitations that need to be considered. Firstly, the study is confined to the central highland areas of Ethiopia, specifically the Adea and Lume districts of the country, due to financial and time limitations, whereas tef and wheat production and SPCs extend to a wider range of areas in the country. Moreover, relying solely on cross-sectional data may not capture the complete historical context, underscoring the need for future studies that use panel and longitudinal data to involve a larger and more diverse group of SPC participants. These future studies should explore the various impacts of SPCs on seed availability, quality, security, prices and employment opportunities, productivity and food security, thus contributing to a more comprehensive understanding of the long-term impacts of SPCs and offering valuable insights for policymaking.

The aforementioned findings and conclusions lead to the following recommendations. To improve the well-being of SPC members, the government should devise mechanisms to ensure that basic seeds are accessible at a reasonable cost. One potential solution to this challenge should involve introducing a subsidy programme for basic seed prices tailored specifically to SPC members. This initiative would enable them to provide high-quality seeds to other farmers at a fair price, particularly benefiting smallholder farmers with limited resources. Governments and development partners should deliver training for SPC members on the production of quality seed and on the management of their farm operations. Furthermore, government and development partners should assist SPCs in setting up seed-storage facilities and acquiring winnowing machines. These resources will enable SPCs to store seeds efficiently and preserve their quality, ultimately contributing to improved agricultural productivity and sustainability.

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Appendix

Table A1: Endogenous switching regression estimates of the commercialisation of tef output

Variables			**Level of commercialisation of tef output**			
	SPC membership		**SPC members**		**SPC non-members**	
	Coef.	**Std err**	**Coef.**	**Std err**	**Coef.**	**Std err**
Age	-0.011*	0.0055	-0.011**	0.0059	0.007	0.006
Age squared	0.0001**	0.00005	0.012**	0.005	0.00006	0.00007
Sex	0.424	0.231	0.035	0.043	0.003	0.051
Household size	-0.112**	0.056	-0.020***	0.004	-0.009*	0.005
Educational level	0.106**	0.046	0.006**	0.003	0.002	0.003
Livestock holding (TLU)	0.348***	0.057	0.011***	0.0048	0.008**	0.004
Ln total income	1.51***	0.264	0.11***	0.03	0.19***	0.016
Ln tef farm land size	0.96 ***	0.193	0.04**	0.018	0.107	0.025
Access to training	3.22***	0.345	0.29***	0.038	0.039	0.035
Extension contacts	0.121**	0.059	0.07***	0.005	0.012	0.027
Membership of other farmers' organisations	2.76**	1.19	0.025	0.102	0.014	0.164
Distance to SPC office	-0.98***	-0.004	-0.007*	0.004	-0.002	0.004
Off-farm income	0.009	0.001	4.70e-07	1.51e-06	8.16e-07	7.93e-07
Adea	0.95	1.6	0.231	0.159	0.016	0.085
Lume	0.42	0.68	0.183	0.157	0.073	0.083
_cons	-6.73***	2.29	-0.739***	0.032	-0.57*	0.31
/lns1	0.836***	0.239				
/lns2	0.9081***	0.11				
/r1	-0.244	0.088				
/r2	2.65	0.303				
Sigma 1	0.159	0.038				
Sigma 2	0.403	0.045				
Rho (ρ1)	-0.854 ***	0.066				
Rho (ρ2)	-0.240***	0.77				
Log likelihood	-62.078					
Wald test χ^2 (15)	123.67					
LR test of independent equations χ^2 (1) -157.45***						

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively; sigma 1 and sigma 2 are the square roots of the variances of the residuals of the regression part of the model, and lns is their log. /r1 and /r2 are the transformation of the correlation between the errors from the two equations.

Table A2: Endogenous switching regression estimates of the commercialisation of wheat output

Variables			Level of commercialisation of wheat output			
	SPC membership		SPC members		SPC non-members	
	Coef.	Std err	Coef.	Std err	Coef.	Std err
Age	-0.020***	0.007	-0.034***	0.0012	-0.04***	0.01
Age squared	0.037**	0.149	0.088***	0.009	0.092	0.56
Sex	-0.164	0.289	-0.0039	0.044	0. 063	.044
Household size	-0.087**	0.042	-0.054***	0.0075	-0.004	0.006
Educational level	0.064***	0.022	0.245***	0.034	0.0008	0.0032
Livestock holding (TLU)	072***	0.023	0.74***	0.22	0.07**	0.03
Ln total income	0.292***	0.0305	0.55***	0.20	0.4***	0.098
Ln wheat farm land size	0.16***	0.071	0.64***	0.09	0. 020	0.017
Access to training	1.00***	0. 153	0.23**	0.11	0.047	0.046
Extension contacts	0.31***	0.087	0.03***	0.007	0.38	0.51
Membership of other farmers' organisations	0.322***	0.112	0.033	0.204	0.061	0.292
Distance to SPC office	-0.032***	0.009	-0.09**	0.03	-0.005	0.006
Off-farm income	0.008	0.005	0.57	0.79	0.29	0.75
Adea	0.98	0.611	0.231	0.159	0.016	0.085
Lume	1.45***	0.61	0.183	0.157	0.073	0.083
_cons	-3.818***	0.797	-0. 72***	0.12	-0.89***	0.18
/lns1	1.82***	0.073				
/lns2	1.92***	0.076				
/r1	-0. 397	0.024				
/r2	0.245	0.394				
Sigma 1	0.16	0.012				
Sigma 2	0.15	0. 011				
Rho (ρ1)	-0.387***	0.021				
Rho (ρ2)	-0. 541	0. 371				
Log likelihood	-62.34					
Wald test χ^2 (15)	140.58					
LR test of independent equations χ^2 (1) -1 279.5***						

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A3: Endogenous switching regression estimates of the commercialisation of tef seed

Variables			Commercialisation of tef seed			
	SPC membership		SPC members		SPC non-members	
	Coef.	Std err	Coef.	Std err	Coef.	Std err
Age	0. 005***	0.002	-0.0001	0.0005	-0.002	0.002
Age squared	0.015	0.042	0.053	0.006	0.071	0.084
Sex	-0.040	0.081	-0.0094	0.016	-0.040	0.086
Household size	0.002	0.015	0.57***	0.047	0.093***	0.0124
Educational level	0.017***	0.0061	0.30***	0.11	0.045***	0.0063
Livestock holding (TLU)	0.019***	0.0063	0.0083***	0.001	0.073	0.066
Ln total income	0.451**	0.203	0.43***	0.052	0.091	0.087
Ln tef farm land size	0.043*	0.024	0.75***	0.049	0. 060	0.039
Access to training	0.264***	0.038	0.094***	0.009	0.058	0.062
Extension contacts	0.106**	0.052	0.08***	0.033	0.54***	0.071
Membership of other farmers' organisations	0.341***	0.142	0.19***	0.017	0.109	0.294
Distance to SPC office	-0.001**	0.001	-0.39***	0.032	-0. 029	0.072
Off-farm income	0.003	0.0021	0.13	0.35	0.75	0.92
Adea	0 .250	0.173	0.0179	0.032	0. 024	0.153
Lume	0.39***	0.17	0.017	0.032	0.024	0.151
_cons	-4.78***	0.899	-0.54***	0.066	-0.68***	0.037
/lns1	0.88***	0.050				
/lns2	1.23***	0 .049				
/r1	-0.273	0.046				
/r2	0.37	0.071				
Sigma1	0.411	0.0207				
Sigma2	0.290	0.0142				
Rho (ρ1)	-0.089***	0.0074				
Rho (ρ2)	-0.375	0.714				
Log likelihood	-258.41					
Wald test χ^2 (15)	159.72					
LR test of independent equations χ^2 (2) -283.06***						

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A4: Endogenous switching regression estimates of the commercialisation of wheat seed

Variables			Commercialisation of wheat seed			
	SPC membership		SPC members		SPC non-members	
	Coef.	Std err	Coef.	Std err	Coef.	Std err
Age	0.0064***	0.0018	-0.000043	0.0002	-0.0023	0.002
Age squared	0.009	0.071	0.082	0.0074	0.056	0.093
Sex	-0.069	0.068	-0.009	0.0075	-0.0055	0.0130
Household size	0.00011	0.0123	0.069***	0.012	0.00073	0.0026
Educational level	0.010**	0.0056	0.016***	0.0150	0.00118	0.0063
Livestock holding (TLU)	0.11***	0.0068	0.068***	0.014	0.00186	0.00129
Ln total income	0.291***	0.030	0.014***	0.0028	0.0047	0.0064
Ln wheat farm land size	0.18***	0.052	0.0092	0.03	0.027***	0.0042
Access to training	0.191***	0.038	0.0128***	0.0031	0.016***	0.0065
Extension contacts	0.0221***	0.0068	0.024***	0.0075	0.0029***	0.00098
Membership of other farmers' organisations	0.319***	0.112	0.00062	0.0085	0.0185	0.045
Off-farm income	0.00068	0.0006	0.0076	0.0059	0.0055	0.0044
Distance to SPC office	0.00175***	0.0005	0.019***	0.005	0.0018	0.004
Adea	0.190	0.126	0.0179	0.032	0.024	0.153
Lume	0.287***	0.123	0.017	0.032	0.024	0.151
_cons	-4.78***	0.899	-0.118***	0.0095	0.237***	0.073
/lns1	2.51***	0.056				
/lns2	2.14***	0.054				
/r1	-5.50	0.77				
/r2	4.74	0.94				
Sigma1	0.080	0.0045				
Sigma2	0.116	0.0063				
Rho (ρ1)	-0.099***	0.0032				
Rho (ρ2)	0.089	0.714				
Log likelihood	-335.7					
Wald test χ^2 (15)	775.30					
LR test of independent equations χ^2 (2) -187.29***						

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A5: Endogenous switching regression estimates of fertiliser commercialisation

Variables			**Commercialisation of fertiliser by tef and wheat farmers**			
	SPC membership		**SPC members**		**SPC non-members**	
	Coef.	**Std err**	**Coef.**	**Std err**	**Coef.**	**Std err**
Age	0.0142	0.0089	0.00043	0.0004	0.0005	0.0006
Age squared	0.008	0.088	0.008***	0.0021	0.05	0.031
Sex	-0.082	0.070	-0.0035	0.0127	-0.009	0.016
Household size	0.059***	0.0127	-0.044***	0.0125	0.085***	0.025
Educational level	0.011*	0.0059	0.055***	0.0108	0.108***	0.026
Livestock holding	0.109	0.07	0.0225	0.019	0.026	0.028
Ln total farm income	0.324***	0.032	0.397***	0.09	0.088***	0.06
Ln farm land size	0.075***	0.030	0.0090**	0.004	0.26***	0.0104
Access to training	0.205***	0.038	0.037***	0.0147	0.0252	0.0173
Extension contacts	0.0062	0.007	0.0071	0.022	0.015***	0.0056
Membership of other farmers' organisations	0.313***	0.1075	0.029***	0.005	0.04***	0.014
Distance from SPC office	0.018***	0.0057	-0.042	0.054	-0.066	0.077
Off-farm income	0.079	0.0085	0.009	0.0073	0.013	0.008
Adea	0.042	0.420	0.042	0.031	0.0075	0.022
Lume	0.770*	0.413	0.0204	0.013	0.041	0.099
Constant	-11.64	2.235	-0.168***	0.081	0.7***	0.064
/lns1	0.586	0.052				
/lns2	1.90	0.0516				
/r1	-0.59	0.048				
/r2	-0. 972	0.581				
Sigma1	0.556	0.0289				
Sigma2	0.148	0.0076				
Rho (ρ1)	-0.799***	0.065				
Rho (ρ2)	-0. 599	0.382				
Log likelihood	-64.089					
Wald test χ^2 (15)	110.89					
LR test of independent equation 417.23						

Source: Results from own survey in 2023
Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A6: Endogenous switching regression estimates of herbicide commercialisation

Variables			**Commercialisation of herbicide by tef and wheat farmers**			
	SPC membership		**SPC members**		**SPC non-members**	
	Coef.	**Std err**	**Coef.**	**Std err**	**Coef.**	**Std err**
Age	0.0134	0.009	0.063	0.038	0.0366	0.061
Age squared	-0.129	0.0085	0.04	0.044	0.051	0.046
Sex	-0.036	0.065	0.0045	0.0080	0.0049	0.0177
Household size	-0.0024	0.0117	0.0034	0.015	0.027	0.019
Educational level	0.0143***	0.0057	0.0137***	0.0048	0.00095	0.001
Livestock holding	0.0157***	0.0065	0.072***	0.0054	0.017	0.0148
Ln total farm income	0.292***	0.0293	0.0093**	0.0046	0.00169	0.0011
Ln farm land size	0.0228	0.0188	0.0147***	0.0014	0.0183***	0.006
Access to training	0.2032***	0.038	0.0043	0.0049	0.086	0.084
Extension contacts	0.020	0.0067	0.0015***	0.0003	0.00087	0.0019
Membership of other farmers' organisations	0.319***	0.1088	0.0072***	0.0027	0.116***	0.011
Farm experience	0.008***	0.003	0.005***	0.0004	0.098***	0.0077
Distance from SPC office	0.0018***	0.00055	-0.00042	0.0013	-0.066	0.077
Off-farm income	0.012	0.007	0.0071**	0.0039	0.00116	0.001
Adea	0.232***	0.121	0.042	0.031	0.0075	0.022
Lume	0.326***	0.119	0.0204	0.013	0.041	0.099
_cons	-20.064	2.311	-0.168***	0.081	0.7***	0.064
/lns1	4.36	0.062				
/lns2	2.13	0.0576				
/r1	-4.50	0.473				
/r2	-4.90	0.243				
Sigma1	0.0127	0.0007				
Sigma2	0.119	0.0067				
Rho (ρ1)	-0.845***	0.059				
Rho (ρ2)	0.552***	0.046				
Log likelihood	-575.52					
Wald test χ^2 (15)	117.54					
LR test of independent equation 342.02						

Source: Results from own survey in 2023
Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively

Table A7: Endogenous switching regression estimates of fungicide commercialisation

Variables			Commercialisation of fungicide by tef and wheat farmers			
	SPC membership		SPC members		SPC non-members	
	Coef.	Std err	Coef.	Std err	Coef.	Std err
Age	0.058	0.038	0.053	0.076	0.025	0.053
Age squared	-0.00562	0.0034	0.04	0.069	0.037	0.052
Sex	-0.120	0.283	-0.009	0.0107	-0.0076	0.0175
Household size	0.0312	0.050	0.012	0.074	0.087***	0.014
Educational level	0.067***	0.0261	0.008	0.049	0.015	0.011
Livestock holding	0.0712***	0.029	0.033	0.085	0.044***	0.015
Ln total farm income	1.22	0.165	0.134***	0.037	0.093**	0.036
Ln farm land size	0.093	0.085	0.0103***	0.0040	0.0082	0.024
Access to training	0.962***	0.179	0.002	0.0038	0.00045**	0.0002
Extension contacts	0.0122	0.029	0.155***	0.0202	0.0054	0.08
Membership of other farmers' organisations	1.46***	0.488	0.15***	0.012	0.0027	0.006
Farm experience	0.0349***	0.0124	0.210***	0.014	0.024	0.051
Distance from SPC office	-0.0079***	0.0025	0.0048	0.008	0.053	0.05
Off-farm income	0.091	0.087	0.013	0.096	0.074	0.089
Adea	1.026*	0.54	0.14***	0.008	0.0141	0.08
Lume	1.41***	0.53	0.54***	0.096	0.054	0.09
_cons	-19.08***	2.19	-1.66***	0.097	-1.89***	0.140
/lns1	1.52***	0.0525				
/lns2	6.3***	0.536				
/r1	-5.35	0.56				
/r2	1.33	0.82				
Sigma1	0.218	0.0035				
Sigma2	0.178	0.0095				
Rho (ρ1)	-0.93***	0.0032				
Rho (ρ2)	0.87	0.051				
Log likelihood	-224.064					
Wald test χ^2 (16)	169.6					
LR test of independent equation -264.77						

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels respectively