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## Article

The impact of Korra tef (*Eragrostis tef*) adoption on commercialization status of tef producing farmers in Northwestern Ethiopia: A propensity score matching analysis

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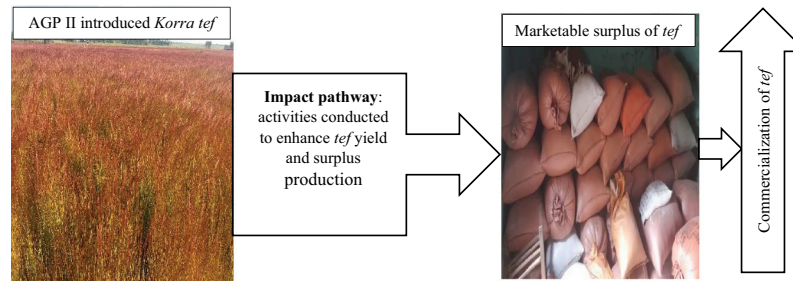
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## DEVELOPMENT ECONOMICS | RESEARCH ARTICLE

# The impact of *Korra tef* (*Eragrostis tef*) adoption on commercialization status of *tef* producing farmers in Northwestern Ethiopia: A propensity score matching analysis

Solomon Zewdu Leul<sup>1,2\*</sup>, Alemu Azmeraw Bekele<sup>3</sup>, Alemseged Gerezgiher Hailu<sup>3</sup> and Solomon Tsehay Feleke<sup>4</sup>

**Abstract:** The government and other development practitioners in Ethiopia have promoted crop technologies like improved *tef* varieties to improve crop productivity of farmers and, in turn, their commercialization status. The commercialization impacts of these crops, however, were not thoroughly examined. This study examined the commercialization impact of adopting improved *tef* variety (*Korra*) in



Solomon Zewdu Leul

### ABOUT THE AUTHORS

Solomon Zewdu Leul is a Doctoral candidate in development studies at Addis Ababa University, and a Lecturer of Sociology and Social Development at Debre Berhan University, Ethiopia. His research interest includes social dimensions of development, agriculture and rural development, environment, development economics, poverty, labor and social protection, social policy, project management, and impact evaluation.

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### PUBLIC INTEREST STATEMENT

*Tef* (*Eragrostis tef*) is a staple food in the country, commonly used to prepare '*Enjera*', the main public dish. As one of the newest superfoods of the twenty-first century, like the ancient Andean grain quinoa, its global adoption is rapidly increasing, and it is now riding the gluten-free wave as the next super grain on the market. With this, it is expected to become a new super crop, increasing global demand; and possibly the next super grain, and '*Enjera*' may be the world's next superfood. However, little investment has been made to improve crop productivity or expand its market, and its desired contribution to improving producers' commercialization status is alleged to be inadequate. To that end, it is widely acknowledged that the lack of adoption of the high-yielding *tef* variety is one of the major reasons for the slow progress of its productivity and commercialization. As a result, the purpose of this research is to investigate the commercialization impact of the new *tef* variety called *Korra* on smallholder farmers.

North-western Ethiopia using cross-sectional data of 479 tef producer farm households drawn from two districts, one from the adopters and the other from non-adopters. A multi-stage sampling procedure was followed to select the respondents. A semi-structured questionnaire was used as a principal primary data collection method to collect household survey data, and interviews were conducted with the relevant key informants of the study. The extent of smallholder commercialization was examined using the Household Commercialization Index (HCI), and the impact of *Korra tef* adoption on adopters' commercialization was estimated using Propensity Score Matching (PSM). The HCI result revealed that 46.95% of sampled farmers sold tef during 2020; while it was 58.92% and 36.7% for the adopters and non-adopters, respectively. This indicated that the non-adopters and adopters were, respectively, semi- and commercialized. The PSM result also revealed a positive and significant impact on households' tef commercialization, with the adopters' commercialization rate exceeding the non-adopters by about 23.43%. Hence, efforts should focus on ensuring that farmers have access to sufficient quantities of high-quality improved *Korra tef* seed as well as encouraging improved access to institutional services for the same.

**Subjects:** Development Studies; Development Policy; Rural Development; Economics and Development; Regional Development; Research Methods in Development Studies; Sustainable Development; Economics

**Keywords:** *Korra tef*; Agricultural Growth Program II; adopters; non-adopters; household commercialization index; impact assessment

## 1. Introduction

Agriculture is a mainstay of the Ethiopian economy. Through its contribution to employment, foreign exchange profits, industrial inputs, and food production, it has continued to play a significant role in the economy. Around 79% of the population is employed therein, it accounts for 79% of foreign earnings, contributes 27.5 billion dollars or around 33.88% of the GDP, and is the main source of raw materials and capital for investment and the market (Diriba, 2020; O'Neill, 2021; Wendimu, 2021). As a result, it has a huge impact on a considerable number of people's livelihoods, food security, reduction of poverty, employment, income, socioeconomic development, and environmental sustainability (Diriba, 2020; Shikur, 2020; Welteji, 2018). However, the country's smallholder farmers, who constitute the bulk of the rural poor of whom only 14% possess more than 2 hectares of farmland, are not fully benefited from the multiple functions of agriculture (Diriba, 2020; Wendimu, 2021). Only households that farm more than two hectares of land are currently able to achieve basic subsistence under normal circumstances (Diriba, 2020). Due to the practice of subsistence-oriented agriculture, studies showed that the majority of the country's smallholder farmers have been excluded from the formal market system and corresponding income-mediated privileges (Beyene, 2018; Demeke & Haji, 2014). As a result, the level of agricultural commercialization for smallholders in the country remained low (Alemu & Berhanu, 2018; Tesfahun et al., 2021).

Since smallholder commercialization is the major pathway from a semi-subsistence agrarian society to a more diversified and food-secure economy, most development practitioners view it as a critical component of the structural transformation (Orr et al., 2021). Additionally, it is argued that smallholder commercialization can greatly increase income and welfare, support overall economic expansion, and lessen poverty (Shadreck et al., 2013). It is crucial for the development and expansion of economies of countries that depend heavily on agriculture (Cheber, 2018). In Ethiopia, one of the agrarian countries, the government's agricultural development policies and

plans have long been focused on transforming smallholder farmers' subsistence-oriented production system into a market-oriented production system (Aman et al., 2014; Gebre-Ab, 2006). For example, to increase competitiveness in domestic, regional, and global markets, the Growth and Transformation Plans (GTP I and II) implemented from 2010–11 to 2019–2020 have encouraged the production and marketing of high-value agricultural products. As a result, significant resources have been channeled toward agricultural commercialization through regular agricultural extension activities and with the assistance of development partners (Gebremedhin & Jaleta, 2010; Getahun, 2020; Tesfahun et al., 2021).

One of the government's partners in agricultural development is the Agricultural Growth Program phase 2 (AGP II). The program has promoted and supplied improved agricultural inputs to help smallholder commercialization and shift their production from subsistence to a market-oriented economy. According to the 2015 Program Design Document, the distribution and marketing of agricultural inputs would help farmers access the market by affecting the quantity and quality of their produce (MoA(a), 2015). With this justification, the program has focused on agriculturally promising areas while taking into account typical farm activities in the selected areas. In light of this, Wara-Jarsoworeda,<sup>1</sup> the area where this study was conducted, is one of the program's intervention areas basing the fact that *tef* (*Eragrostis tef*) is a common crop that is cultivated in all agro-ecological zones and altitudes of the area, and as the area is considered a potential for greater *tef* production.

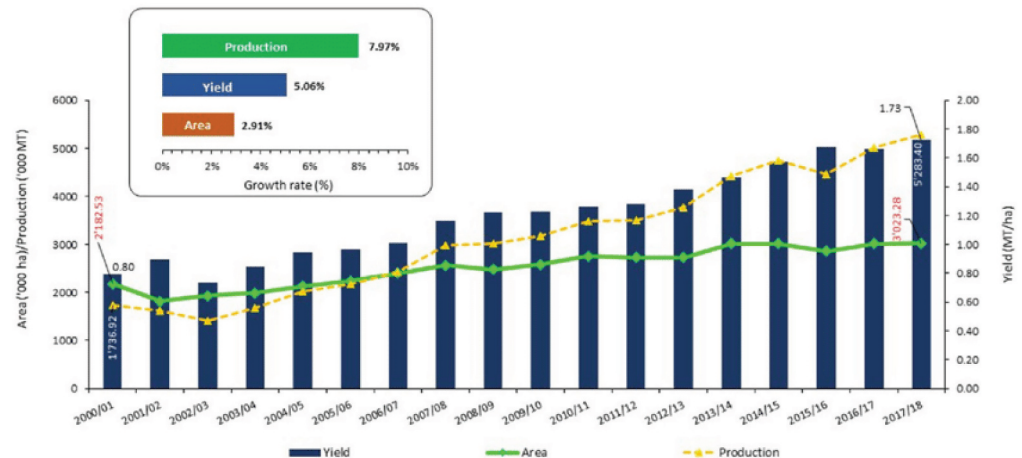
Ethiopia is the largest *tef* producer in the world (Lee, 2018). *Tef* is the most popularly grown and consumed cereal in Ethiopia. The crop has the largest area under cultivation, making up 29.5% of all cultivated land and producing 19.7% of all cereals (Diriba, 2020). Likewise, it is the main staple food crop in the study area and ranked first in terms of its contribution to overall grain output and market share, with wheat coming in second (Wara Jarso woreda Agriculture and Natural Resource Office, 2019). Besides home consumption, it is used as a cash crop, animal feed, and construction material. Its high resilience capacity withstanding periods of drought and flood as it attracts few insect pests and diseases, and its minimal post-harvest loss all increase its importance (Fufa et al., 2011; Minten et al., 2018). Solomon et al., (2019) computed its trend of cultivation and production in Ethiopia from statistical reports of the Central Statistical Agency (CSA) of Ethiopia for the years 2000/01–2017/18 in which its increments in area, yield, and output have been demonstrated (Figure 1).

However, Ethiopia has yet to tap its *tef* production and market potential and develop an efficient *tef* value chain and marketing scheme (Lee, 2018). Grounded on this, AGP II has distributed the new high-yielding *tef* variety known as “Korra” in the study area as part of its strategy to enhance the crop productivity and commercialization of *tef* producer farmers. Despite the advocacy and promotion for the adoption of improved *tef* varieties by development practitioners like AGP II, studies examining the commercialization impacts of the adoption of improved *tef* varieties in general and Korra *tef* variety in particular on adopter farmers are uncommon. Additionally, previous studies on smallholder commercialization have neglected the commercialization impacts of the adoption of improved seed types in favor of focusing primarily on their market orientation and engagement. Some studies have indeed examined smallholder commercialization (Afewerk & Endrias, 2016; Gebre-Ab, 2006), the challenges they encounter (Boka, 2017), and the potential for sustainable intensification (Mutyasira, 2020). Others highlighted the smallholder commercialization processes, determinants, and impacts by emphasizing *tef*, wheat, maize, and other horticulture crops (Aman et al., 2014; Edosa, 2018; Endalew et al., 2020; Gebreselassie & Sharp, 2007; Getahun et al., 2019; Jaleta et al., 2009). Generally, little evidence exists on the commercialization impacts of producing *tef* in general and Korra *tef* variety in particular. Therefore, this study is planned to investigate the commercialization impact of the adoption of the Korra *tef* variety on smallholder farmers in Wara-Jarso woreda, North-Western Ethiopia, taking into account the Korra *tef* variety as a crop technology. Information on the impact of the *tef*'s commercialization is needed to help the



**Figure 1. Trend of tef cultivation and production in Ethiopia from 2000 to 2018 (Solomon et al., 2019, p. 755).**

Note: Growth rates are calculated using the semi-log function ( $\ln X_t = a + bt$ ).



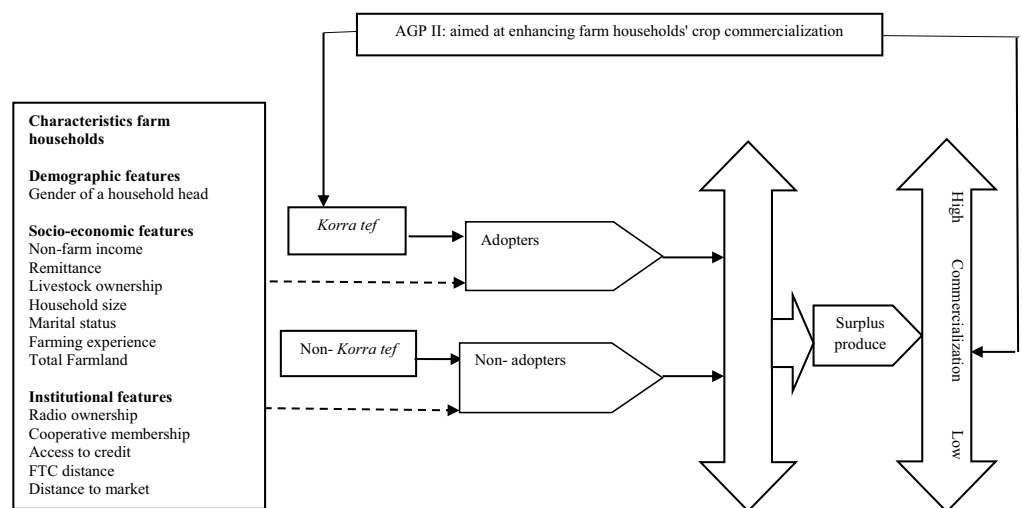
government in its efforts to encourage the adoption of improved *tef* varieties in general and its commercialization in particular.

### 1.1. Conceptual framework

Based on studies that examined the impact of crop technology adoption on farm households' status of crop commercialization, we developed the conceptual framework shown in Figure 2 (Afework & Endrias, 2016; Assefa, 2022; Gebremedhin & Jaleta, 2010; Gerezgiher, 2016; Mazengia, 2016; Poulton, 2017; Shadreck et al., 2013; Tadele et al., 2017; Taffesse et al., 2012). To compare the characteristics of adopters and non-adopters of the *Korra tef*, we first identified the demographic, socioeconomic, and institutional traits that both groups' farm households had in common on the left. The idea that the use of *Korra tef* leads to the production of surplus products, which in turn enables an improved *tef* commercialization, is given on the right side. Therefore, our conceptual framework's main thesis is founded on the hypothesis that because the adopter and non-adopter farm households are often comparable in terms of the aforementioned characteristics, it is expected that the adoption of *Korra tef* has a positive impact on the commercialization of *tef* for the adopters through an increase in its yield.

**Figure 2. *Korra tef* adoption and farm households' commercialization.**

Source: Authors' construction.



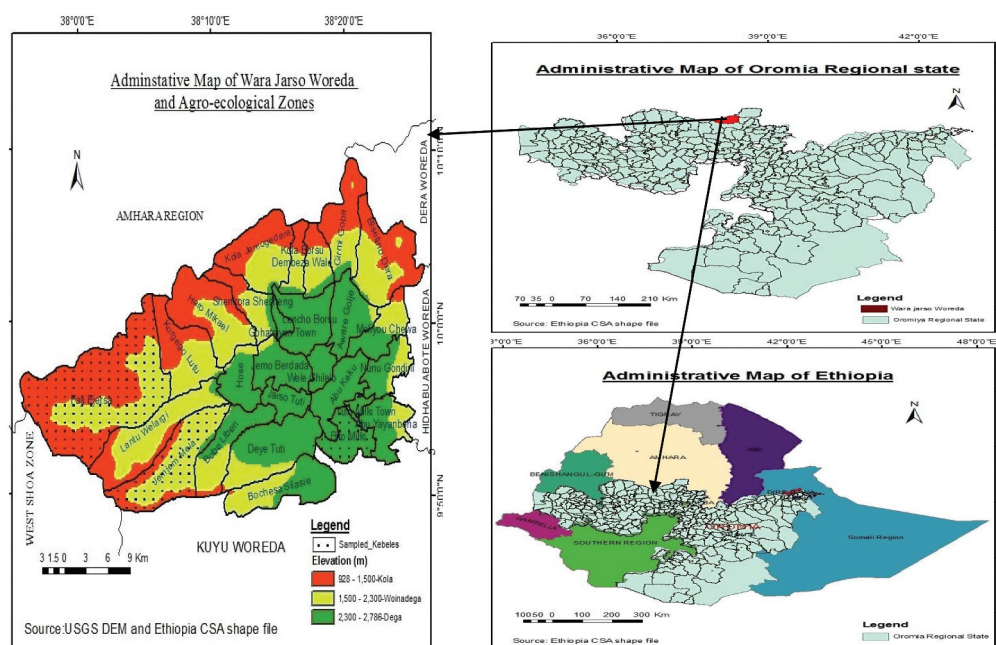
## 2. Research methodology

### 2.1. Description of the study area

The study area was *Wara-Jarso woreda*. It is one of the *woredas* of the Oromia regional state in North-West Ethiopia. It is geographically located between 9°49'59.99" North latitude and 38° 14' 60.00" East longitude (Figure 3). Highland (7.3%), temperate (43.4%), and lowland (49.5%) are the three major agro-ecologies of the area (National Meteorological Agency of Ethiopia [NMAE], 2020). The *woreda's* diverse agro-climatic zones allowed local farmers to practice mixed farming and grow a range of crops. The major cereal crops grown in the *woreda* include *tef*, wheat, maize, and sorghum. The area is renowned for its greater production of *tef*, and the crop is grown in all agro-climatic zones of the area.

**Figure 3. Map of the study woreda.**

Source: Ethio GIS and CSA (2007).



### 2.2. Research design and ethical procedures

The study used a mixed-methods research approach with a cross-sectional time frame. As per the Concurrent Embedded Strategy of the mixed method, the survey data was used as a guide and the qualitative data were embedded within the survey data to support the descriptive and explanatory functions (Creswell & Creswell, 2017). The Center for Rural Development Studies at Addis Ababa University provided ethical approval and clearance that were necessary to satisfy the ethical requirements for scientific research. Based on this, the aim and length of the study, and the right to stop participation at any time were all told to the study participants so that they could feel free to choose whether to participate in the study without facing any consequences or negative effects. Additionally, they were told that any information they provide will be held in the utmost secrecy that data will only be presented aggregately, and responses will not be linked to them on an individual basis. Based on these, the required data were collected after the verbal and written consents of the key informants and survey respondents were obtained.

### 2.3. Sampling procedures and data sources

The study's target population was *Wara-Jarso woreda's Korra tef* producer households. The sample households were selected by using a multi-stage sampling method. First, the study *woreda* was selected purposefully. Second, *Korra tef* adopters were identified with the assistance of the study *woreda's* AGP II coordination office and the DAs. Two *kebeles*<sup>2</sup> from each agroecological zone were



chosen based on the alleged classifications of high and medium *Korra tef* growers, and to ensure sample representativeness. As a result, the study *kebeles* were found to be six. The same procedures were employed to select the control *woreda*, the nearby *Kuyu woreda*, the respective *kebeles*, and the corresponding households within each *kebele* to estimate the counterfactual data. *Tef* producers, however, replaced the *Korra tef* producers criterion. Likewise, *Kuyu woreda* comprises three main agroecological zones and is comparable to *Wara-Jarso woreda* in terms of the crops grown there as well as other institutional, cultural, and socio-economic aspects. The lists of farm households for both groups were compiled by using the official records of the study *kebeles*. The sample size was computed by” (Yamane, 1967)s subsequent sample size determination formula on account of the finite character of the population under study.

$$n = \frac{N}{1 + N(e^2)} \quad (1)$$

Finally, 479 farm households were obtained with the 95% desired level of precision. 221 adopters from the treatment group and 248 non-adopters from the control group were selected to keep a balance between the two groups for the use of an impact assessment model. As shown in Table 1, the sample sizes in each *kebele* were calculated using the Probability Proportionate to Size (PPS) of the identified number of farm households.

As it is indicated in the introduction section, *tef* is the most widely grown crop in the study area and is produced in all of its agro-climatic zones. Thus, AGP II has introduced the *Korra tef* variety into the study area as part of its effort to increase the yield and commercialization of *tef*. Non-mechanized farming and subsistence agriculture characterize the area, and farmers in the area are comparable in terms of the size of their farmland, credit use, livestock ownership, market distance, and family size among others. The program particularly considered the area because of its significant potential for *tef* production. Farm households in the area were chosen for the adoption of *Korra tef* based on several factors, including their willingness to grow it on a minimum of one hectare and to consult with local development agencies, and their level of readiness for the

**Table 1. Distribution of population and sample households across the study kebeles**

Respondent type	Kebeles	Population size (Korra tef producers)	Sampled households
Adopters	Lencho Borsu	1100	70
	Wale Chilalo	540	35
	Abo Yayambana	510	33
	Dhaye Tuti	600	39
	Jemjem Mela	370	24
	Faji Ejersa	305	20
	<b>Sub-total</b>	<b>3425</b>	<b>221</b>
Non-adopters	<b>Kebeles</b>	<b>Population size (Non-Korra tef producers)</b>	<b>Sampled households</b>
	Liban Kura	865	56
	Bonde Gidabo	925	60
	Dire Hacho	835	54
	Hariro Derso	430	28
	Dawicha Kerensa	425	28
	Jila Kerensa	495	32
	<b>Sub-total</b>	<b>3975</b>	<b>258</b>
<b>Total</b>		<b>7400</b>	<b>479</b>

Source: Own field survey (2020).

practice. Thus, provided that the program has apparent criteria for the selection of beneficiaries and the study accordingly considers these criteria, the probability of possessing a selection bias is narrow. In other words, even though the study area is purposively selected, the selection of samples from both adopter and non-adopter groups was randomly conducted. This in turn marks the non-occurrence of selection bias.

The study used both primary and secondary data. The main primary data (*i.e.* quantitative data) were collected from the *Korra tef* producers in the treatment *woreda* and non-*Korra tef* producers in the control *woreda*. The data was collected in September and October of 2020 using paper versions of semi-structured questions and trained enumerators. The questionnaire was originally developed in English, translated into *Afan Oromo*, and interviewed by the latter. A pilot test was conducted to determine whether the survey tool is well comprehended by the real responders. The supporting primary data (*i.e.* qualitative data) was obtained from DAs from each agro-ecology zone, the regional AGP II monitoring and evaluation officer, the zonal AGP II facilitator, the study *woreda*'s AGP II coordinator, and six *Korra tef* producer farmers (two farmers from each agro-ecology labeled as high and medium producers). The study's lead investigator collected it by using interview guides. Relevant journal articles, websites, and the study *woreda*'s AGP II coordinating office were visited to obtain secondary data.

#### 2.4. Tools and techniques of data analysis

Both econometric analysis and descriptive statistics were used to examine the quantitative data. The STATA version 16 Software Package was used for the analysis. The qualitative data were used to substantiate the interpretation of quantitative data. The demographic, socioeconomic, and institutional characteristics of farm households were examined and described using descriptive statistical analysis techniques like mean, standard deviation, proportions, frequency, and percentages. Gebremedhin & Jaleta, (2010); Gerezgiher, (2016); Govereh et al., (1999); Osmani et al., (2014) determined the level of commercialization in each household using HCI. Household Commercialization Index measures the ratio of the gross value of crop sales by household *i* in year *j* to the gross value of all crops produced by the same household *i* in the same year *j*, expressed in percentage.

$$HCI = \frac{\text{Gross Value of } Korra \text{ variety } tef \text{ sale of farmer } i \text{ at year } j}{\text{Gross Value of all } Korra \text{ tef production of farmer } i \text{ at year } j} \times 100 \quad (2)$$

As to them, the benefit of such a measure is that commercialization is regarded as a continuum, avoiding the crude distinction between households that are "commercialized" and those that are "non-commercialized." It gives the degree of commercialization for each household individually. HCI has a value between 0 and 100%. A household that is entirely subsistence-oriented would have a value of zero, and the closer the index is to 100, the more commercialized the household is. As a result, this study has used the above indicator to determine how much more market-oriented the households of *Korra tef* adopters are than non-adopters.

The commercialization impact of *Korra tef* was measured by the method of Propensity Score Matching (PSM). The model was chosen due to the lack of baseline data and the ability of the matching technique to account for observed selectivity. It was also decided to examine the impact of receiving treatment (in this case, the *Korra tef*) since the random assignment of treatments to subjects is not feasible in this study. The conclusion was drawn from the *Korra tef* adopters based on the comparison with the non-adopter farm households. Hence, we turn in to determining the average treatment effect on the treated (ATT) since it is hard to know the outcomes for adopters when they have not adopted and non-adopters when they have adopted. According to (Rubin, 2001), the average treatment effect (ATE) can be calculated as follows:

$$\tau_{ATE} = E[Y|X, d = 1] - E[Y|X, d = 0] \quad (3)$$

The above equation) assumes that the commercialization level of the adopters before their adoption  $E(Y_0 | D = 1)$  can be approximated by the commercialization level of non-adopters at times of data collection  $E(Y_0 | D = 0)$ . However, it is hard to precisely estimate ATE using the above-stated equation as we do not observe  $E(Y_0 | D = 1)$  yet we do observe  $E(Y_1 | D = 1)$  and  $E(Y_0 | D = 0)$ . Additionally, the presence of self-selection bias emanating from the adoption of *Korra* through the placement of AGP II may result in a biased estimation. In other words, in the context of this study, the households considered in the treated group came into the category of adopters through the program placement of the AGP II. As a result, they are less likely to be statistically equivalent to the comparison group. In such a case, PSM adjusts for selection bias, minimizes the limitation from matching on many observed variables, and estimates counterfactual effects. The propensity score,  $p(x)$  conditional on a set of characteristics  $x$  according to (Rosenbaum & Rubin, 1983) is given as:

$$p(x) = P_r[d = 1|x] = E[d|x] \quad ([4])$$

Where,  $d = \{0, 1\}$  is the indicator of exposure to treatment and

$x$  is the multidimensional vector of pre-treatment characteristics.

Econometric literature suggests that the soundness of the outputs of the PSM method depends on the employability of two basic assumptions namely: the Conditional Independence Assumption (CIA) and the Common Support Condition (CSC). CIA (also known as Unconfoundedness Assumption) notes that the potential outcome variable ( $Y_0$ ) is independent of the treatment status (adoption of *Korra*) conditional on a set of observable variables  $x$ . Thus, it is important to precisely detect the impact as it considers the difference between the treated and control groups to reduce the selection bias. This allows the units from the control group to be used to construct a counterfactual for the treatment group. The assumption of common support, on the other hand, enables appropriate comparison by facilitating a sufficient overlap in the features of the treated and untreated units to find adequate matches. Since the impact estimates calculated using propensity scores are highly sensitive to the matching method itself, robustness can be further improved by bounding matches only to adopters and non-adopters who have common support in the distribution of propensity scores (Smith & Todd, 2005). Hence, the four commonly used matching algorithms, namely nearest neighbor, radius, caliper, and kernel matchings were employed to find the optimal estimation model for the commercialization impact of adopting the *Korra tef* variety.

## 2.5. Definition of variables and working hypothesis

Commercialization of the study area's smallholder farmers is a dependent variable, indicated by HCI, which is measured as the ratio of the gross value of *Korra tef* sales to the gross value of the *Korra tef* produced by the AGP II beneficiary smallholder farmers in the 2011/12 E.C cropping season, expressed in percentage. The use of *Korra tef* variety is the treatment variable of the study. A review of the theoretical and empirical literature on household commercialization indicated that the characteristics shown in Table 2 are influencing the commercialization of smallholder farmers, and are considered the independent variables of the study.

## 3. Results and discussion

### 3.1. Descriptive results

Tables 3 and 4 give the summary statistics of the chi-square ( $\chi^2$ ) and t-test of the selected variables believed to be relevant in demonstrating the commercialization characteristics of the surveyed households. The  $\chi^2$  was used to test relationships between dummy and/or categorical variables (Table 3), and the means of continuous variables are reported based on the adoption status of the study households (Table 4). The explanatory variables used for estimation in the model were selected from these variables.

**Table 2. Definition and measurements of the independent variables used in the study**

Notation	Name of the variables	Type	Unit/ Measurement	Expected sign
SEXHH	Gender of household head	Dummy	1 for male, 0 for female	±ve
MARSTATUSHH	Marital status of household head	Categorical	Scores from 1–6	±ve
FARMEXPHH	Farming experiences of household head	Continuous	Farm experience of household head (in years)	+ve
HHSIZE	Family size of household	Continuous	Total number of household members	+ve
TOTLAND	Total farmland	Continuous	Household's total farmland (ha)	+ve
TLU	Livestock owned by household	Continuous	Tropical Livestock Unit	+ve
RADIOOWN	Functional radio	Dummy	1 for yes, 0 for none	+ve
CREDUSE	Access to credit services	Dummy	1 for yes, 0 for none	+ve
FTCDIST	Distance household travels from home to Farmers' Training Centers (FTC <sup>3</sup> ), where AGP II focal personnel resides	Continuous	Km	-ve
MAINPARTCCOOP	The cooperative and/or association households largely engaged in	Categorical	Scores from 1–10	+ve
MRKTDIST	A distance from home to the main market (to input and output market))	Continuous	Km	+ve
INONFARMACT	Income from non-farm activities	Continuous	Ethiopia birr (ETB <sup>4</sup> )	+ve
REMIT	Remittances, money transferred both from inside the country and abroad	Continuous	ETB	+ve

The analysis covers 479 households in total, of whom 221 (46.14%) adopt the *Korra tef* variety in 2020 and 258 (53.86%) do not. As shown in Table 3, a statistically insignificant difference was observed in the gender of the household heads of the two groups. However, 90.81% of the sample households are male-headed. This perhaps plays a positive role for both groups *tef* commercialization since male-headed households are believed to have a higher chance to participate in the market than women-headed due to higher social networks (Gebreselassie & Ludi, 2008). The  $\chi^2$  results also revealed a statistically insignificant difference in terms of their access to credit services, and whether they have attended a formal education or not. Whereas the two groups vary in terms of their marital status, and the cooperative and/or association they largely engaged in.

Access to market information could be an important factor in commercialization since it presents farmers with a range of options. With this, ownership of functional radio is imperative in the dissemination of information hence affecting smallholders' commercialization. The majority of farm households, 264 (55.11%), lacked a functional radio. Only 111 (50.23%) adopters and 104

(40.31%) non-adopters, respectively, have functional radios. The qualitative data showed that most of the households in the area listened to both agricultural and non-agricultural programs. This may imply that households with access to information (whether agricultural or non-agricultural) are aware of numerous methods for improving the commercialization of their *tef*.

A significant difference was found between the groups in terms of experiences they have in *tef* farming and the average size of their families. The total sizes of farmland, livestock owned, average distance household travel from home to Farmers Training Center (FTC) and from home to input-output market, as well as the amounts of remittances received, are all comparable. The income from non-farm activities, however, shows a statistically insignificant difference between the two groups, suggesting that the non-farm income both groups received might be equally correlated with households' level of commercialization or decision to sell their *tef*. The simple comparison of the two groups of households indicated that adopters and non-adopters differ significantly by the majority of the factors chosen as relevant to explain them (*i. e.* statistically significantly different in 10 variables and showed no significant difference in 3 variables) (see Tables 3 and 4).

### 3.1.1. Farm inputs used in *tef* production

In the literature on smallholder commercialization, commercialization of the output side is often realized with the precondition of commercialization on the input side (Gebremedhin & Jaleta, 2010). It is also assumed that the use of improved farming inputs increases output-side commercialization (Getahun et al., 2019). In light of such allegations, describing farm inputs used for the production of *tef* is imperative. Farmers of the study area used different inputs for *tef* production in 2020. The common farm inputs used include improved seed, fertilizers, herbicides, insecticides, soil fertility reclamation, compost, and labor. The analysis took into account the costs of these inputs (by ETB) at the time.

As shown in Table 5, an average of 22.43 kg of improved seed and 91.93 kg and 109.3 kg of DAP and urea, respectively were used per hectare. On average, herbicide and pesticide used per hectare were 0.99 and 1.07 liters, respectively. Generally, the t-test result revealed a significant mean difference between the groups in the uses of the selected inputs at the *p* values of less than 0.01 and 0.05 in which the inputs usages of the adopter significantly surpassed their non-adopter counterparts except in the case of seed usage. The key informants as well confirmed the survey result that the *Korra tef* variety reduces the amount of seed sowed per hectare. In congruent with the survey result indicated in Table 5, a higher fertilizer usage of the *Korra tef* variety in general, and more usage of Urea than DAP, in particular, were also reported by all the key informants. As to them, the relatively higher usage of Urea has emanated from the fact that they added Urea twice and DAP only once. Thus, the adopters' increased fertilizer use could have been influenced by the *Korra tef* variety's higher fertilizer consumption. The same is true for the use of herbicide and pesticide; the key informants added that using the *Korra tef* variety has urged them to use more of these than they would have otherwise.

Except for the applications of soil fertility reclamation and compost, significant mean differences between the two groups were observed in the costs of other major inputs used to produce *tef* (Table 6). To begin with the cost of seed, some possible causes include the fact that 1 kg of *Korra tef* cost higher back then than other *tef* varieties—its price ranged from 48 to 52 ETB per kg, compared to its contemporaries' range of 37 to 48 ETB—and the disparity in seed use between the two. The tiny differences in the costs of the fertilizers for the two groups could also emanate from the amount of their utilization since comparable prices of fertilizers were reported.

The key informants also confirmed that using more insecticide and herbicide on the *Korra tef* farm has increased the cost of production compared to growing other *tef* varieties. The mean difference in labor costs is in agreement with the qualitative finding that the production of the *Korra tef* variety needs more labor than the production of other *tef* varieties. This is in line with

Table 3. Statistical summary of  $\chi^2$ -test distribution for dummy and categorical variables

Explanatory variables	Categories	Total sample (%)	Non-adopters (%)	Adopters (%)	$\chi^2$ (p-value)
SEXHH	Male	435 (90.81%)	238 (92.25%)	197 (89.14%)	1.3782 (0.240)
	Female	44 (9.19%)	20 (7.75%)	24 (10.86%)	
MARSTATUSHH	Married, Single Spouse	442 (92.28%)	241 (54.52 %)	201 (45.48%)	11.3183 (0.045**)
	Married, more than one spouse	5 (1.04%)	2 (40.00%)	3 (60.00%)	
	Single	4 (0.84%)	3 (75.00%)	1 (25.00%)	
	Divorced	9 (1.88%)	4 (44.44%)	5 (55.56%)	
	Widowed	10 (2.09%)	1 (10.00%)	9 (90.00%)	
RADIOOWN	Not together for any reason	9 (1.88%)	7 (77.78%)	2 (22.22%)	4.7314 (0.030**)
	Yes	215 (44.89%)	104 (40.31%)	111 (50.23%)	
	No	264 (55.11%)	154 (59.69%)	110 (49.77%)	
	Yes	271 (56.58%)	113 (43.80%)	95 (42.99%)	
CREDUSE	No	208 (43.42%)	145 (56.20%)	126 (57.01%)	0.0319 (0.858)
	Agricultural cooperative	275 (57.41%)	128 (49.61%)	147 (66.52%)	
MAINPARTCCOOP	Village saving and loan association	35 (7.31%)	26 (10.08%)	9 (4.07%)	24.6069 (0.003****)
	RUSSACO	47 (9.81%)	23 (8.91%)	24 (10.86%)	
	Iddir	12 (2.51%)	8 (3.10%)	4 (1.81%)	
	Equub	9 (1.88%)	6 (2.33%)	3 (1.36%)	
	Kebele council	20 (4.18%)	9 (3.49%)	11 (4.98%)	
	Youths' association	27 (5.64%)	19 (7.36%)	8 (3.62 %)	
	Women's association	8 (1.67%)	6 (2.33%)	2 (0.90%)	
	Local representative	22 (4.59%)	16 (6.20%)	6 (2.71%)	
	Religious organization	24 (5.01%)	17 (6.59%)	7 (3.17%)	

\*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; Standard errors in parenthesis.

Source: Computed from own survey data (2020).



**Table 4. Statistical summary of t-test for continuous variables**

Explanatory variables	Mean values			t (p-value)
	Non-adopters	Adopters	Combined	
FARMEXPHH	17.004	18.702	17.787	-2.0607 (0.0399**)
HHSIZE	6.589	7.235	6.887	-2.9413 (0.0034***)
TOTLAND	1.805	1.871	1.872	-2.0189 (0.0441**)
TLU	4.546	3	3.834	4.8607 (0.0000***)
FTCDIST	2.908	2.317	2.635	4.9171 (0.0000***)
MRKTDIST	10.46	11.504	10.942	-4.1677 (0.0000***)
INONFARMACT	3050.194	3581.9	3295.511	-0.8295 (0.4072)
REMIT	1937.597	1172.851	1584.76	2.0512 (0.0408**)

\*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; Standard errors in parenthesis.

Source: Computed from own survey data (2020).

studies by (Abate et al., 2015; Coelli et al., 2005) which reported that higher-yielding varieties needed more labor but produced more output per unit of labor. As both groups engage in various soil erosion prevention techniques and supplement agricultural land with organic matter to increase its potential, the closeness in the costs of soil fertility restoration and compost could be signs of the presence of comparable soil types. The exceptions in the costs of soil fertility reclamation and compost could be indicators of the presence of comparable soil types as both groups correspondingly engage in various soil erosion prevention techniques and supplement agricultural land with organic matter to increase its potential.

Overall, a significant difference was observed between adopters and non-adopters in terms of the overall cost of *tef* production in the cropping season of 2020. This is in agreement with the assertion of key informants that the *Korra tef* farm incurs higher costs than the indigenous *tef* varieties. Similar findings came from a study on the Boset *tef* variety, where greater production expenses, particularly for fertilizer and seed, were noted (Natnael, 2019). Another study on *Korra* and *Boset tef* has consistently shown that they have a higher variable cost of production than local *tef* variants (Bekele et al., 2019).

### 3.1.2. Tef production and income

The mean production of *tef* for adopters and non-adopters were 2037.63 and 1434.26 quintals with standard deviations of 169.01 and 132.44, respectively (Table 7). At a 1% level of significance,

**Table 5. Average input use for tef production by respondent types (kg or liter/ha)**

Inputs	Mean values			t (p-value)
	Non-adopters	Adopters	Combined	
Seed ( <i>Korra tef</i> variety for adopters and other than <i>Korra</i> for non-adopters) (kg/ha)	27.174	16.91	22.438	73.0644 (0.0000***)
DAP (kg/ha)	90.407	93.716	91.933	-3.9723 (0.0001***)
Urea (kg/ha)	108.074	110.737	109.303	-2.5934 (0.0098***)
Herbicide (liter/ha)	0.959	1.047	0.999	-2.1322 (0.0335**)
Pesticide (liter/ha)	1.05	1.093	1.071	-2.3060 (0.0215**)

\*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; Standard errors in parenthesis.

Source: Computed from own survey data (2020).

**Table 6. Average input costs of tef production by respondent types (ETB/ha)**

Inputs	Mean values			t (p-value)
	Non-adopters	Adopters	Combined	
Seed ( <i>Korra</i> tef variety for adopters and other than <i>Korra</i> for non-adopters)	1079.703	825.147	962.256	40.9736 (0.0000***)
DAP	1356.088	1405.731	1378.992	−3.9731 (0.0001***)
Urea	1458.994	1494.947	1475.582	−2.5933 (0.0098***)
Soil fertility reclamations	35.773	39.598	37.53753	−0.2819 (0.7781)
Compost	1342.651	1332.908	1338.156	0.1827 (0.8551)
Herbicide	172.499	188.386	179.829	−2.1270 (0.0339**)
Insecticide	262.487	273.322	267.486	−2.2999 (0.0219**)
Labor	11206.33	17047.5	13901.32	−37.1498 (0.0000***)
Total production cost	17180.57	23223.27	19968.54	−29.8676 (0.0000***)

\*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; Standard errors in parenthesis.

Source: Computed from own survey data (2020).

the result showed a significant mean difference between the *tef* produced by the groups. Even though it is impossible to infer causality from a mere descriptive finding, respondents who adopted the *Korra tef* have higher *tef* income. The average net income reported by all respondents from the *tef* farm was 48,354.46 Ethiopian Birr (ETB). The adopters' and non-adopters average net earnings were 64,310.19 ETB and 34,686.96 ETB, respectively, and at a 1% probability level, there was a significant mean difference between the two groups.

The mean production of *tef* for adopters and non-adopters was 2037.63 and 1434.26 quintals with standard deviations of 169.01 and 132.44, respectively (Table 7). The result indicated the significant mean difference between *tef* produced by the groups at a 1% significance level. Even though a causal relationship cannot be exclusively generated from a mere descriptive finding, respondents who adopted *Korra tef* earn more *tef* income. The average net income reported by all respondents from the *tef* farm was 48,354.46 Ethiopian Birr (ETB). The adopters' and non-adopters average net earnings were 64,310.19 ETB and 34,686.96 ETB, respectively, and, there was a significant mean difference between the two groups at a 1% probability level.

### 3.1.3. Categories and levels of commercialization of *tef* producers

Based on the taxonomy of commercialization by (Samuel and Kay, 2008; Tadele et al., 2017), the commercialization of smallholders is grouped into three categories: less commercialized farmers (those who sell up to 25% of their output), semi-commercialized farmers (those who sell between 25% and 50% of their output) and commercialized farmers (those who sell more than 50% of their output). The results showed that the majority of the sample households – 226 (47.12%)—are commercialized farmers and that 80 (16.70%) of them fall into the category of 1–25% commercialization index, suggesting that they are less commercialized in terms of *tef* output. Among 226 farm households in the category of “commercialized farmers”, the majority of them 190 (84.07%) belong to the adopter category selling up to 75.75% of their *tef* yield, while the remaining 36 (15.93%) are from the non-adopter category selling up to 66.67% of their *tef* produce (Tables 8 and 9).

Table 9 presents the results that show the aggregate levels of household *tef* commercialization in the study areas. Considering the gross value of *tef* sold, the overall average level of

Table 7. Average tef production and net income by respondent types						
	Respondent type					
	Total sample	Std. Dev.	Non-adopters	Std. Dev.	Adopters	Std. Dev.
Average production (kg/ha)	1712.639	336.514	1434.26	132.446	2037.632	169.0124
Average net income (ETB/ha)	48354.46	16091.03	34686.96	5177.219	64310.19	7513.002
						t (p-value)
						-576.288 (0.0000***)
						-50.8017 (0.0000***)

\*\*\*p < 0.01; Standard errors in parenthesis.  
Source: Computed from own survey data (2020).

Table 8. Categories of commercialization of tef producers in 2020						
Categories	Non-adopters		Adopters		Combined	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Less-commercialized farmers (1–25%)	78	97.5	2	2.5	80	16.70
Semi-commercialized farmers (26–50%)	144	83.24	29	16.76	173	36.12
Commercialized farmers (≥51%)	36	15.93	190	84.07	226	47.18
Total	258	53.86	221	46.14	479	100

Source: Computed from own survey data (2020).

**Table 9. HCI of tef producers in 2020**

Variable	Category	Obs	Mean	Std. Dev.	Min	Max
HCI	All sample households	479	46.95	15.50	13.43	75.75
	Adopters	221	58.92	8.456	20	75.75
	Non-adopters	258	36.70	12.52	13.429	66.67

Source: Computed from own survey data (2020).

commercialization of the *Korra tef* growers in the study area was 46.95%. This result is consistent with the national average which is about 46.53% of *tef* produced are sold in Ethiopia as reported by (CSA, 2020). It is also comparable with the findings of (Assefa, 2022; Degefa et al., 2022; Eshetu, 2018; Getahun et al., 2019), but outdistances some and lags behind others. This situation could be attributed to the reason that *tef* is the most commonly grown crop and used for consumption in the area. The qualitative data also evidenced that *tef* is extensively consumed and valued as a cash crop by local farmers. On the other hand, the HCIs were 58.92% and 36.7% for the adopters and non-adopters, respectively. This suggests that adopter and non-adopter farmers in the study areas sold 58.92% and 36.7% of their *tef* yield, respectively. This in turn indicates that the extent of commercialization of the adopter and non-adopter households, in general, was in the categories of commercialized and semi-commercial farmers, respectively. The adoption of the *Korra tef* variety could be attributed to the fact that adopter households are more commercially successful than non-adopter households. This is also an indicator that the adoption of *Korra tef* variety could be vital in enhancing its marketing. Detail of the impact of *Korra* on its growers' commercialization status is addressed by the subsequent econometric analysis.

Figure 4 shows the kernel density estimates of the commercialization index of the adopters, denoted by the red color, and non-adopters by the blue color.

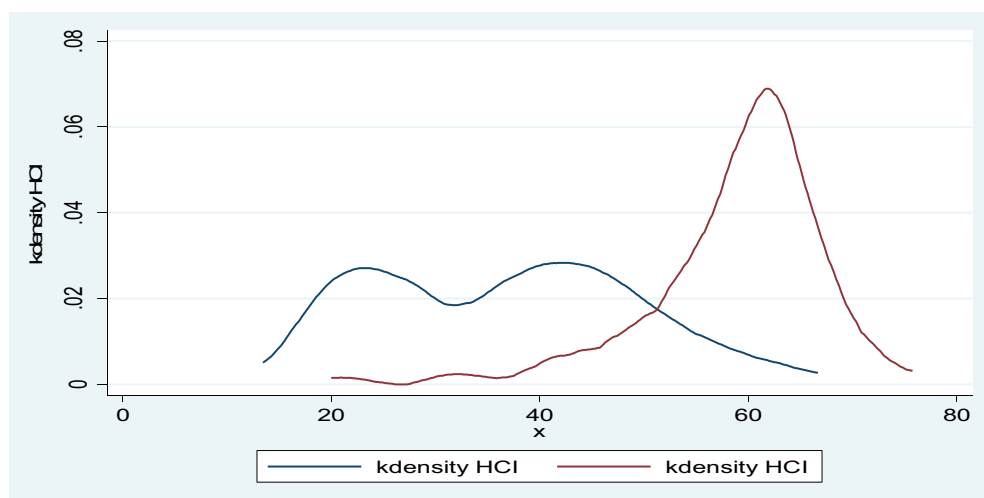
### 3.2. Impact of *Korra tef's* variety on smallholder farmers' commercialization

**Hypothesis:** The adoption of the *Korra tef* variety increases the commercialization of *tef* in adopter farm households.

As indicated in the aforementioned hypothesis, the commercialization status of *tef* producer households is the outcome variable used to calculate the commercialization impact of adopting the *Korra tef*

**Figure 4. Kernel density estimate of commercialization index.**

Source: Own survey data (2020).



variety. The treatment and control groups, respectively, were households that adopted *Korra tef* and households that did not. The results of the counterfactual control, which is non-adoption, were compared to the observed outcomes of adoption of the *Korra tef* variety using the PSM. With this, the average treatment effects on the treated (ATT) is estimated purely emphasizing the effects of the adoption of *Korra tef* variety on the adopters. Since the intention of using the PSM is to develop an index that can be used to match the adopters and non-adopters, the choice of variables to be included in the propensity score estimation is key. Thus, basing the (Heckman et al., 1997) s notion that omitting important variables can increase the bias in the processes of estimation, demographic, socioeconomic, and institutional factors that are unaffected by whether a factor is adopted or not were chosen to determine the impact that adoption of the *Korra tef* variety has on the status of households *tef* commercialization (see Tables 3 and 4). Yet, significant differences were found between the two groups in 10 of the 13 chosen variables (see Tables 3 and 4). Fortunately, the PSM enables the extraction of a set of comparable households from non-adopters.

Before estimating the propensity score for the adopter and non-adopter households, the hypothesized explanatory variables were examined for the likelihood of multicollinearity. Tests of the Variance Inflation Factor (VIF) for continuous variables and Contingency Coefficient (C) for discrete variables were thus employed. The results showed that the value of VIF for each of the continuous variables was found to be less than 1.21 with a mean value of 1.09 (Appendix 1), and the value of C for the discrete variables did not exceed 0.75 (Appendix 2), indicating the independence of the study variables from one another (Tattao, 2007). Hence, there is no multicollinearity problem among all the conjectured explanatory variables included in the model. This gives us the assurance we need that the model is devoid of multicollinearity issues, enabling us to move forward with the regression.

### 3.2.1. Estimation of propensity score

A probit regression model was used to estimate the p-score of the selected variables for the adopter and non-adopter households. The p-score result shows that the two groups are

**Table 10. Results of the propensity score of the two groups**

Variables	Coef.	Std.Err.	P>z
SEX	-0.3809371	0.2389731	0.111
HHSIZE	0.1157336***	0.0282889	0.000
MARSTATUSHH	0.0106221	0.0695231	0.879
FARMEXPHH	0.0161557**	0.007943	0.042
TOTFARMLAND	0.4486467**	0.2001243	0.025
TLU	-0.1182213***	0.0233214	0.000
MAINPARTCCOOP	-0.0745842***	0.0203583	0.000
RADIOOWN	0.4734555***	0.1324159	0.000
CREDUSE	0.0021285	0.1321177	0.987
FTCDIST	-0.2699168***	0.0512259	0.000
MRKTDIST	0.1143858***	0.0239768	0.000
INONFARMACT	7.41e-06	9.33e-06	0.427
REMIT	-0.0000329**	0.0000164	0.045
_cons	-1.775279***	0.5628004	0.002
Log-likelihood	-265.18831		
Number of obs	479		
LR chi2(13)	130.80		
Prob > chi2	0.0000		
Pseudo R2	0.1978		

Source: Computed from own survey data (2020).



statistically different in all explanatory variables except gender, marital status, access to credit, and income from non-farm activities (Table 10). However, a high degree of covariate balance between the treatment and control samples is required before the estimation of the impact. Hence, it is implied that the variables need to be corrected before the estimation of ATT.

### 3.2.2. Testing the balance of propensity score and covariates

As shown in Table 11, except for variables of sex, marital status, access to credit, and income from non-farm activities, the two groups significantly differed in other variables selected for estimating households' commercialization status. The difference between them, however, was kept to a minimum after matching since the percentage of bias dropped from the ranges of 1.6 and 45.6 before matching to the ranges of 0.2 and 6.8 after matching. As a result, the percentage of bias has minimized to the level where it falls below the 20% cutoff point (Rosenbaum & Rubin, 1983), indicating the absence of a statistically significant correlation between the controlled and treated groups. The p-values in Table 11 show the variations in the selected variables before and after matching, where the covariates of the variables exhibited significant differences were balanced. The presence of a balance of covariates between the two groups in turn allows for further impact estimation procedures.

### 3.2.3. Choice of matching algorithm

For a relatively better estimation algorithm, the four major matching estimators were tried with different bandwidths and trim levels by considering the PSM assumptions that the percentage of mean bias and value should be  $< 5\%$  and  $\beta < 25\%$ , respectively (Caliendo & Kopeinig, 2008). As shown in Appendix 3, many of the matching estimates have fitted the' (Rubin, 2001)s suggestion of the required balance in which the value of B is expected to lie below 25, of R between 0.5 and 2, and the mean bias below 5. All estimation algorithms have shown insignificant LR  $\chi^2$ , which is considered an additional indicator for the presence of a high degree of covariate balance between the adopters and non-adopters that are ready for use in the estimation process. The values of Ps  $R^2$  are also lower in all of the estimators. Nevertheless, we opted for the Kernel estimation algorithm with Bandwidth (0.1) as it has shown the lowest Ps  $R^2$ , mean bias, and B and R values. A relatively lower Ps  $R^2$  (0.002 in the estimator we choose) confirms that adopter households do not exhibit many divergent characteristics.

Furthermore, as per the Minima and Maxima criterion, those observations whose propensity score is both smaller than and larger than that of the opposing group were eliminated while determining the common support region (Caliendo & Kopeinig, 2008). Fortunately, only six observations were shown outside of the common support region in all matching estimators calculated. As a result, observations whose propensity score is lower than the minimum of 0.065 and higher than the maximum of 0.893 in the opposite group were not included for matching (Table 12).

The propensity score of the density of distribution in adopters and non-adopters, as graphically depicted in Figure 5, indicates the presence of a wide common support region and the reasonable distribution of the p-score across both groups. This suggests that the fair balance required to estimate the impact of adopting the *Korra tef* variety on the adopters' *tef* commercialization status has been attained.

### 3.2.4. Estimating treatment effect on the treated (impact of adoption on the adopters)

The PSM result shows that the adoption of *Korra tef* variety has a positive and significant impact on the adopters' status of *tef* commercialization. As indicated in Table 13, the ATT is positive, and adopters were significantly ( $P < 0.01$ ) more commercialized than non-adopters by about 23.43%. The result implied that the adoption of the *Korra tef* variety increased adopters' commercialization of *tef* by about 23.43% more than the non-adopters. That is, the rate of commercialization among adopters is 23.43% higher than that of households in the matching control group. This result is consistent with the findings of (Degefa et al., 2022; Gebreselassie & Sharp, 2007; Mazengia, 2016) in which a positive and significant effect have observed from the adoption of improved *tef* varieties.

Table 11. Propensity score and covariate matching for the variables used						
Variables	Unmatched Matched	Mean		% bias	% reduction  bias	P> t
		Treated	Control			
SEX	U	0.894	0.923	-10.7		0.241
	M	0.893	0.893	0.2	97.8	.981
HHSIZE	U	7.235	6.589	27.0		0.003
	M	7.149	7.195	-1.9	92.8	.832
MARSTATUSHH	U	1.299	1.229	7.2		0.434
	M	1.289	1.322	-3.4	52.2	.744
FARMEXPHH	U	18.7	17	19.0		0.040
	M	18.428	18.295	1.5	92.2	.875
TOTFARMLAND	U	1.871	1.805	18.5		0.044
	M	1.87	1.878	-2.2	88.3	.818
TLU	U	3	4.546	-45.5		0.000
	M	3.026	3.065	-1.1	97.5	.870
MAINPARTCCOOP	U	2.516	3.589	-32.8		0.000
	M	2.535	2.669	-4.1	87.6	.634
RADIOOWN	U	0.503	0.403	20.0		0.030
	M	0.493	0.5	-1.5	92.4	.876
CREDUSE	U	0.57	0.562	1.6		0.859
	M	0.572	0.58	-1.7	-3.4	.861

(Continued)

Table 11. (Continued)						
Variables	Unmatched Matched	Mean		% bias	% reduction  bias	P> t
		Treated	Control			
FTCDIST	U	2.317	2.91	-45.6		0.000
	M	2.35	2.438	-6.8	85.1	.446
MRKTDIST	U	11.5	10.46	38.6		0.000
	M	11.476	11.582	-3.9	89.8	.686
INONFARMACT	U	3581.9	3050.2	7.6		0.407
	M	3542.3	3496.9	0.6	91.5	.948
REMIT	U	1172.9	1937.6	-19.0		0.041
	M	1178.6	1235.9	-1.4	92.5	.859

Source: Computed from own survey data (2020).

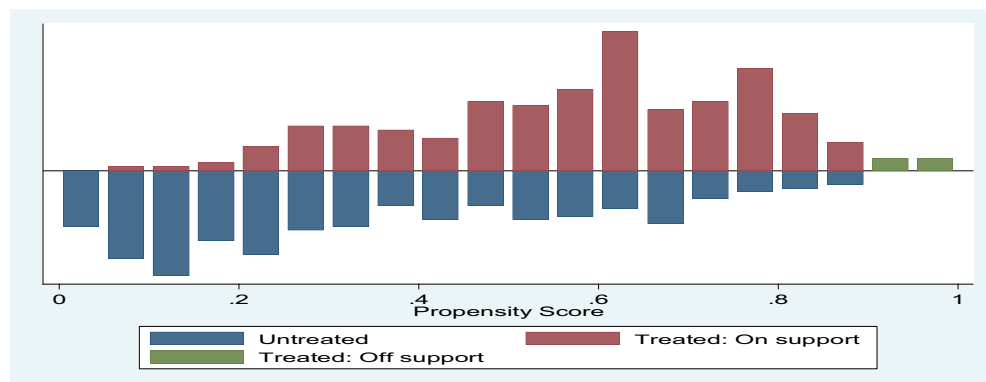
**Table 12. Distribution of estimated propensity scores**

Variable	Groups	Obs.	Mean	Std. dev.	Min	Max
pscore	Total HH	479	0.459	0.247	0.0007765	0.9636034
	Treated	221	0.589	0.189	0.0653953	0.9636034
	Control	258	0.346	0.237	0.0007765	0.8932305

Source: Computed from own survey data (2020).

**Figure 5. Distribution of propensity score generated from Kernel Matching.**

Source: Own survey data (2020).



### 3.2.5. Sensitivity analysis

Sensitivity analysis is recommended for the estimation of unobservable biases from the result of the PSM (Liu et al., 2013). Appendix 4 displays the output of Rosenbaum bounds sensitivity analysis. A critical value known as  $e$  (Gamma) is used to estimate the hidden bias's magnitude.

For the outcome variable of household commercialization, the lowest critical value ( $e_y$ ) that includes zero is 34.5 (95% confidence interval). This showed that to label the obtained result as sensitive to unobserved factors than inferring the impact of the adoption of the *Korra tef*, the adopter and non-adopter households should have been different up to 3350% ( $e_y = 34.5$ ) in terms of unobserved covariates which would appear improbable under normal circumstances. The result also implies that for the household commercialization status estimated, at various levels of critical value  $e_y$ , the p-critical values are significant which further indicates that important covariates that affected the outcome have been considered. Hence, the hidden bias magnitude confirms that significant differences between adopters and non-adopters in the commercialization of *tef* are insensitive to unobserved selection bias, in which the positive impact found could only be attributed to the adoption of the *Korra tef* variety.

### 3.3. Study limitations and areas for further studies

The lack of previous research on the study topic is the major limitation of this study. There are very few studies on the impact of adopting different *tef* varieties on the commercialization status of *tef* farm households in general and no similar research on our study topic in particular. This might impede the scope of the study under consideration. Thus, for a mature understanding of the commercialization impacts of *Korra tef* and to gain additional insight into its commercialization

**Table 13. Commercialization result of average treatment effect on the treated (ATT)**

Variable	Sample	Treated	Controlled	Difference	S.E	T-stat
Commercialization	Unmatched	58.923	36.698	22.228	0.994	22.38
	ATT	58.999	35.567	23.432	1.241	18.88

Source: Computed from own survey data (2020).

implications, future studies could address determinants of its adoption in the study area and/or other comparable areas. This would also help to identify the essential traits or actions of farmers that are linked to more dynamic paths of commercialization of *Korra tef*.

#### 4. Conclusion and policy implications

Many studies have been conducted on the linkage of the adoption of an improved variety of *tef* seed and *tef* productivity and its contribution to households' income gain from the same. However, a study on whether the adoption of the same crop technology has contributed to smallholders' commercialization status has received little attention. The empirical literature on the possible direction of a relationship between the adoption of *Korra tef* and smallholder commercialization is not found. Micro-level information regarding the impact of the adoption of improved *tef* variety on the household commercialization status would be helpful for the design of pro-poor development policies and/or strategies. Hence, a comprehension of the impact of the adoption of crop technology on smallholder commercialization is imperative in implying development policies and strategies that revolve around farm households' commercialization.

In this study, we consider households who adopted the AGP II introduced *Korra tef* variety as the treatment group from the AGP II intervention *woreda* and households who did not adopt *Korra* as the control group from the adjacent non-AGP II *woreda*. The average commercialization impact on the treated was estimated using the HCI for the descriptive analysis and PSM for econometrics analysis. Considering the volume of *tef* sold, the average level of commercialization of the sample households is 46.95%. The level of *tef* commercialization varies between adopter farm households and non-adopter farm households, with the former accounting for 58.92% and the latter for 36.7%, respectively. The majority of the adopter households 190 (84.07%) lie in the category of commercialized farmers while 144 (83.24%) of the non-adopters lie in the category of semi-commercialized farmers. The PSM estimative has also indicated that adoption of the *Korra tef* variety has a positive and significant effect on adopter households' by which the rate of their *tef* commercialization was found to be 23.43% higher than non-adopters *tef* commercialization. This is indeed consistent with the qualitative finding in which it was alleged that adoption of the *Korra tef* promotes the adopters' commercialization by enhancing their productivity, and hence, raising marketable surpluses of their *tef*.

The policy implication of our finding is that intensifying the adoption of improved varieties of *tef* (i.e. *Korra* in this case) is paramount to augment smallholders' productivity. This in turn could support the commercialization of *tef* producers by creating a surplus of produce. Hence, policies, strategies, and programs designed to strengthen *tef* producer smallholders' linkage to the output markets should need to consider the supply of improved *tef* varieties with all required packages. The concerned government structures at all levels in general and the agricultural offices, in particular, need to encourage the adoption of improved varieties of *tef* by strengthening extension services, availing supportive agricultural technologies, and enhancing market access.

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#### Disclosure statement

No potential conflict of interest was reported by the author(s).

#### Authors contribution

The corresponding author generated the research issues and title of the study. All the authors did conceptualize the research ideas and the study design. The

corresponding author gathered the data, carried out the data analysis, and prepared a draft of the study report. The first co-author, Dr. Alemu Azemeraw supervised the fieldwork and reviewed the report. Dr. Solomon Tsehay helped with the statistics and visualization and read and edit the content. Dr. Alemseged Geregziher as well read and reviewed the manuscript. All authors have read and agreed to the published version of the manuscript.

#### Data availability statement

The data used to support the findings of this study are available from the corresponding author upon request.

#### Geolocation information

The study area, *Wara-Jarso woreda*, is located in the Oromia region, Northwest Ethiopia. It is found 185km far from Addis Ababa, the capital city of the country. It is situated at 38° 14' 60.00" East longitude and 9° 49' 59.99" North latitude.

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#### Notes

1. *Woreda* refers to the second smallest administrative level above the *kebele* and below the *zone* in Ethiopia, except the capital, Addis Ababa.
2. *Kebele* refers to the smallest administrative unit in Ethiopia, except the capital, Addis Ababa.
3. FTCs are structures established in rural Ethiopia to support smallholder farmers. They were established throughout the country to train farmers on the use of technological packages and to facilitate agricultural extension services.
4. ETB is the national currency of the Federal Democratic Republic of Ethiopia.

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#### Appendix 1: Result of Variance Inflation Factor (VIF)

Variables	VIF	1/VIF
HHSIZE	1.06	0.943059
FARMEXPHH	1.21	0.824110
TOTFARMLAND	1.20	0.830737
TLU	1.07	0.931316
FTCDIST	1.05	0.953237
MRKTDIST	1.02	0.979941
INONFARMACT	1.07	0.934798
REMIT	1.05	0.952393
	1.09	

Source: Computed from own survey data (2020).

#### Appendix 2: Contingency coefficients test for discrete variables

Variables	(1)	(2)	(3)	(4)	(5)
(1) SEXHH	1.000				
(2) MARSTATUSHH	-0.397	1.000			
(3) MAINPARTCCOOP	-0.114	0.086	1.000		
(4) CREDUSE	0.086	-0.068	0.026	1.000	
(5) RADIOOWN	0.025	0.012	-0.071	-0.031	1.000

Source: Computed from own survey data (2020).

Appendix 3: Comparison of the matching estimators for both productivity and income

Performance criteria	Unmatched	Matching estimates														
		Nearest Neighbor					Caliper			Radius Caliper			Kernel			
		NN (1)	NN (2)	NN (3)	NN (4)	NN (5)	0.01	0.05	0.1	0.01	0.05	0.1	Bandwidth 0.01	Bandwidth 0.05	Bandwidth 0.1	
Ps R <sup>2</sup>		0.009	0.009	0.007	0.005	0.004	0.009	0.009	0.009	0.006	0.003	0.003	0.008	0.003	0.002	
LR chi <sup>2</sup>	130.80	5.57	5.08	4.10	2.86	2.61	5.57	5.57	5.57	3.75	1.97	1.57	4.77	1.74	1.30	
p>chi <sup>2</sup>	0.000	0.96	0.973	0.990	0.998	0.999	0.960	0.960	0.960	0.994	1.000	1.000	0.980	1.000	1.000	
MeanBias	22.5	5.7	4.9	4.2	3.1	3.2	5.7	5.7	5.7	3.5	3.0	2.5	4.3	2.7	2.3	
MedianBias	19.0	5.5	4.9	4.3	2.8	3.6	5.5	5.5	5.5	2.4	2.2	1.9	5.1	2.6	1.7	
B	112.4*	22.8	21.8	19.5	16.3	15.5	22.8	22.8	22.8	18.7	13.5	12.1	21.1	12.7	11.0	
R	0.50*	0.86	0.97	0.98	0.92	0.90	0.86	0.86	0.86	0.88	0.61	0.71	0.95	0.65	0.68	
%Var	60	40	40	40	40	40	40	40	40	40	50	40	40	30	40	

Source: Computed from own survey data (2020).

Appendix 4: Rosenbaum bounds sensitivity analysis (Kernel matching algorithm, bandwidth = 4, 4,)

Outcome variable	*Gamma (hidden bias magnitude)	Significance level		Hodges-Lehmann point estimate		Confidence interval (95%)	
		upper bound (sig+)	lower bound (sig-)	upper bound (t-hat+)	lower bound (t-hat-)	upper bound (CI+)	lower bound (CI-)
Commercialization	1	0	0	24.4312	24.4312	23.3467	25.4169
	10	0.000048	0	14.9933	30.3394	11.5257	31.6954
	20	0.003644	0	11.6792	31.6587	5.89751	33.6658
	30	0.016628	0	9.55868	32.3805	2.15523	35.1593
	34	0.024047	0	8.89761	32.5849	0.284837	35.9246
	34.1	0.024245	0	8.8966	32.5949	0.124757	35.9605
	34.2	0.024443	0	8.88137	32.6042	0.007188	35.9716
	34.3	0.024642	0	8.86757	32.6115	0.005375	35.9821
	34.4	0.024841	0	8.84788	32.6194	0.000637	36.0288
	<b>34.5</b>	0.025041	0	8.83937	32.6195	<b>-0.043041</b>	36.0364
	34.6	0.025241		8.82634	32.6232	-0.075189	36.0475

\*- gamma (Γ)—log odds of differential assignment due to unobserved factors.

Notes: The lowest critical value of gamma for 95% CI including zero is bolded.

Source: Computed from own survey data (2020).