EXPLORING THE NEXUS OF RICE TECHNOLOGY ADOPTION, COMMERCIALIZATION, AND CONSUMER PREFERENCES IN ETHIOPIA

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Ph.D. Dissertation

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Food and Resource Economics program

Graduate School of Horticulture

CHIBA UNIVERSITY, JAPAN

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EXPLORING THE NEXUS OF RICE TECHNOLOGY ADOPTION, COMMERCIALIZATION, AND CONSUMER PREFERENCES IN ETHIOPIA

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FOOD AND RESOURCE ECONOMICS

I hereby certify that I have read and evaluated the Dissertation entitled "**Exploring the Nexus of Rice Technology Adoption, Commercialization, and Consumer Preferences in Ethiopia**" prepared under my guidance by Abebaw Assaye and examined the candidate. I recommend that it be submitted as fulfilling the dissertation requirement for the degree of Doctor of Philosophy.

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DEDICATION

This dissertation is dedicated to my wife, Melkam Asteraye, and my children, Hasset, Yemariam, and Natay Abebaw.

STATEMENT OF THE AUTHOR

With my signature below, I declare and affirm that this dissertation is my work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis, and dissertation compilation. Any scholarly matter included in the dissertation has been recognized through citation.

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BIOGRAPHICAL SKETCH

Abebaw Assaye was born in the Zala kebele of Guagusa Shikudad district, Awi zone, in the Amhara National Regional State of Ethiopia on December 28, 1982. He attended Kualafaj Elementary School for his primary education and Tilili Junior and Secondary School for his junior secondary education. He then joined Ankesha Senior Secondary School and completed his secondary education in 2001. He enrolled at Ambo University (formerly known as Ambo College of Agriculture) in 2001 and obtained a diploma in general agriculture in July 2003. After completing his studies, he served as an agricultural expert in the Ministry of Agriculture in Wombera and Sekela districts until 2006.

Thereafter, he joined Haramaya University in 2006 and graduated with a Bachelor of Science degree in Agricultural Economics in September 2010. Soon after his graduation, he joined the Ethiopian Institute of Agricultural Research (EIAR) based at Pawe Agricultural Research Center (PARC) as a researcher until he re-joined the postgraduate program at the same university for his Master of Science degree in Agricultural Economics in 2014. He obtained his Master's degree in Agricultural Economics from Haramaya University in June 2016. He then returned to the EIAR based at Fogera National Rice Research and Training Center in June 2016 to serve as a researcher until he joined the Doctoral Program of the Graduate School of Horticulture at Chiba University, Japan, for his Ph.D. degree in Agricultural Economics in 2021.

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ACRONYMS AND ABBREVIATIONS

ATT: average treatment effect on treated households

ATU: average treatment effect on untreated household

CAPI: Computer-Assisted Personal Interview

CSA: Central Statistics Agency

CSPro: Census and Survey Processing System

ESR: Endogenous Switching Regression

FAO: Food and Agriculture Organization

FAOSTAT: Food and Agriculture Organization Corporate Statistical Database

FDRE: Federal Democratic Republic of Ethiopia

GDP: Gross Domestic Product

Ha: Hectare

Kg: Kilogram

LR: Likelihood Ratio

MoA: Ministry of Agriculture

MPI: Multidimensional Poverty Index

MVP: Multivariate Probit Model

PDC: Planning and Development Commission

PSM: Propensity Score Matching

RCI: Rice commercialization index

SNNP: Southern Nations Nationalities and People

SWEP: Southern Nations Nationalities and People

TLU: Tropical Livestock Unit

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Exploring the Nexus of Rice Technology Adoption, Commercialization, and Consumer Preferences in Ethiopia

ABSTRACT

The agriculture sector is the most important segment of the Ethiopian economy, accounting for 32.8% of the national GDP, producing 90% of its exports, and providing employment for 72.7% of the total population. In light of the problems and the research gaps identified, this study seeks to identify and generate information on factors influencing improved rice technology adoption, the commercialization of smallholder farmers, and consumer behavior and preference for rice consumption in Ethiopia. The study utilized two sets of cross-sectional data collected from 594 rice-producing households and 200 rice consumers in the years 2018 and 2023, respectively, through a multistage sampling technique. We used descriptive statistics and econometric models to look at the data. These models included multivariate probit, probit, Tobit, endogenous switching regression, and propensity score matching. A multivariate probit (MVP) model involving a system of five equations was used to assess the determinant for the decision to adopt improved rice technologies and practices. The results showed that the adoption levels of improved rice varieties, row planting, recommended rate of Urea fertilizer, recommended rate of DAP/NPS fertilizer, and recommended weeding frequency were 24.4%, 23.4%, 40.9%, 38.6%, and 52.4%, respectively. The model results attest that improved rice production technology packages are complementary. This finding implies that farm-level policies that affect the use of one improved agricultural technology can have a positive effect on other technologies. On the other hand, the endogenous switching regression model results indicate that the adoption of improved rice varieties has a robust and positive impact on rice yield, income, and commercialization. Controlling the variations in household characteristics, the average effect of improved rice variety adoption on productivity was 0.564 t/ha. Similarly, the econometric result showed that improved rice variety adoption decreased multidimensional poverty and subjective poverty by 1.7% and 12.4%, respectively. The Tobit model result for rice output commercialization showed that the educational status of the household head, credit use, the share of irrigated land cultivated, membership in social groups, and land dedicated to rice production were found to influence significantly and positively the level of output commercialization. Conversely, total cultivated land and distance to the main market were found to have a negative influence. On the other hand, the Tobit model results of rice input commercialization indicated that farming experience of the household head, credit, irrigated *land, extension service, and land allocated for rice was found to influence significantly and positively the degree of input commercialization, while distance to the main market affected the degree of input commercialization negatively. In addition, the findings reveal that consumers' choices and preferences are shaped by socioeconomic factors, affordability, perceived quality, convenience, and cultural compatibility of rice types. Furthermore, key quality attributes, including color, price, level of impurities, and breakage, play pivotal roles in shaping consumer choices, varying in importance across regions. Generally, the government should devise ways to ease the accessibility of improved rice seeds and fertilizers along with the introduction of labor-saving technologies to increase productivity, commercialization, and reduce reliance on imported rice in the country. In addition, there is a need to implement different policies that address the specific determinants of smallholder farmers' improved technology adoption and commercialization.*

Keywords: Adoption, Impact, Improved rice, Commercialization, consumers' preferences, Ethiopia

CHAPTER ONE

1. Introduction

1.1. Background of the research

The agriculture sector is the mainstay of the Ethiopian economy and the people at large. The sector contributes 32.8% of the country's GDP, produces 90% of its exports, and provides employment for 72.7% of the total population. The official data for Ethiopia show that the country's economy experienced strong and broad-based growth, averaging 9.2% per year, and the agriculture sector has grown on average by 5.3% per year from 2010 to 2020 (PDC (FDRE Planning and Development Commission), 2021). This consistent and higher economic growth, especially in agriculture, has significantly contributed to Ethiopia's important poverty reduction observed during the last decade. Enhancing the productivity of this sector is, therefore, crucially important, not only for the development of the sector itself but also for the development of other sectors in the economy.

Rice is among the targeted commodities that received due attention in transforming agricultural production in the country. The Ministry of Agriculture has recognized the importance of rice in agriculture and designated it as the "millennium crop" to ensure food security and import substitution (MoA, 2020). The cultivation of rice in Ethiopia is a recent phenomenon. It is linked with the introduction and testing of improved varieties in the early 1970s in different parts of the country to address various challenges related to settlement and food security during the Derge regime (Alemu et al., 2018). Since its introduction, rice production has rapidly expanded to various parts of the country, especially since the mid-1990s, following rice research initiatives and the generation of high-yielding improved varieties. The total area under rice production has increased from about 35,088 ha in 2009 to over 85,289 ha in 2021, and the national production has increased from 71,394 tons in 2009 to 268,224 tons in 2021 (CSA, 2021). Among cereals, rice ranked second after maize in terms of productivity. Between 2005 and 2021, rice productivity increased from 1.8 t/ha to 3.14 t/ha, and the contribution of new technologies disseminated to farmers is instrumental.

Increasing agricultural productivity through the adoption and diffusion of modern agricultural technologies is a key pathway for economic growth and agricultural transformation in developing countries (Chilot & Dawit, 2016; Jaleta et al., 2018; Pingali, 2012). This is particularly relevant for many sub-Saharan African countries, including Ethiopia, where the performance of the agriculture sector determines the livelihoods of more than eighty million of the population. Meaningful changes in agricultural productivity through improved technologies, for example, can be one means of ensuring food security by increasing production and reducing food prices.

Improving the agricultural production systems and marketing infrastructures of smallholder farmers is becoming a key strategy for agricultural commercialization and poverty reduction. Smallholder farmers' market participation has been recognized as crucial for transforming agriculture from subsistence-oriented to market-oriented and achieving expected agricultural growth. Consequently, as smallholder farmers begin to produce an agricultural surplus for the market, the farmers are more likely to increase productivity through intensification and then through their market participation (Abdullah et al., 2019; Block, 1999; Wiggins, 2014). Thus, their commercialization can be considered an indicator of a step toward a market-oriented farming system.

Commercial-oriented farm households make production decisions based on market signals and comparative advantages in the market, while semi-commercial and subsistence farm households make production decisions based on their subsistence requirements and participate in marketing the surplus left after meeting their household's consumption requirements. Hence, production decisions vary among smallholder farmers based on their level of commercialization, demographic, socio-economic, and farm-level variables (Abdullah et al., 2019; Barrett, 2008; Ogutu & Qaim, 2019; Pingali, 2012). Therefore, improving agricultural marketing facilities, access to improved technologies, productive assets, and rural infrastructure could enable farm households to plan their production more in line with market signals, schedule their agricultural product processing, and decide which markets and to whom to sell their products (Barrett, 2008). Moreover, a proper agricultural marketing system could also enable farm households to increase production and market efficiency.

Furthermore, enhancing the commercialization of the rice sector is a vital pathway toward ensuring food security and import substitution for smallholder farmers in Ethiopia. Commercialization stimulates agricultural productivity by increasing the opportunity to use the income obtained for input purchases, leading to increased agricultural productivity and surplus production for the market. The commercialization of rice is believed to lead smallholder rice-producing farmers to a more specialized rice production system based on the comparative advantage of rice in resource utilization. The productivity of rice is by far better than most cereal crops except maize, and the market price of rice is also the highest among cereals next to tef (CSA, 2021; Assaye et al., 2022).

Marketing is the process of identifying and addressing the human and social needs of consumers. It is both an art and a science, involving the identification and targeting of specific markets, the development of strategies using the marketing mix elements, and the establishment, communication, and promotion of consumer value (Kotler & Keller, 2021). Consumer preferences can vary based on factors such as income levels, lifestyles, culture, and other influences. Satisfying consumer demands and preferences requires innovative approaches to maintaining the existing customer base while also attracting new ones (Carreras-Simó et al., 2023; Custodio et al., 2019; Sgroi et al., 2022). Moreover, improving marketing facilities for crops in general and the rice sector in particular will enable farmers to plan their production more in line with market demand, schedule rice processing and marketing at the most profitable times, and decide which markets to sell to. Besides, a proper rice marketing system based on consumer behaviors and preferences can also encourage rice technology adoption and commercialization.

Furthermore, a market-driven approach that integrates consumer insights can significantly boost the adoption of improved rice technologies. Farmers are more likely to adopt new practices and innovations when they notice a direct correlation between adopting improved technologies and meeting consumer demands. This, in turn, leads to increased productivity and improved overall agricultural practices, benefiting both farmers and consumers. On the other hand, the commercialization of rice, driven by a consumer-centric marketing system, can also lead to economic growth and increased employment opportunities. Moreover, a consumer-centric marketing system not only meets consumer needs but also benefits farmers and the whole rice value chain by promoting sustainability and technological advancement in rice production and marketing. Therefore, studies on consumer rice preferences, rice commercialization, and improved technology adoption are important in guiding investment efforts, particularly in rice production and marketing, to boost the rice sector in Ethiopia.

1.2. Statement of the Problem

Ethiopia, a country with an area of about 1.12 million square kilometers, is one of the most populous countries in Africa, with a population of 115 million in 2020 and an annual growth rate of 2.6% (World Bank, 2021). This growing population requires better economic performance than ever before, at least to ensure food security. However, the agricultural sector in the country is characterized by small-scale, traditional farming and is heavily dependent on rainfall. As a result, production is primarily for self-consumption (Alelign et al., 2017), with the possibility of supplying only a small share of the total output produced to the markets.

The development of agricultural value chains is crucial for transforming the sector by creating connections between different actors involved in the production, processing, packaging, storage, transport, and distribution of agricultural products (Alemu & Assaye, 2021; Demont & Ndour, 2015; Stryker, 2013). The government of Ethiopia has implemented several initiatives to promote the growth and development of the agriculture sector in the country. Some of the most prominent policies and strategies are Agricultural Led Industrialization (ADLI), the Sustainable Development and Poverty Reduction Program (SDPRP), Participatory and Accelerated Sustainable Development to Eradicate Poverty (PASDEP), and successive Growth and Transformation Plans (GTP I and II). These strategies intend, among others, to attain food self-sufficiency at the national level by increasing productivity through the adoption of improved agricultural technologies and innovative approaches, promoting commercialization, and ensuring the rehabilitation and conservation of natural resources (Welteji, 2018). Despite efforts made to commercialize and transform subsistence production, the current reality shows that commercialization of smallholder farming is much below expectations, and farmers are not yet out of subsistence-oriented agriculture and low productivity (Azam et al., 2012; Gebremedhin & Jaleta, 2010; Kay Sharp, 2007; PDC (FDRE Planning and Development Commission), 2021).

Increasing rice productivity and production is essential to ensure national food security, reduce foreign currency spent on rice imports, and safeguard against rice market volatility. The use of high-yielding crop varieties, along with other recommended technology packages, can increase rice production and facilitate the growth of agro-processing enterprises and non-farm sectors. However, the availability of improved technologies alone is not sufficient to increase productivity; they also need to be used by farmers. Given that rice is a relatively recent introduction to Ethiopia compared to other African countries, estimating the gains from the use of improved technologies in a more robust setting can stimulate investments. Whether improved rice variety adoption has led to better welfare outcomes is a question of great relevance to policy and development in the country. On the other hand, development initiatives and policymakers require information on rice commercialization to address existing development gaps and opportunities that help boost economic contribution and secure national self-sufficiency in rice.

Despite considerable efforts put into commercializing rice production, the development and dissemination of improved rice technologies, the extent to which these technologies are used, and their contributions to productivity gain, income, and household welfare have been barely addressed in the literature. In addition, most earlier studies have emphasized non-rice crops, such as tef, maize, and wheat, and examined the factors that influence agricultural technology adoption and its subsequent effects on welfare and poverty reduction (Genet & Feyso, 2020; Getahun, 2019; Giziew & Mebrate, 2019; Jaleta et al., 2018; Shiferaw et al., 2014). Furthermore, the literature does not address consumers' behavior and consumption preferences for rice or how rice is consumed in Ethiopia. Moreover, most studies on rice in Ethiopia have been somewhat limited in scope, often focusing on specific locations and relying on small sample sizes (Abera, 2021; Abera & Assaye, 2021; Asmelash, 2014; Assaye et al., 2020; Belayneh & Tekle, 2017; A. Hagos & Zemedu, 2015; Takele, 2017).

In general, most of the previous empirical studies conducted in Ethiopia have limitations in identifying the connection between improved rice technology adoption, productivity, commercialization, consumption, and the welfare of smallholder farmers. Moreover, there is a negligible amount of information available, and the interplay between improved rice technology adoption, commercial orientation, and welfare at the household level is not adequately researched and verified in Ethiopia. In addition to the above challenges, the FAO (FAO, 2011) has identified research gap priorities in areas such as smallholder farmers' commercialization, access to improved agricultural inputs, and increased involvement of the private sector in production, which need to be addressed to promote sustainable agricultural development in Ethiopia.

Thus, it is critically important to generate empirical evidence on factors determining improved rice technology adoption, rice consumer preferences, rice commercialization, and their contributions to the welfare of smallholder rice-producing households. Therefore, this study has been designed to answer the following key research questions:

1. What are the key drivers of the expansion of rice production and marketing?
2. What factors determine rice technology adoption?

3. What are the levels of rice technology adoption, and what are the determinant factors of rice technology adoption?

4. Does improved rice technology adoption affect smallholder farm households' welfare?

5. What factors determine rice commercialization (input and output marketing)?

6. What is the preference of consumers for rice in their daily diet? How do Ethiopian consumers consume rice?

1.3. Objective of the study

The general objective of the present study is to generate empirical evidence on factors determining improved rice technology adoption, commercialization, and their contributions to the welfare of smallholder rice-producing households in Ethiopia. The study intends to achieve the following specific objectives:

1. To document the level of rice technology adoption and its determinants among smallholder rice farmers.
2. To assess the impact of adopting improved rice technologies on smallholder rice farmers' welfare.
3. To assess the extent of smallholder rice commercialization and its determinants.
4. To assess the behavior and preferences of Ethiopian rice consumers.

1.4. Scope and Limitations of the Study

This study used cross-sectional data collected from 594 sampled rice producer households and 200 rice consumers from the main rice-producing areas of Ethiopia. The study used households as the primary unit of analysis because they play a central role in decision-making in the study area. However, for future research, a more detailed examination at the individual household members' level may be needed to apply the findings of this research. This could provide a more nuanced understanding of decision-making processes and enhance the practical applicability of our findings.

The study focuses on understanding the intricate interplay of factors that influence rice technology adoption and commercialization. It also encompasses an in-depth examination of various dimensions, including socioeconomic, demographic, institutional, and farm-level factors that influence smallholder farmers' improved rice technology adoption and commercialization. The research content also extends to characterizing the study areas, profiling smallholder rice farmers, and analyzing the behaviors of rice consumers in both rural and urban contexts. Furthermore, the study investigates the extent of rice technology adoption and its impacts on yield, income, commercialization, and poverty reduction.

Although this study might have demonstrated some strength, it may also have some limitations in collecting data from the study areas that emanate from limited financial resources, facilities, and time. As a first limitation, the study utilized cross-sectional data due to the difficulty of obtaining panel data, which could have revealed changes over time. As a result, managing the dynamic household's behavior about the changes in their technology choices and consumption preferences over time might affect the study’s findings. Additionally, the study used data collected from a small sample size of 594 rice producers and 200 rice consumers, which might not be sufficient for making comparisons at the district level despite the researcher’s efforts to maintain external validity. Lastly, the research was limited to only the main rice-producing regions, which could not address the newly emerging rice-producing areas. Hence, the results of this study can be interpreted and used in other areas where rice is not the dominant crop throughout the country.

1.5. Organization of the Dissertation

The dissertation is organized into seven chapters. A description of the research background, statement of the research problem, research questions, objectives, scope, and limitations of the study are presented in the first chapter. The second chapter presents concepts and definitions and a brief description of the nexus of rice technology adoption, commercialization, and consumer preference for rice consumption in Ethiopia. From chapters three to six, individual papers are presented, along with an abstract, a brief background, the methodology, the results, conclusions and policy recommendations. The final chapter summarizes the main findings of the research work and provides conclusions and recommendations. Chapters 3, and 4 of the dissertation are based on published articles, and chapter 5 is based on the paper presented in the conferences (bibliographic details are provided in Appendix 4).

CHAPTER TWO

2. Definitions, Concepts, and Overview of Rice Sector in Ethiopia

This chapter provides a comprehensive overview of rice production in Ethiopia, the nexus of smallholder farmers' technology adoption, commercialization, and consumers' behavior and preference for rice consumption, and the basic concepts and definitions of technology adoption, commercialization, and consumers' behavior and preference.

2.1. Definitions and Concepts

2.1.1. Agricultural Technology Adoption

Agriculture remains a cornerstone of sustainable development, poverty reduction, and improving the food security and welfare of smallholder farmers in developing nations. It stands as a robust avenue for boosting economic growth, eradicating poverty, and creating a conducive environment for overall economic development. Consequently, there is a pressing demand to increase agricultural productivity by introducing and implementing improved agricultural technologies and promoting the commercialization of agricultural production (World Bank, 2008; Moreno and Sunding, 2005).

Adoption and diffusion of agricultural technologies are the processes governing the utilization of innovations (Sunding and Zilberman, 2001). There is often a significant interval between the time an agricultural innovation is developed and available on the market and the time it is widely used by producers. Most adoption behavior studies focus on the factors that influence the adoption of agricultural technologies agricultural technology adoption. It is important to determine when and to what extent new technologies are adopted by individual users. Adoption behavior can be measured by a binary choice, such as whether or not to use an innovation, or by a continuous variable indicating the level of use of a divisible innovation.

The adoption of an innovation within a social system takes place through its adoption by individuals or groups. According to Feder et al. (1985), adoption may be defined as the integration of an innovation into farmers' normal farming activities over an extended period of time. Dasgupta (1989) noted that adoption, however, is not a permanent behavior. This implies that an individual may decide to discontinue the use of an innovation for a variety of personal, institutional, and social reasons, one of which might be the availability of another practice that is better at satisfying farmers' needs.

Rogers (2003) defines the adoption process as the mental process through which an individual passes from first hearing about an innovation or technology to final adoption. This indicates that adoption is not a sudden event but a process. Farmers do not accept innovations immediately; they need time to think things through before reaching a decision. The rate of adoption is defined as the percentage of farmers who have adopted a given technology. The intensity of adoption is defined as the level of adoption of a given technology. The amount of input used per hectare or the number of hectares planted with improved seed (also tested as the percentage of each farm planted with improved seed) will be used to measure the intensity of adoption of each technology.

Griliches' (1957) exploration of the economics of technological change was one of the earliest studies on technology adoption and hybrid corn varieties across the agricultural regions of the United States. This study led to the possibility of performing an economic analysis of the process of innovation and the adoption of a particular invention. Dasgupta (1989) indicates that the decision to adopt an innovation is not normally a single, instantaneous act and that it involves a process. Adoption is a decision-making process involving a period of time during which an individual goes through a number of mental stages before making a final decision to adopt an innovation. Lionberger (1960) and Rogers and Shoemaker (1971) indicate that the innovation decision process is the mental process through which an individual passes from knowledge of innovation to a decision to adopt or reject it and to confirmation of this decision.

Shields et al. (1993) conducted a longitudinal analysis of factors influencing increased technology adoption in Swaziland maize production. Their study provided insight into the adoption process, which is shaped by different factors and endowments. Recommended farming practices included improved seed varieties, tractor plowing, chemical fertilizers, and insecticides. Results of the logistic model of adoption showed the significant influence of four factors on maize farmers' decisions to adopt new technology: farmers' ability to mobilize sufficient labor, the availability of capital, farm size, and risk aversion. Lack of cash would reduce the use of hybrid seed, basal, and top-dressed fertilizers. Certainty in the expected rainfall, associated with higher anticipated output levels, would encourage farmers to adopt new technology. Although farmers often reject an innovation instead of adopting it, non-adoption of an innovation does not necessarily mean rejection. Farmers are sometimes unable to adopt an innovation, even though they have mentally accepted it, because of economic and situational constraints (Dasgupta, 1989).

The extent of adoption is typically slow at first until the beneficiaries of the technology or innovation gain awareness, according to Lionberger (1960) and Rogers (2003). They gradually increase after a slow start, until approximately half of the potential adopters have accepted the change. Following that, acceptance continues, but at a decreasing rate. It reaches a peak when half of the potential adopters in the system have adopted the innovation, and then gradually increases at a decreasing rate as the few remaining people adopt it.

2.1.2. Agricultural Commercialization

The commercialization of agriculture takes many forms and is defined in different ways. Generally, smallholder commercialization in agriculture can be defined in terms of smallholder participation in commercial input and output markets, the types of crops grown by smallholder farmers, and the goals of smallholder farmers. Govereh et al. (1999) define agricultural commercialization as the proportion of agricultural production that is marketed. According to these researchers, agricultural commercialization aims to bring about a shift from production for solely home consumption to production dominantly for the market. Commercialization can be measured along a continuum from zero (total subsistence-oriented production) to unity (100% of production is sold). The commercialization of agriculture involves a transition from subsistence-oriented to increasingly market-oriented patterns of production and input use.

Policy discourses around various dimensions of agricultural commercialization tend to separate producers into different types of farms (small farms, large farms) growing different types of crops (food crops, cash crops), with simple distinctions made between ‘subsistence' and ‘commercial' or ‘export’ agriculture (Leavy and Poulton, 2007). A lack of clarity about what commercialization means may give rise to misconceptions, evoking certain fears that can obstruct the passage of policy into practice.

A farm household is considered commercialized if it produces a significant amount of cash commodities, allocates a significant portion of its resources to marketable commodities, or sells a significant portion of its agricultural outputs (Immink and Alarcon, 1993). However, the definition of commercialization extends beyond simply supplying surplus products to markets. It has to consider both the input and output sides of production and the decision-making behavior of farm households in production and marketing simultaneously (Pingali, 1997; von Braun, 1995). Moreover, commercialization is not limited to cash crops; traditional food crops are also frequently marketed to a significant extent (Gebremedhin & Hoekstra, 2007; von Braun, 1995).

Commodities traditionally considered as food crops may increasingly be marketed during the transformation process as households specialize. The commonly accepted concept of commercialization is, therefore, that commercialized households are targeting markets in their production decisions, rather than being related simply to the amount of product they would likely sell due to surplus production (Pingali and Rosegrant, 1995). In other words, the production decisions of commercialized farmers are based on market signals and comparative advantages, whereas those of subsistence farmers are based on production feasibility and subsistence requirements, and selling only whatever surplus product is left after household consumption requirements are met (Gebremedhin and Tegegne, 2012). Generally, agricultural commercialization refers to households targeting markets in their production decisions, focusing on market signals and comparative advantages rather than selling surplus products after meeting household consumption requirements.

2.1.3. Choice and consumption behaviour

Changes in the environment have a significant impact on changes in consumer attitudes and behavior, both on the market and in other social spheres. Consumers keep taking action under the influence of a variety of factors in their daily lives. Some are brand loyal, others choose products that align with their beliefs, and others are willing to pay more for no reason other than fashion, opinions, etc. It is unclear what motivates consumers to participate in certain buying and consumption habits. The definition formed by Solomon et al. (2009) describes consumer buying behavior as a process of choosing, purchasing, using and disposing of products or services by the individuals and groups in order to satisfy their needs and wants.

Peter and Olson (2005), defines consumer behavior as any human behavior at home, in a shop, or on the street where people plan to buy, buy, or use purchased products. In other words, they defined as “the interactions and exchanges of experiences that involves the thoughts and feelings people experience and the actions they perform in consumption processes. It also includes comments from other consumers, advertisements, price information, packaging, and product appearance”. According to Bennett (1995), consumer behavior is the dynamic interaction of perception, behavior, and the environment in which individuals are experiencing in their live.

According to Kotler and Armstrong (2008), four types of factors can influence behavior: Psychological, personal, social, and cultural. Kotler and his colleagues (Kotler & Keller, 2021) categorized factors influencing buyer behavior into four types: cultural, social, personal, and psychological. Cultural factors encompass elements like culture, subculture, and social class. Social factors involve peer groups, family, societal roles, and status. Personal factors encompass age, life cycle stage, profession, material situation, lifestyle, and personality. Finally, psychological factors encompass motivation, perception, selective memory, the learning process, and beliefs. Furthermore, some of the specific constructs that researchers focus on include consumer perceptions (quality preference, usefulness, etc.), brand/product awareness, attitudes, social influences, and more (Asante-Addo, 2020; Rahman & Islam, 2020; Šostar & Ristanović, 2023; Yang et al., 2021). This is especially useful for market researchers, who frequently measure aspects of consumer behavior through surveys and studies in order to better understand customers' needs, wants, and preferences.

In the meantime, Kotler and Keller (2011) highlight the importance of understanding consumer buying behavior and the ways how the customers choose their products and services can be extremely important for producers as well as service providers as this provides them with competitive advantage over its competitors in several aspects. For example, they may use the knowledge obtained through studying the consumer buying behavior to set their strategies towards offering the right products and services to the right audience of customers reflecting their needs and wants effectively. Another valuable argument is provided by Egen (2020) on the importance of understanding the consumer behavior. According to the author, better awareness of consumer buying behavior is a positive contribution to the country’s economic state. The author further argues that the quality of goods and products are exceptionally good in countries where buying behavior of consumers is well understood. This in turn increased the competitiveness of the products and services in the international market increasing the export potential of the country (Blackwell et al, 2001).

Although the definitions given above are various, they all lead to a common view that consumer buying behavior is a process of selecting, purchasing, and disposing of goods and services according to the needs and wants of the consumers. However, there is a general consensus among researchers and academics that this process is subject to continual change over time as the purchase characteristics of the customers change due to their physical and psychological needs.

2.2. Overview of the rice sector in Ethiopia

The government of Ethiopia has recognized the potential of the rice sector and has been implementing policies and programs aimed at boosting production and productivity. The government of Ethiopia has put in place a number of initiatives to ensure the growth and development of the rice sector in the country. In recognition of the importance of rice, the government developed the National Rice Research and Development Strategy (NRRDSE, 2010–2019), the National Rice Development Strategy-II (NRDS-II, 2020–2030), and the National Rice Flagship Program (NRFP, 2023–2027). The National Rice Research and Development Strategy (NRRDSE, 2010–2019) was established in 2010 to address the challenges of the exploitation of existing rice production potential and to guide the overall rice research and development in the country. Subsequently, the National Rice Development Strategy-II (NRDS-II, 2020–2030) was developed in 2020 to ensure food security, enhance income generation, and facilitate import substitution. Recently, in 2022, the National Rice Flagship Program (NRFP, 2023–2027) was launched to facilitate the implementation of NRDS-II (MoA, 2020; MoARD, 2010).

The rice sector in Ethiopia has been experiencing steady growth in recent years, with both cultivation and consumption showing consistent increases. Over the period from 2005 to 2020, Ethiopian rice production demonstrated an upward trend in terms of area, production, and the number of smallholder farmers engaged in rice farming (Figure 1). These trends reflect Ethiopia's successful efforts to enhance rice production, improve agricultural productivity, and create opportunities for smallholder farmers in the sector over the past 15 years. However, despite the production growth, the country still relies heavily on rice imports, importing more than five times the domestic production to meet local demand (FAOSTAT, 2022). The demand for rice in Ethiopia is driven by a combination of factors, including population growth, urbanization, inflation, and changing consumer diet habits and preferences.

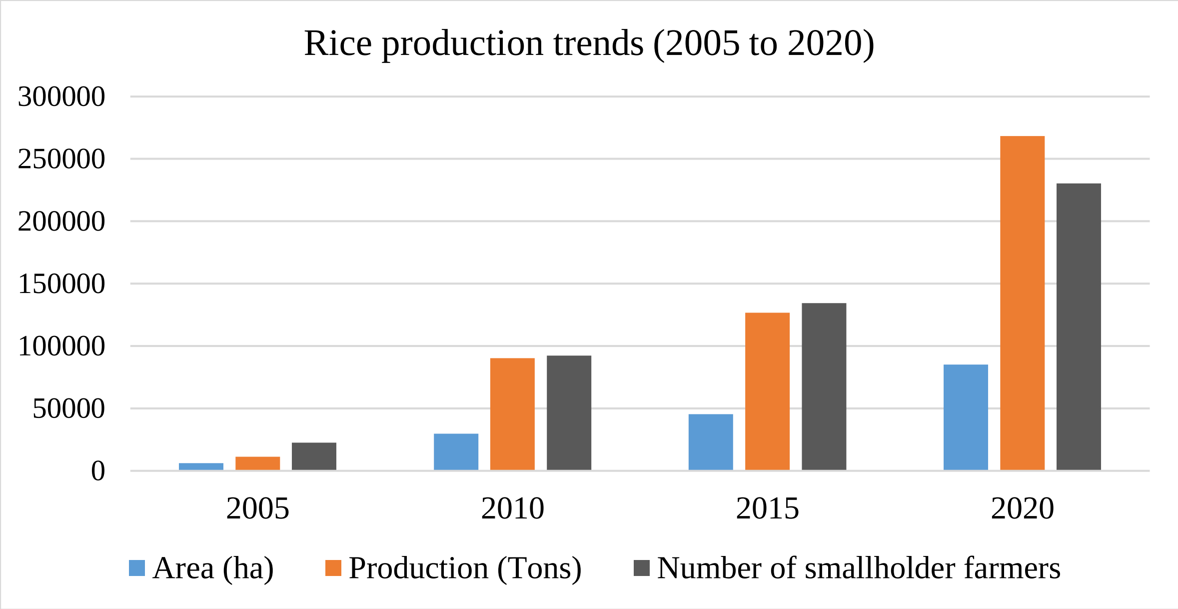

Figure 1. Trends of rice production over the past 15 years
Source: Adopted from CSA data

Even though rice production has been increasing for the last fifteen years, the supply could not satisfy the entire domestic market. Because the consumption of rice in Ethiopia is growing faster than domestic production, this has resulted in a significant decline in the self-sufficiency rate of rice. Rice consumption has been increasing by 19.9% per year over the past decade, from 2010 to 2020. The demand for rice has been increasing quickly due to population growth, urbanization, consumption habit change, increased prices of tef, and the compatibility of local rice for making *injera*[1]. Ethiopia's estimated annual rice demand was 1.6 million metric tons, while annual production was about 0.27 million metric tons in the year 2020. The market gap for rice is more than five-fold of its rice production and is filled by imports (FAOSTAT, 2022). This huge gap between domestic production and consumption demand indicates the availability of a big domestic market opportunity for rice producers and other actors in the sector. As indicated in Figure 2, the self-sufficiency in rice consumption in Ethiopia has decreased from about 70.5% in 2009 to about 17.0% in 2020. Rice imports increased from 43,252 tons in 2010 to 1,311,077 tons in 2020 (Figure 2). The country has been importing rice mainly from three countries (India, Pakistan, and Thailand).

Furthermore, the federal government of Ethiopia, the Ministry of Trade and Industry, issued a regulation that allowed companies to import basic food items like rice, flour, and other food items duty-free in April 2021. Over the last three years, particularly since the start of the

[1] Injera is a traditional Ethiopian and Eritrean flatbread mainly made from flour of tef, and other cereals

COVID-19 pandemic in Ethiopia, the government has issued far-reaching policy measures that have helped the national economy stay on track. Basic food items have been allowed to enter the country duty-free to reduce the impact of the CVD-19 epidemic on society. The importation of essential food items like rice with no taxation cannot be recommended as a permanent measure because it affects local rice producer farmers. The exemption of tax on imported rice could immensely contribute to the stabilization of prices, but this might discourage rice value chain actors in the long run. The type and quality of rice to be imported have to be clearly mentioned in the regulation to protect domestic rice value chain actors. At the same time, the government has to support domestic value chain development actors to address rice value chain problems.

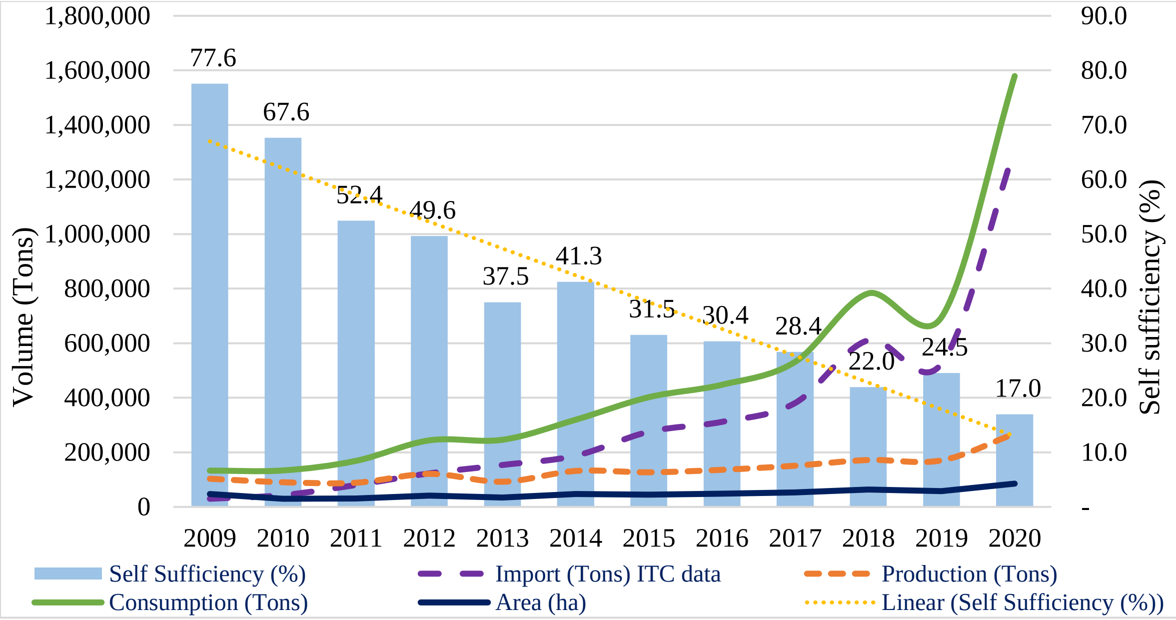

Figure 2. Rice production, imports and consumption trends (2009-2020)
Source: ITC Trade map, 2021

2.3. The Nexus of Technology Adoption, Commercialization, and Consumer Preferences

This chapter provides a comprehensive view of various aspects related to smallholder farmers' improved technology adoption, crop commercialization, and consumption. Rice is an important global economic and staple food crop, providing nutrition and calories for more than half of the world's population (Abdulai et al., 2018; Ndagi et al., 2016). Enhancing productivity growth in the agricultural sector is paramount, and this can be achieved by adopting improved agricultural technologies, such as improved varieties, inorganic fertilizers, and integrated farm management systems. In recent years, rice has become a significant staple crop in Ethiopia

(Alemu et al., 2018). The adoption of improved rice technology, coupled with commercialization efforts, has emerged as a critical factor in enhancing rice production and meeting the growing demand. Moreover, understanding consumer preferences for rice products is crucial for guiding rice research and development programs in the sector. This complex interplay between technology adoption, commercialization, and consumer preferences forms the core of our exploration in this study. We explore the intricate dynamics that connect these three facets to offer insights into how they collectively shape the rice sector in Ethiopia.

The adoption of improved rice technologies and practices by smallholder farmers in Ethiopia is a pivotal factor that influences the broader dynamics of the rice sector. Factors such as access to improved seeds, fertilizers, irrigation, and knowledge transfer play a significant role in encouraging farmers to adopt these practices. This technology adoption not only affects the yield and quality of rice produced but also has implications for the commercialization and consumption of rice products. For instance, improved technology can lead to increased production, thereby influencing the supply of rice in local markets. It can also enhance the quality and consistency of rice, aligning it more closely with consumer preferences. On the other hand, the commercialization of rice production in Ethiopia is closely linked to the adoption of improved technologies and farming practices. Smallholder farmers who adopt improved technologies are often better equipped to participate in rice marketing. However, the process of commercialization is not without its challenges, such as issues related to market access, pricing, and the involvement of intermediaries. How effectively farmers engage with markets and value chains impacts not only their income but also the availability and variety of rice products for consumers. Commercialization efforts can lead to a more diverse range of rice products available in local markets, catering to different consumer preferences.

Consumer preferences for rice products are instrumental in shaping the strategies of both farmers and other stakeholders who are involved in the rice value chain in Ethiopia. Preferences can vary by region, demographic, and socio-cultural factors. For instance, some consumers may have a preference for specific rice grain types, such as long-grain, medium-grain, or aromatic varieties. Others may prioritize quality attributes like taste, aroma, texture, and appearance. Furthermore, consumers may have preferences regarding rice processing methods, such as parboiled or milled rice. These preferences guide farmers in selecting suitable rice varieties to grow and influence rice processors and marketers in producing and marketing rice products that align with consumer expectations.

Generally, the interactions between technology adoption, commercialization, and consumption in Ethiopia's rice sector form a complex web of influences. Improved technology adoption can lead to increased production and a more reliable supply of rice products in the market, affecting price stability and consumer access. Conversely, consumer preferences can influence the choices made by rice farmers and traders. For example, if consumers exhibit a strong preference for a particular rice grain type, farmers may adjust their cultivation practices accordingly. Market dynamics and consumer feedback create a feedback loop, influencing the incentives for farmers to adopt new technologies and for businesses to meet consumer demands effectively. This interplay highlights the importance of considering all three elements—technology adoption, commercialization, and consumption—as interdependent factors that collectively shape the trajectory of Ethiopia's rice sector.

In general, the nexus of technology adoption, commercialization, and consumption in Ethiopia's rice sector is dynamic and intricate. The adoption of modern farming practices influences the supply and quality of rice products in the market, while consumer preferences drive product choices and innovation. Recognizing the interconnections between these elements is essential for policymakers, farmers, researchers and agribusinesses as they work together to enhance the sustainability and growth of the rice sector in Ethiopia.

CHAPTER THREE

3. Adoption of Improved Rice Technologies in Major Rice Producing Areas of Ethiopia: A Multivariate Probit Approach

(Published in the Journal of Agriculture and Food Security)

Abstract

The need for adopting improved rice technologies and practices has become more important in Ethiopia as the national self-sufficiency gap has increased. This article examines the adoption level and factors governing the adoption of improved rice technology packages and practices using data collected from 594 rice-producing households in Ethiopia. A multivariate probit (MVP) model involving a system of five equations was used to assess the determinant for the decision to adopt improved rice technologies and practices. The results showed that the adoption levels of improved rice varieties, row planting, recommended rate of Urea fertilizer, recommended rate of DAP/NPS fertilizer, and recommended weeding frequency were 24.4%, 23.4%, 40.9%, 38.6%, and 52.4% respectively. The model results attested that improved rice production technology packages are complementary. This finding implies that farm-level policies that affect the use of one improved agricultural technology can positively affect other technologies. The various demographic, socioeconomic, and institutional variables were found to influence the decisions to adopt different technologies of improved rice technology packages with different signs. Therefore, the government should devise ways to ease the accessibility of improved seeds and fertilizers along with the introduction of labor-saving technologies to promote row planting and achieve wider adoption of the technologies. Policies and interventions that are informed about such factors are required to accelerate the adoption of improved rice technology packages in Ethiopia to realize the green revolution and secure the sustainable self-sufficiency of rice.

Keywords: Adoption, Ethiopia, Improved rice, Smallholder farmers

3.1. Introduction

Rice is an important global economic and staple food crop, providing nutrition and calories for more than half of the world's population (Abdulai et al., 2018; Ndagi et al., 2016). The Green Revolution in Asian countries helped to achieve self-sufficiency in rice production through the introduction of high-yielding varieties and the adoption of improved agricultural production techniques (Abate, 2021; Eliazer Nelson et al., 2019). Productivity improvement for rice is therefore possible through the adoption of improved agricultural techniques (Abdulai et al., 2018). Adoption of modern agricultural technologies (improved varieties and inorganic fertilizer) and integrated farm management system is considered as an essential component of productivity growth for the agriculture sector (Donkoh et al., 2019; Takahashi et al., 2020).

The cultivation of rice in Ethiopia is a recent phenomenon. It is linked with the introduction and testing of improved varieties in the early 1970s in different parts of the country to address various challenges of different public interventions during the Derge regime (Alemu et al., 2018). These challenges were related mainly to settlement and food security. The first areas of rice introduction were Gambella (1973–1982), Pawe (1985–1988), and Fogera Plain (early 1980s). Because of its high productivity, good market price, adaptability, and compatibility with the prevailing farming systems, rice production in the country in general and in Amhara, Benishangul Gumuz (BG), Oromia, and South West Ethiopia Peoples' (SWEP)[2] regional states, in particular, has increased dramatically during the last two decades. This increase has brought many changes to the rice production and marketing systems.

Rice is among the targeted commodities which received due attention in transforming agricultural production in the country. The Ethiopian Ministry of Agriculture recognized the importance of rice, considering it as the "millennium crop" that is expected to ensure food security in the country. Since its introduction, rice production has shown rapid and widespread expansion to various parts of the country. The expansion has been greatest since the mid-1990s, following rice research initiatives and the consequent generation of high-yielding improved varieties. The total area under rice production has increased from about 29,866 ha in 2011 to over 57,576 ha in 2020. Production during the same period has increased from 90,412 tons to more than 170,630 tons (CSA, 2021). Rice productivity also reached close to 3 t/ha in 2020,

[2] The South West Ethiopia Peoples' Region (SWEP) is a regional state in southwestern Ethiopia. It was split off from the Southern Nations, Nationalities, and Peoples' Region (SNNP) on 23 November 2021 after a successful referendum (Wikipedia)

up from 1.8 t/ha in 2005. The proliferation of improved rice production technologies over the last three to four decades is believed to have contributed to productivity growth.

Increasing agricultural productivity through the adoption and diffusion of modern agricultural technologies is a key pathway for economic growth and agricultural transformation in developing countries (Chilot & Dawit, 2016; Evenson & Gollin, 2003; Jaleta et al., 2018; Pingali, 2012; Shiferaw et al., 2014; Sileshi et al., 2019). This is particularly relevant for many sub-Saharan African countries in general and for Ethiopia in particular, where the performance of the agriculture sector determines the livelihood of more than eighty million of the population. Meaningful change in agricultural productivity through improved technologies, for example, can be one means of ensuring food security by way of increased production and reduced food prices.

Concisely increasing rice productivity and production is essential to ensure national food security, reduce foreign currency spent for rice imports, and safeguard against rice market volatility. The use of high-yielding crop varieties along with other recommended technology packages can increase rice production and consequently facilitate the growth of agro-processing enterprises and non-farm sectors. Nonetheless, inadequate availability of improved rice technologies to small-scale farmers is the major constraint for increasing productivity. While there were efforts made to examine the extent to which the technologies are used, most of the adoption studies on rice in Ethiopia were limited to a specific location (district or zone[3]) and relied on small sample sizes (Asmelash, 2014; Belayneh & Tekle, 2017; A. Hagos & Zemedu, 2015). Hence, to fill this information gap, this paper was designed to provide information on the adoption of rice technologies in major production areas in the country, along with factors that govern the farm household's decisions to use or not to use the technologies.

[3] Zone is the next lower administrative tier after regional states. The highest tier is the Federal state.

3.2. Methodology

3.2.1. Description of the Study area

The study was conducted in major rice-producing areas of the country (Figure 3). The area allocated for rice in 2018 was considered to determine the share of sampled household heads to be drawn in the study area. Among the regional states of Ethiopia, four major rice-growing regional states, namely Amhara, Benishangul Gumuz, Oromia, and SWEP together constitute up to 98% of the total cultivated area of rice in the country (CSA, 2020). The rice farming system in Ethiopia comprises complex production units involving a diversity of interdependent mixed cropping and livestock activities and is mainly characterized by rain-fed agriculture. Rice is the dominant crop, followed by maize and grass pea. According to this study result, rice, maize, grass pea, soybean, and millet took up 39%, 12%, 10%, 7%, and 7% of the cultivated crop area, respectively. As to total production, rice has the highest share and contributes 54% of the total grain production of the households. Rice is grown under rain-fed conditions and is planted and harvested once a year, from early June to early November. Besides, livestock production is an important means of livelihood next to crop production in the area.

A diverse topographic condition which consists of undulating terrain, gentle sloping lowlands, gorges and small rounded hills characterizes the study area. The study area mainly lies in moist *Woina Dega* (cool sub-humid) and *Kolla* (warm semi-arid) agro-ecological zones and experiences both high temperature and rainfall. Its altitude ranges between 985 meters and 2049 meters above sea level. The area receives the maximum rain in June, July, August, September, and October. The area is mainly covered by vertisols, luvisols, and lithosols, and it has huge potential for forests, woodlands, and grasslands (Ali et al., 2022).

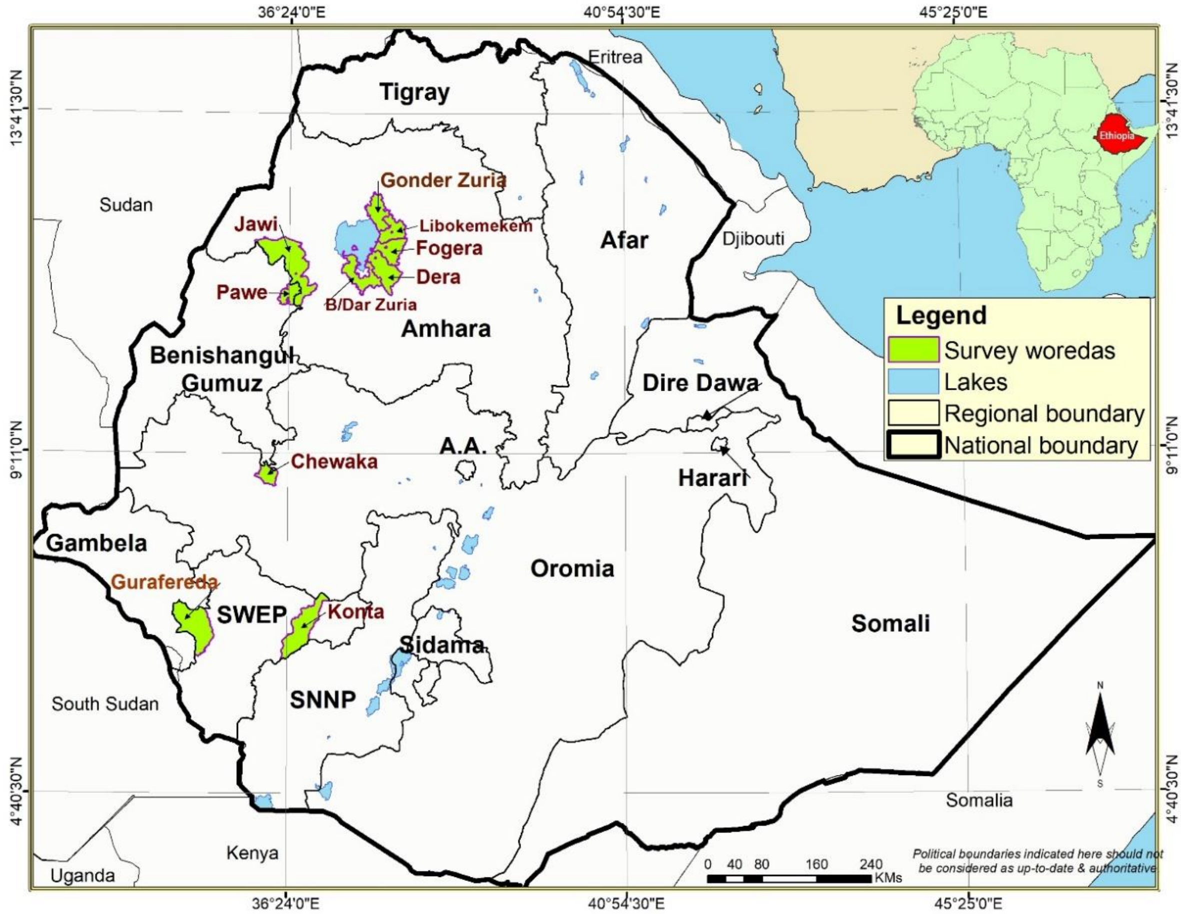

Figure 3. Study area map of rice technology adoption

3.2.2. Data and survey design

This study was based on cross-sectional data collected from rice-based farming systems in the four regional states of Ethiopia during the 2018 production year. The proportion of sample household heads assigned to each regional state (considered here as a strata) was based on the density of the rice production area. The primary data were collected from sample household heads using structured questionnaires through the interview method. Relevant secondary data was also collected from different organizations, including the Ministry of Agriculture (MoA), CSA, FAOSTAT, ITC, and other published and unpublished sources. The target population for this study was all agricultural household heads who participated in rice production in 2018 and were permanent residents of the selected *kebeles*[4] in the study districts. Farm households that produced rice in the Amhara, Benishangul Gumuz, Oromia, and SWEP regional states constituted the population (N) from which the sample was drawn.

[4] *Kebele* is the smallest administrative unit in Ethiopia. It is equivalent to a village in some countries

The sampling technique employed to select sample household heads for the study involved both purposive and random sampling techniques. The four regional states were selected purposely based on the share of area allocated for rice production in the country and were used as strata. A multistage sampling approach was followed to identify farm households, in which districts were the primary sampling unit; *kebeles* the secondary, and household heads the tertiary sampling unit. The sampling frame includes information about the list of rice growing districts in each of the strata, a list of *kebeles* in the sample districts, and a roster of rice producing farm household heads in the sample *kebele*s. A *kebele* consists of about 248 -1835 rice-producing households. Accordingly, we sampled 594 householders for this study, which was determined based on the sample size determination technique outlined by Yamane Taro (1967). The proportions of the sample households assigned to each stratum were based on the density of the rice production area in the respective strata. Accordingly, 11 out of 26 rice-growing districts were selected using a random sampling technique. Then 35 *kebeles* were selected randomly from the sampled districts. Finally, a systematic random sampling technique was used to identify 594 respondent farmers from the list of household head rosters at the *kebele* level. Expecting unavailability and rejection of participation in the survey, we included five extra sample households as a reserve from each *kebele*.

Detailed household and plot-level data were collected using structured questionnaires administered to sampled farmers. Before the actual survey, the questionnaire was pretested in non-sampled villages to control validity, and modifications were made to address the relevant issues. Necessary data were also collected from various sources including secondary sources, community surveys, and focused formal household surveys. In addition, important information related to recommended rates of fertilizer and timing of its application, weeding frequency and so on were collected from secondary sources. The community survey was aimed at collecting community-level data from focused group discussions with community leaders and key informants. The information from the community survey provided useful insights into the farming systems of the areas.

Table 1. Study area and the sampling distribution of the household

Regional state	Share (%) from the total rice		No of rice growing zones	Name of selected zones	Name of selected districts	No of sampled Kebeles	No of sampled households
	Area	Production					
Amhara	57.9	63.0	8 (S. Gondar, C.Gondar, N.Gondar, W.Gondar,	South Gondar	Fogera	13	269
					Libokemkem	6	109
					Dera	2	31
				Central Gondar	Gonder Zuria	2	30

			W.Gojam, Awi, N. Wollo and N.Shewa)	West Gojam	B/ Dar zuria	1	14
				Awi	Jawi	2	37
BG	22.2	19.3	1 (Metekel)	Metekel	Pawe	3	48
Oromia	13.2	11.9	5 (Ilu Aba Bora, Buno Bedele, Jima, W. Welega, E. Welega and K. Welega)	Ilu Aba Bora	Chewaka	2	19
SWEP	6.0	5.2	5 (Bench Maji, Gamo Gofa, Kefa, dawero, Konta)	Benchi Maji	Guraferda	2	17
				Konta Woreda	Konta	2	20
Total					35	594	

Source: Survey result, 2018

3.3. Analytical Framework

The data were analyzed using STATA 17 and R statistical software packages for descriptive and econometric statistics. The data obtained through interviews and the review of documents were compiled, organized, summarized, and interpreted. Descriptive statistics such as mean, percentage, frequency, chi-square test, and standard deviation were used to assess rice technology packages. It was also used to explain the different socio-economic characteristics of the sample respondent households and their adoption statuses.

Multivariate probit (MVP) regression was used to estimate the factors that influenced the adoption decision of improved agricultural technologies for rice production. Statisticians and econometricians view the multivariate probit model as a generalization of the probit model used to estimate several correlated binary outcomes simultaneously (Greene, 2002). Generally, a multivariate model can be extended to more than two outcome variables merely by adding equations. Farmers often use diverse information from different sources when making decisions to adopt improved technologies. Therefore, the decision to adopt one improved agricultural technology or practice might influence the decision to adopt another, which makes adoption decisions inherently multivariate. In such cases, using univariate techniques can exclude crucial information about interdependent and simultaneous adoption decisions. The multivariate probit model helps us to determine possible complementarities (positive correlation) and substitutability (negative correlation) between the improved technologies and practices.

In addition, technology adoption decisions can be path-dependent. Recent technology adoption decisions might be partly associated with earlier technology choices. Hence, the analysis of technology adoption without properly controlling for technology interdependence can either underestimate or overestimate the influences of various factors related to the adoption decision (Assaye et al., 2020; Donkoh et al., 2019; Kassie et al., 2015; Teklewold et al., 2013). Consequently, it is crucially important to assess whether farmers' multiple technology adoption decisions are interrelated or not. In acknowledgment of these issues, this study applied a multivariate probit model to analyze the joint decisions to adopt multiple improved rice technology packages. The applied multivariate probit model accommodates the possibility of a correlation between adoption decisions across different technology practices.

The multivariate probit econometric approach used for this study is characterized by a set (n) of binary dependent variables y_{hpj} such that:

$$y^{*}_{hpj} = x'_{hpj}\beta_j + u_{hpj} \qquad j = 1, 2, 3, \ldots . m. \tag{1}$$

$$\begin{cases} y_{hpj} = 1, if \;\; y^{*}_{hpj} > 0 & \text{or (if the farmer adopts)} \\ \quad =0, \text{ otherwise} & \end{cases} \tag{2}$$

Where j=1,2, 3...m denote improved rice technology packages available; x'_{hpj} is a vector of explanatory variables, β_j denotes the vector of the parameter to be estimated, and u_{hpj} are random error terms distributed as a multivariate normal distribution with zero means and unit variance. It is assumed that a rational h^{th} farmer has a latent variable, y^{*}_{hpj} which captures the unobserved preferences or demand associated with the j^{th} choice of technology packages. This latent variable is assumed to be a linear combination of observed households and other characteristics that affect the adoption of improved rice technology packages, as well as unobserved characteristics captured by the stochastic error term.

The Wald test in the MVP probit model is often used to test the null hypothesis of no correlation across equations (Hauseman, 1978). Lack of statistical evidence to reject the null hypothesis suggests that the choices are mutually independent, implying that we could equivalently fit m independent univariate probit models for each improved technology package and practice. In contrast, if the null hypothesis is rejected, it suggests that estimation of m independent univariate probit models for each improved technology package and practice would engender to inefficient estimates.

The dependent variables in the MVP model include five dummy variables corresponding to the use of improved rice technology packages. The dependent variable in the empirical estimation for this study is the choice of rice technology packages from the set of rice technology packages: improved rice variety, row planting, using recommended Urea and DAP/NPS fertilizer rate, and recommended weeding frequency. Adopters are farmers who used one or more of the technology packages including improved rice varieties, row planting, recommended rate of Urea, recommended rate of DAP/NPS, and recommended rate of weeding frequency whereas non-adopters are farmers who did not adopt those technologies in the production year.

The explanatory variables often considered in modeling the adoption decisions of farmers included household and farm characteristics, attributes of the technology, resource ownership, institutional factors, and access to information variables (Araya, 2020; Donkoh et al., 2019; Habte et al., 2019; Yirga et al., 2015). For this study, based on the review of the relevant literatures, a range of household, farm, and plot characteristics, and institutional factors are hypothesized to influence the adoption of improved rice technology use by smallholder farmers in rice-based farming systems of Ethiopia. Detailed definitions of the explanatory variables and hypotheses about the effects of the adoption of technologies are presented in Table 2.

Table 2. Definition of variables hypothesized to influence adoption

Variable	Description	Values	Sign
Demographic Characteristics			
Gender	Gender of the household head	0=female, 1=male	+/-
Age	Age of the household head	Years	+/-
Family Education	Average education level of the family	Years of schooling	+
Household size	Number of family members	Number	+/-
Asset Ownership			
Rice area	Total area covered by rice	Area in ha	+/-
TLU	Livestock ownership	TLU	+
Communication Asset	Mobile phone or Radio ownership	1=Yes, 0=No	+
Non/off-farm	Non or off-farm income	1=Yes, 0=No	+/-
Institutional Variables			
Extension	Frequency of extension contact in a year	Count	+
Receive credit	Did you receive credit last year	1=Yes, 0=No	+
Irrigation access	Did you have access to irrigation	1=Yes, 0=No	+
Market distance	distance to main market in walking minutes	Walking minutes	-
Social capital index[5]	Index of social capital	Number	+
Plot characteristics			
Soil fertility	Soil fertility status perception	0=fertile,1=medium,2=infertile	+/-
Plot distance	Rice plot distance from the residence	Distance in km	-
Crop rotation	Crop rotation practice in the plot	1=Yes, 0=No	+/-
Rice ecosystem	Rice ecology	1=lowland, 0=upland	+/-

[5] The social capital index is an index number calculated using the membership of the household heads in local and social institutions or organizations (*Equb, Edir, Debo, Kebele* administration, development committee, and religious group) ranging from zero to one.

3.4. Results and Discussion

3.4.1. Characteristics of the rice production system in the study area

Rice has been grown in a wide range of agro-ecologies. Rice-growing environments are classified into three types of rice ecosystems: rain-fed lowland, rain-fed upland, and irrigated rice. Lowland rice is a type of rice grown in flooded and wetland areas, whereas upland rice is rice grown on a relatively drained vertisol, like most other cereal crops. Lowland rain-fed rice ecosystem production is the most dominant rice production system, and it covers 74.7% of the total rice production share in the country, while upland rice ecosystem production takes 25.3% of the total rice production share in the country (Table 3). There were no irrigated rice production practices in the study area at the time the survey was conducted. The farmers of the Amhara region have experience using supplementary irrigation for rice plots when rainfall is scarce.

Table 3. Distribution of different rice production systems in the study area

Rice growing ecosystem	Amhara	Oromia	SWEP	Benishangul	Over All
Lowland rice	84.5	0.0	2.1	25.4	74.7
Upland rice	15.5	100.0	97.9	74.6	25.3
Total	100.0	100.0	100.0	100.0	100.0

Source: Own survey result

3.4.2. Demographic characteristics of the households

Age is one of the demographic factors that can influence a household's use of new technologies and practices. According to the findings, the average age of a household head was 43.6 years, ranging from 22 to 80 years. The sampled farm household heads had rich experience in farming (23 years) in general and rice farming (11 years) in particular. Most of the demographic variables have comparable figures across adoption status. The family size of the total sample respondents ranged from 1 to 12 people, with an average family size of 5.6. A large family size might assist rice-producing farmers in better participation in rice production because rice production often requires more labor for cultivation than other cereal production does (Table 4). Among the sampled household heads, 89% were male-headed. In both theoretical and practical situations, education plays an immense role in ensuring households have access to basic information that helps with decision-making. Not only the education level of the head of the household affects the decisions of the household, but also the education level of the family members might contribute to technology uptake. The overall average education level of the family members was 2.6 years of schooling. The average educational level of the household members was 4.3, 3.5, 3.3, and 2.4 in Oromia, Benishangul Gumuz, SWEP, and Amhara, respectively. The literacy level of rice-producing farmers' families is the lowest in the Amhara region compared to others in the study area. The literacy level also follows a similar pattern when the educational level of the head is considered.

Table 4. Demographic characteristics of the sampled households

Household characteristics	Regional state					Improved seed	
	Amhara	Oromia	SWEP	BG	Overall	Adopters	Non adopters
Age of the household head	43.8	40.1	39.7	45.5	43.6	42.2	44.0
Farming experience	23.3	22.0	20.8	24.6	23.2	22.8	13.4
Rice farming experience	11.6	8.6	7.3	12.4	11.3	12.1	11.0
Education level of the head	1.7	3.7	2.9	2.4	1.9	2.3	1.7
Average family's education	2.4	4.3	3.3	3.5	2.6	3.1	2.5
Household size	5.5	6.4	5.4	5.5	5.6	5.7	5.5

Source: Own survey result

3.4.3. Economic characteristics of sample households

3.4.3.1. Land ownership and tenure system

One of the most important factors that influence crop production is land availability. The major land tenure system was owned, shared-in, and rented-in lands. Farmers who are unable to cultivate their land for different reasons (illness, shortage of draft animal or labor), share or rent their land. Mostly female-headed households and elderly people use sharecropping arrangements, whereas those who have sufficient land and who want to change their main occupation use renting arrangements (Table 5).

Table 5. Land tenure system across regional states

Regional states	Own land (ha)	Shared in (ha)	Rented in (ha)
Amhara	1.17	0.13	0.08
Oromia	1.65	0.11	0.43
SWEP	2.65	0.20	0.17
Benishangul	3.20	0.37	0.70
Total	1.44	0.16	0.15

Source: Own computation results, 2018

Landholding varies considerably across study regions, reflecting differences in population density, availability of arable land, and frequency of land redistribution. The average landholding size for the sample households is about 1.44 ha, with considerable variability across regional states. As depicted in Figure 4, the highest average landholding size was in Benishangul Gumuz with 3.20 ha per household, whereas land pressure is more evident in the Amhara and Oromia regions, respectively, with 1.17 and 1.65 ha per household.

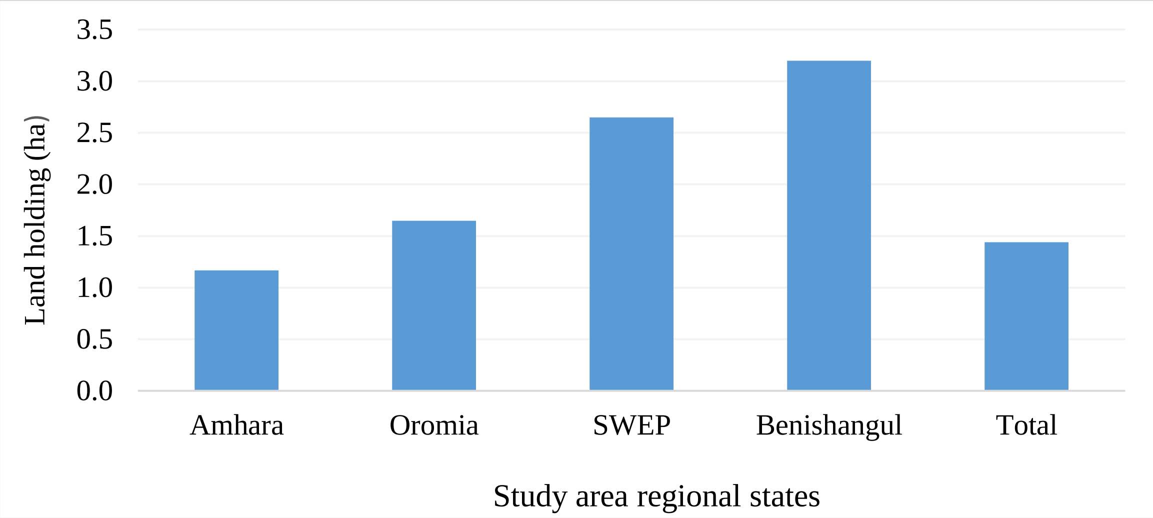

Figure 4. Average landholding across regional states

3.4.3.2. Livestock rearing

Livestock holding size is an indicator of wealth status and the most important asset for rural households in most parts of Ethiopia. Smallholder farmers get both food and income from livestock and use livestock as a source of transport, traction, and threshing power. Based on Storck et al.'s (1991) standard conversion factors, the livestock population number was converted into a Tropical Livestock Unit (TLU) to ease comparison across study areas in the regional states (Appendix Table 49). Except for farmers in Benishangul Gumuz, who had as high as 11.18 TLU, all the remaining three regions had comparable average livestock ownership, which ranges between 4.05 and 5.83 TLU (Table 6). Adopters of improved rice varieties had higher livestock ownership, both in all regional states and in the overall average than non-adopters.

Table 6. Livestock ownership of sample farmers across locations and adoption status

Region	Improved seed		Total
	Adopter	Non-adopter	
Amhara	5.83	5.26	5.39
Oromia	7.45	4.37	5.83
SWEP	5.58	3.48	4.05
Benishangul	14.42	9.97	11.18
Overall	6.68	5.50	5.79

Source: Own computation results, (2018)

3.4.3.3. Asset ownership

Apart from land and livestock, equipment and devices for communication, transport, and rural energy are important assets for improving farm households' lives. The study has also assessed households' asset ownership, and the result showed that most farmers own mobile phones and functional radios. Mobile phone ownership is an indication of the farmers' ability to communicate and connect with distant places. Recently, mobile phone ownership has become popular in almost all parts of the country due to the expansion of mobile networks. In the study area, mobile ownership has varied considerably among sample households. Rice farmers in Oromia had the highest proportion of mobile phone ownership (79%), followed by SWEP (73%), and Benishangul Gumuz (65%). Similarly, the findings of the study showed that most rice farmers (63%) in Benishangul Gumuz and the least (25%) in Amhara have functional radios, respectively. According to the findings, on aggregate, 56% and 30% of farm households owned mobile phones and functional radios, respectively (Table 7). While most of the remaining items indicated in the Table were least owned in the study area, none of the household's reported car or truck ownership. Compared to non-adopters, adopters are better off in terms of ownership of all types of assets indicated. Rural households obtain information related to improved farming practices and farmers' best practices from the radio. This has contributed to their awareness of and exposure to improved farming technologies.

Table 7. Asset ownership across regional states and improved seed adoption (%)

Regional states	Mobile phone	Radio	Bicycle	Television	Motorcycle	Bajaj[6]
Amhara	52.4	24.5	0.8	0.8	0.2	0.4
Oromia	78.9	52.6	0.0	0.0	0.0	0.0
SWEP	73.0	51.4	5.4	5.4	2.7	0.0
Benishangul	64.6	62.5	2.1	4.2	0.0	2.1
Adopters	71.7	41.4	3.4	1.4	0.7	1.4
Non-Adopters	50.3	26.5	0.4	1.3	0.2	0.2
Total	55.6	30.1	1.2	1.3	0.3	0.5

Source: Own survey result

3.4.4. Access to institutional services

The patterns of crop production, livestock rearing, choice, and use of improved technologies of smallholder farmers can be determined mainly by the nature and development of

[6] Bajaj is tricycle three wheeler motorcycle used for transportation in Ethiopia

institutional infrastructure such as credit, extension services, distance to market, and membership in cooperatives. Credit availability for resource-poor farmers is quite important to finance agricultural technologies and management options that could enable them to increase farm productivity. From the sampled farmers, the highest proportion of farmers in Amhara regional state took credit (25%) compared to Oromia (11%) and Benishangul Gumuz (10%). Among the sampled farm household heads, nearly half reported that they were members of agricultural farmers' cooperatives. As depicted in Table 8, farmers' cooperative membership is high in the Amhara (54%) and Benishangul Gumuz (35%). In addition to input and market related services, cooperatives provide basic information related to agriculture and enhance farmers’ knowledge and skills. Extension services provide rice farmers in Oromia and SWEP with more frequent contact than those in the other regional states. For sampled farmers, the average travel time to reach the nearest main market in walking time was 100.6 minutes. On average, farmers in Oromia (35.3 min) and SWEP (36.5 min) had better proximity to the market than farmers in Benishangul (70.7 min) or Amhara (110.9 min). Smallholder farmers have different social institutions and organizations (*Equb*[7], *Edir*[8], *Debo*[9], *Kebele* administration, development committee, and religious group) in the study area. The membership of the sample household heads in these social institutions or organizations was measured as an index ranging from zero to one (Table 8).

Table 8. Access to basic services

Region	Credit Received (%)	Coop membership (%)	Frequency of extension contacts
Amhara	25.9	53.9	12.10
Oromia	10.5	26.3	25.63
SWEP	13.5	27.0	20.05
Benishangul	10.4	35.4	11.02
Adopters (improved seed)	24.8	57.2	15.3
Non adopter (improved seed)	22.9	47.4	10.9
Total	23.4	49.8	12.94

Source: Own survey result

3.4.4.1. Sources of information about improved rice varieties and practices

Farmers in the study area receive information related to improved rice varieties and complementary farm practices from various sources. The survey results showed that about 59% of the respondents learned about improved rice varieties from other farmers. The next

[7] Ekub is a local institution used for saving money regularly depending on the agreement of the members
[8] Edir is a local institution by which people help each other in case of emergency (death, funeral)
[9] Debo is also a local institution that helps people to work together during the peak season of crop production

important source of such information was government extension (29%). Farmer organizations were also described as sources of advice, but they were sought by fewer than 7% of all farmers (Table 9). The importance of other household members, research centers, and NGOs as sources of advice was quite notable in the study areas. Looking into the regional disparity in terms of information sources for rice farmers, while other farmers are important sources in regions such as Amhara and SWEP, the government extension is a major source of information in Oromia and in Benishangul Gumuz regional states.

Table 9. Main sources of information for improved seed

Main Source of information	Percentage of respondents				
	Amhara	Oromia	SWEP	Benishangul Gumuz	Total
Another farmer (relative)	61.6	21.4	60.4	35.6	58.9
Government extension	28.4	46.4	14.6	37.3	28.8
Farmer Coop or groups	4.4	25.0	18.8	10.2	6.0
Other household members	3.6	0.0	0.0	0.0	3.1
Research center	0.6	7.1	4.2	16.9	1.9
NGOs	0.8	0.0	2.1	0.0	0.8
Other source	0.6	0.0	0.0	0.0	0.5
Radio/TV/Newspaper	0.1	0.0	0.0	0.0	0.1

Source: Own survey result

3.4.4.2. Types of agricultural extension service

Most of the information and/or advice they receive from the extension is mainly on pre-harvest operations, especially on land preparation, fertilizer application, varietal choice, and seed rate in that order (Figure 5). The extension service is not that strong in providing advice on post-harvest processing and marketing. As a commercial crop for many of the producers (selling about one-third of the total rice production) and having challenges associated with post-harvest processing, the extension service needs to provide information and advice on these two aspects.

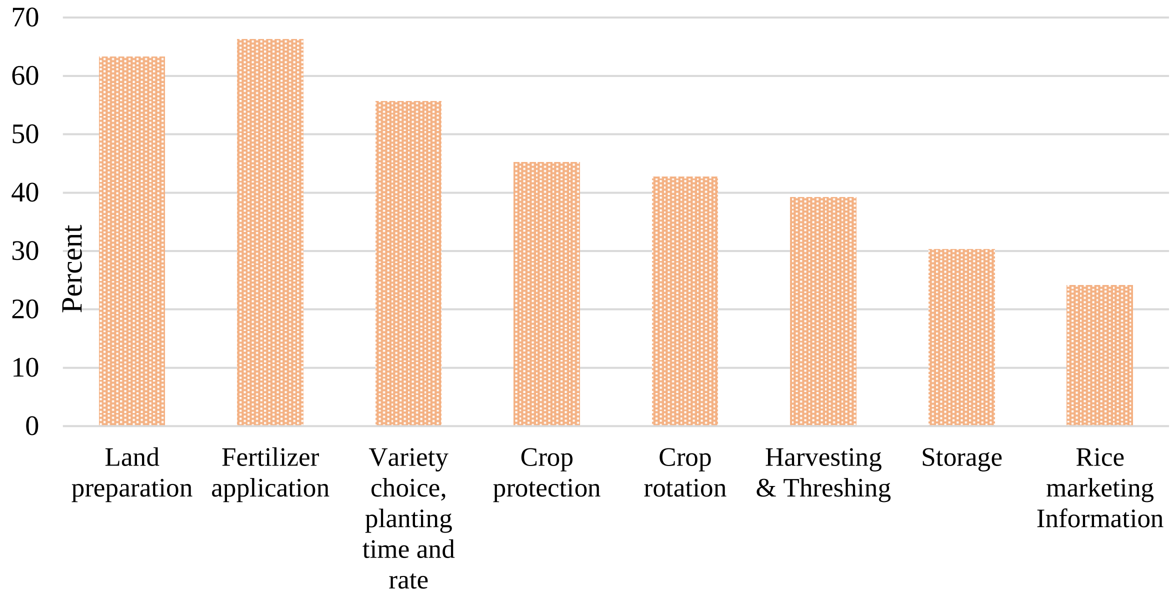

Figure 5. Proportion of farmers receiving extension service on rice farm operations
Source: Own survey result

3.4.4.3. Sources of improved seed

Rice-producing farmers obtained seeds of improved varieties from various sources. Once the farmers receive improved rice seed from any source, they typically recycle it for up to three to five years. Accordingly, the results of the study indicated that the first sources of seed for the respondents were farmer-to-farmer seed exchange (41%), and local markets (29%). About 46%, 36%, and 11% of the respondents in the Oromia region, on average, received rice seed through the office of agriculture, the farmers' cooperative, and other farmers, respectively. While farmers in the Benishangul Gumuz region get improved rice seed from other farmers through seed exchange (42.4%) and from the agricultural research center (28.8%) (Table 10),

Table 10. Main sources of information for improved seed

Main source of the first seed	Percent				
	Amhara	Oromia	SWEP	Benishangul	Total
Farmer to farmer seed exchange	41.9	10.7	41.7	42.4	41.1
Local market	32.5	3.6	12.5	10.2	29.4
Government Extension	16.4	46.4	10.4	10.2	16.6
Research center	3.1	3.6	6.3	28.8	4.8
Local seed producer	3.7	0.0	2.1	1.7	3.4
Farmer groups/Coops	1.0	35.7	18.8	6.8	3.2
Other	1.4	0.0	6.3	0.0	1.5
NGOs	0.0	0.0	2.1	0.0	0.1

Source: Own survey result,

3.5. Rice production and varietal distributions in the study area

3.5.1. Rice production in the study area

Based on the estimates of interviewed households, the average area that a household allocated for rice production was 0.74 ha of land, and they harvested 3475 kg of rice from a hectare of land. The average productivity of rice farmers in Oromia is higher than the national average yield, while the average productivity of rice farmers in Benishangul Gumuz, and SWEP is below the national average. The quantity of rice consumed at home is comparably equal to that supplied to the market in the Amhara and Benishangul Gumuz, while in Oromia and SWEP, the quantity of rice supplied to the market is too high as compared to the quantity of rice consumed at home (Table 11). Rice production in Oromia and SWEP was mainly meant for the market as compared to that in Amhara and Benishangul Gumuz, where it is also largely consumed at home.

Table 11. Rice production and utilization by sample farmers across regional states

Regional states	Yield (kg/ha)	Average area (ha)	Amount consumed (%)	Amount marketed (%)
Amhara	3632	0.67	35.2	35.9
Oromia	4582	0.83	17.7	49.0
SWEP	2509	0.85	22.6	53.6
Benishangul	2181	1.22	36.9	38.6
Total	3475	0.74	33.9	37.7

Source: Own survey result,

3.5.2. Distribution of rice varieties the study area

According to Table 12, the number of plots planted with different rice varieties shows that the varieties are mostly spread out differently in the study areas because of differences in the rice ecosystem. Comparing the regions, X-Jigna was the dominant rice variety cultivated in the Amhara region, covering 72.6% of the rice area. The varieties known as Superica-1 and Chewaka were more popular in the Oromia region, covering 57.0% and 36.2% of the rice land area, respectively. Pawe-1 and Nerica-4 varieties were widely cultivated in Benishangul Gumz and SWEP regions, covering 35.1% and 27.2% of the rice land area, respectively.

An older rice variety known as X-Jigna was the most popular variety planted in 57% of the total area of rice cultivated by the sample farm households. The next popular variety was Gumara (8%), followed by Pawe-1 (5%) and NERICA-4 (4%). About 7% and 14% of the areas covered by rice were identified as improved and old local varieties, but the farmers were not able to identify them by a particular name. The most popular variety, X-Jigena, is not registered under formal rice varieties in Ethiopia. However, farmers' demand for this variety was very high. Most of the remaining newly released rice varieties, such as Shaga, Wanzaye, Abay, Rib, Edget, Fogera-1, and others, had not been well received by the farmers. The varietal importance in terms of coverage suggests that new varieties are not going fast and that expansion is limited to the old varieties. This can be related to dysfunctional seed systems and technology promotion for rice. Among more than 40 rice varieties released in Ethiopia, only about 15 (including two unidentified) were adopted by farmers and are currently under production. A few varieties, such as X-Jigena, Gumera, Pawe-1, Nerica-4, and Superica-1, were the dominant varieties in rice production. Of the 13 varieties adopted by the farmers, 5 belong to the lowland production system, and the remaining 8 to the upland production system.

Table 12. Varietal distribution of rice in the study area

Rice Varieties	Amhara	Oromia	SWEP	Benishangul	Overall
X-Jigena	72.6	0.0	0.0	20.8	57.4
Gumara	9.8	0.0	0.0	1.3	7.6
Pawe-1	0.0	0.0	0.0	35.1	4.6
NERICA-4	0.9	0.0	27.2	8.1	4.0
SUPERICA-1	0.0	57.0	0.0	0.0	2.4
Chewaqa	0.0	36.2	0.0	0.0	1.2
Shaga	1.3	0.0	0.0	0.0	1.0
Ediget	0.3	0.0	0.0	0.0	0.3
NERICA-15	0.2	0.0	0.0	0.0	0.1
Erib	0.3	0.0	0.0	0.0	0.2
NERICA-1	0.0	0.0	0.3	0.0	0.1
Wanzaye	0.1	0.0	0.0	0.0	0.1
Getachew	0.0	0.0	0.0	0.0	0.0
Improved rice (but don’t know)	4.3	0.0	29.9	13.3	7.4
Old rice variety (don’t know)	10.2	6.8	36.8	21.4	13.8
Total	100.0	100.0	100.0	100.0	100.0

Source: Own survey result

3.5.3. Farmer's preference for rice varietal attributes

Farmers decide to adopt a particular variety based on the traits (attributes) of the variety that they value most. Respondent farmers were asked to identify their most preferred varietal attributes of rice by putting them in their preferred position. Accordingly, about 84% of the sample farmers reported grain yield as the first most preferred trait, grain color as the second top trait, and straw yield as the third top varietal attribute (Table 13).

Table 13. Main attributes for varietal adoption across regions (%)

REGION	Amhara	Oromia	SWEP	Benishangul	Overall
Grain yield	80.4	100.0	100.0	95.8	83.5
Grain color	60.4	84.2	97.3	62.5	63.6
Straw yield	36.3	36.8	40.5	25.0	35.7
Injera making quality	36.7	0.0	0.0	50.0	34.3
Grain yield stability	26.5	100.0	75.7	50.0	33.8
Grain size	24.9	78.9	83.8	41.7	31.6

Source: Own survey result

3.5.4. Major production constraints in rice production

Sample respondent farmers mentioned several factors constraining improving production, productivity, and income from the sale of rice. Exploiting the productivity potential of the crop is contingent upon the availability and accessibility of production and marketing-related inputs. The main rice production constraints identified by the sample households are access to improved seed, price of fertilizer, access to the market, timely availability of fertilizer, crop pests, access to the milling machine, access to quality seed, and price of improved seeds, in that order. Providing the necessary knowledge and input for the production of rice alone could not be sufficient to achieve better yield and income until rice processing and marketing aspects are equally addressed (Figure 6).

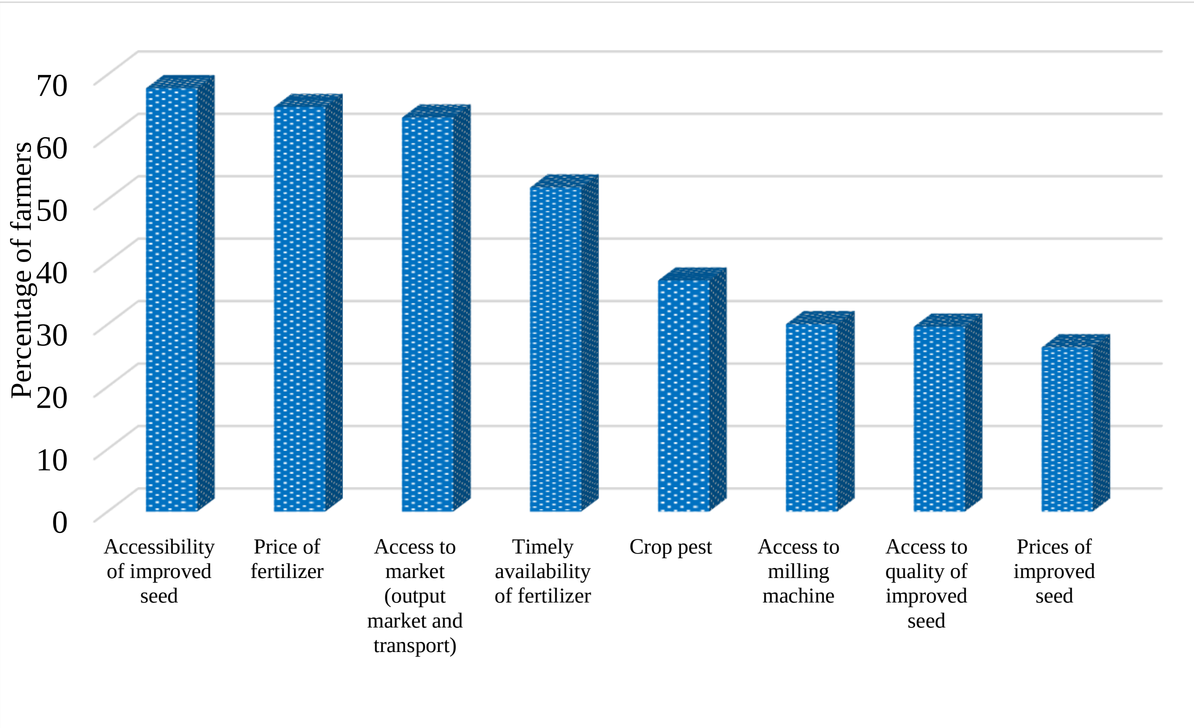

Figure 6. Major rice production constraints by sample rice farm households
Source: Own computation results, (2018)

3.5.5. Adoption of Improved Rice Technology Packages

Different improved agricultural technologies and practices are used by smallholder farmers in the study area to improve rice productivity. A significant proportion of sample farmers adopted different rice production technologies. The most common improved rice production technology packages used by the farmers were improved rice variety, row planting, recommended fertilizer (Urea and DAP), and weeding frequency. Operationally, for our study, sample farmers who used these technologies in the study area are identified as adopters, whereas farmers who did not adopt those technologies are considered as non-adopters.

The interviewed household heads indicated that the adoption of improved rice varieties had increased steadily in the study area. The old rice variety "X-Jigena," with its high yielding, white seed color, compatibility for injera making (a staple food made of an indigenous cereal crop known as tef (Eragrostis tef)), and high biomass varietal attributes, had been adopted most widely in the study areas. A given variety is expected to lose its productivity when it is reused beyond the optimal number of times, in which case it is difficult to consider it as improved. Nonetheless, it is difficult to know the number of times a farmer recycled a variety at the time of the interview, mainly because a farmer might get seed from non-formal sources and that seed might not be fresh. Therefore, in light of this constraint, for the purpose of this study, we considered farmers who used fresh rice seed from a known source as adopters of improved varieties and others as non-adopters. Accordingly, the adoption rate of improved rice varieties was the highest in Oromia (47.4%), followed by Benishangul Gumuz (27.1%). The aggregate adoption rate of improved rice varieties was 24.4% (Table 14).

The planting method is one of the agronomic practices that can enhance productivity. Diverse planting methods are used for rice production throughout the world, such as hand transplanting, mechanical transplanting, direct hand row seeding, mechanical seeding, and broadcast seeding (Bian et al., 2018). The most common planting methods for crops in the study area were broadcasting, row planting, and transplanting. Row planting is one of the main improved rice technology packages that extension workers and researchers recommend for better productivity and a significant reduction in seed rate. Moreover, row planting is one of the agronomic practices used to make weeding, cultivation, and other agronomic activities easier and increase the efficient use of fertilizer, and water (Bian et al., 2018; Donkor et al., 2016; Nasrin et al., 2015). The interviewed household heads describe that row planting demands much labor and time during the busiest period of planting. The adoption rate of row planting in the study area was 23% and was practiced widely by farmers in Oromia (84%), followed by Benishangul Gumuz (48%) (Table 14). The research findings conducted in Fogera indicated that row planting brings a substantial yield increment over broadcasting (Tadesse et al., 2013).

The agricultural extension system of the country encourages farmers to apply chemical fertilizer to their cropland. Rice was not included in the agricultural extension package until 2018, but researchers and agricultural extension workers have tried to promote the use of fertilizer in the study area. The findings also revealed that fertilizer use is very common, especially for rice production. Almost all interviewed farmers use some amount of fertilizer for rice production. Appropriate fertilizer application is an important management practice for improving soil fertility and rice production (Redda et al., 2018). The recommended rate of fertilizer was 60 kg N and 20 kg P_2O_5 for upland rice production in Metama, Amhara, and 69 kg N and 23 kg P_2O_5 per hectare in Tigray. The economic analysis of fertilizer in Fogera indicated a 69 kg N and 23 kg P_2O_5 rate per hectare as the most profitable rate (Redda et al., 2018; Tadesse & Tadesse, 2019). In this study, the farmers are considered to be adopters of the recommended rate of Urea, and DAP/NPS fertilizers if the farmers applied 120 kg and more of Urea and 40 kg and more of DAP/NPS per hectare. The overall adoption rates of the recommended Urea and DAP/NPS in the study area were 40.9% and 38.6%, respectively. About 47% of interviewed household heads from Amhara applied the recommended rate of Urea to their rice farms, whereas households in SWEP did not apply the recommended rate of fertilizer. Almost 84% of sample household heads from Oromia use the recommended rate of NPS/DAP, while the corresponding proportions of household heads for SWEP were 47.9%, Amhara, 37.3%, and Benishangul Gumuz, 38.6% (Table 14).

Weed management for rice production is much more demanding than it is for other field crops. Rice is a weak competitor against weeds. Moreover, it is sown at close spacing, which makes mechanical weed control difficult, thereby resulting in a high yield reduction (Becker et al., 2003; Johnson et al., 2018; Sureshkumar et al., 2016). Different studies have demonstrated that weeds significantly reduce crop productivity. Weeds aggressively compete for water, nutrients, and sunlight, thereby affecting crop yield and quality. Weeds also serve as alternative hosts for insects and diseases (Amare, 2014; Masset & García Hombrados, 2019; Zewditu et al., 2020). In the study area, among rice farming activities, weeding followed by harvesting requires extra hired labor in addition to family labor. In this study, the farmers are regarded as adopters of a recommended weeding practice if the farmers weed their plots three or more times over a production season; otherwise, they are regarded as non-adopters. The overall adoption rate of the recommended frequency of weeding in the study area was 52.4%. About 78.9% and 56.3% of the interviewed household heads in Oromia and Amhara did weed their rice plot three or more times, whereas only 14.6% of the household heads in Benishangul Gumuz applied the weeding recommendations (Table 14).

Generally, on average, 23.4% to 52.4% of household heads across the four regional states adopted improved rice technology packages and practices on their rice plots during the study year. However, adoption rates of the improved rice technology package varied across locations. In general, the highest adoption rate among the rice production technologies was for the recommended weeding practice (52.4%). Row planting (23.4%) and improved rice seed (24.4%) were comparatively the least used technology packages in the study area (Table 14).

Table 14. Summary of adoption of improved rice technology packages across regions (%)

Technologies and practices	Amhara	Oromia	SWEP	BG	Total
Improved seed	23.1	47.4	27.0	27.1	24.4
Row planting	21.8	73.7	5.4	33.3	23.4
Recommended use of Urea	46.9	21.1	0.0	18.8	40.9
Recommended use of DAP/NPS	37.3	84.2	18.9	47.9	38.6
Recommended weeding frequency	56.3	78.9	35.1	14.6	52.4

Source: own survey data (2018)

3.5.6. Returns from improved rice technologies

The descriptive statistics result showed that the mean productivity of rice for adopters of improved rice varieties was 4,144.3 kg/ha and 3,244.9 kg/ha for non-adopters, with an extra yield of 900 kg/ha yield advantage for adopters. Similarly, there was a significant mean difference in the average income of rice between adopters and non-adopters of improved rice varieties. The results also revealed that the adoption of row planting, the recommended frequency of weeding, and the recommended rate of fertilizer (Urea and DAP/NPS) had significantly higher mean rice productivity and income from rice than non-adoption (Table 15).

Table 15. Yield and income mean differences across technology adopters

Improved rice technology packages	Rice yield in kg (overall mean=3464.4)	Rice income in USD[10] (overall mean=319.2)

[10] 1 USD = 29.21 Birr when the survey was conducted.

	Adopters	Non-adopters	t- stat	Adopters	Non-adopters	t- stat
Improved rice seed	4144.3	3244.9	-6.36	425.9	284.8	-5.84
Row planting	4100.1	3270.2	-5.75	449.5	279.4	-7.03
Recommended weeding frequency	4056.6	2813.7	-10.83	393.6	237.5	-7.67
Recommended rate of Urea	4117.4	3012.4	-9.26	399.8	263.5	-6.50
Recommended rate of DAP/NPS	3730.3	3297.6	-3.39	375.6	283.8	-4.25

Source: Own computation results, (2018)

The majority of farmers (79.3%) adopted at least one improved rice technology package in the study area. As indicated in Table 16, our sample farmers adopted improved rice technologies in combinations rather than adopting a single technology. Around 54% of the farmers simultaneously adopted two or more improved technology packages in their rice fields. Interestingly, farmers who adopt a combination of improved rice technology packages get better yields and income from rice sales. The productivity of rice, as well as the income from sale of rice increases as the number of improved rice technologies adopted increases. Rice farm households that adopted improved rice technologies in combinations harvested higher yields and income than those who adopted a single technology. Adopting four of the five improved technologies can double the rice yield as compared to non-adopters. Generally, the adoption of multiple complementary improved rice technologies (improved seeds, row planting, recommended weeding frequency, recommended rate of Urea, and DAP/NPS fertilizer) can substantively increase the productivity of rice and the income derived thereof.

Table 16. Yield and income gains across the number of technologies adopted

No. of technologies adopted	Adopters (%)	Rice yield in kg	Rice income in USD
None	20.7	2326.1	172.2
One	25.4	3344.4	289.7
Two	23.6	3601.3	324.3
Three	18.2	3751.9	342.5
Four	8.1	4680.0	566.3
All	4.0	5497.2	629.6
Total	100	3463.1	319.2

Source: Own computation results, (2018)

3.6. Results of multivariate probit model

A multivariate probit model was used to identify the determinants of the adoption of improved agricultural technologies. Several factors can influence rice-producing farmers' decisions to adopt a particular technology or practice. We have modeled five dependent variables (improved rice technology packages listed in Table 17) over twenty-three explanatory variables in the multivariate probit regression framework. Before running the model, the whole set of explanatory variables fitted to the MVP model were tested for the existence of outliers and collinearities. The existence of outliers was checked for basic explanatory variables. The variance inflation factors (VIF) for all variables were less than 5, and the conditional index number is below 30 which indicates that multicollinearity is not a serious problem in this model (Appendix Table 17).

The MVP model is significant because the null hypothesis that the probabilities of adoption of the five rice technology packages are independent was rejected at the 1% significance level. The model results revealed that the Wald test (Wald chi2 (95) = 207.023; Prob > chi2 = 0.000) is significant at the 1% level, which indicates that the subset of coefficients of the model is jointly significant and that the explanatory power of the factors included in the model is satisfactory. Furthermore, the results of the correlation coefficients of the error terms also indicate interdependence among the decisions to use technology options by farmers. The results support the assumption of interdependence between the different technology options. The maximum likelihood method of estimation results suggested a positive and significant interdependence between household decisions to adopt improved rice seed, row planting, recommended rate of Urea, recommended rate of DAP, and the recommended weeding frequency.

The results revealed that several hypothesized demographic, farm, institutional, and resource ownership variables have a significant effect on decisions to use improved rice technologies. Furthermore, most of the estimated parameters confirmed the expectations for influencing the adoption of improved rice technology packages. Table 17 presents the model results, and the conditional and unconditional marginal effect results of the MVP model on the adoption of improved rice technology packages are also presented in Appendices Table 50 to 52.

Improved rice variety adoption: The results showed that the average education level of the household members, frequency of extension contacts, information related asset (mobile/radio) ownership, and livestock ownership have a significant and positive effect on improved rice variety adoption, while cultivated land size, rice plot distance, distance to the main market and rice ecosystem have an opposite relationship. The positive effects of education, frequency of extension contacts, and mobile phone ownership on the decision to adopt improved rice varieties are expected given the importance of awareness and access to various forms of information from different sources, which enhances farmers' willingness to use improved rice varieties. The result is consistent with the findings reported earlier in the related literature (Bezu et al., 2014; Donkoh et al., 2019; Giziew & Mebrate, 2019). Cost and risk-related issues are important factors for adopting agricultural technologies. Livestock ownership helps the farmers to adopt improved seed technology by reducing the financial constraints of the households to purchase seeds of improved rice varieties. This finding is also consistent with many reports of earlier work (Donkoh, 2020; Kassie et al., 2015; Leake & Adam, 2015; Yokamo, 2020). In contrast, the total area of cultivated land, distance to rice plots and distance to the main market have significant and negative effects on decisions to adopt improved rice varieties. The total area of rice farms was significant and had a negative relationship with the adoption of improved rice varieties. This might be due to the tendency to either thinly spread the limited resources or compete with other enterprises. The result is in line with the studies reported by and Donkoh et al. (2019), suggesting that land scarcity motivates agricultural intensification through the adoption of improved technologies. The results contradict earlier reported findings by Donkor et al. (2016), a large farm provides sufficient space for farmers to experiment with the technology and to assume some risks of adoption, but this holds when the household can afford to invest extra resources. Rice farm plot distance to home in walking minutes increases the cost of production because of the time spent commuting to the plot. Farmers who live far away from market centers could have less access to information related to improved technologies. Therefore, they are unlikely to adopt new technologies. Distance in this particular case could also mean, distance from urban centers, which serve as market outlets for the produce of the farmers. The result is consistent with the hypothesized sign and earlier findings reported in the literature (Donkoh, 2020; Giziew & Mebrate, 2019; H. Hagos et al., 2018).

Row planting: The average education level of family members, information related asset (mobile/radio) ownership, membership in social institutions, and rice ecosystems are found to be positive drivers of using row planting practices in rice production. The positive effects of education and information related asset (mobile and/or radio) ownership on adopting row-planting practices are related to the expansion of information in favor of the value of this practice. Therefore, educated households are better at participating in the row planting of rice than illiterate households. These results corroborate the findings of Giziew & Mebrate (2019), and Amare (2018) that education, participation in off- or non-farm income, and total farm income increase the likelihood of adoption of row planting technology. Membership in social institutions helps farmers get labor during the peak season of rice production. Sometimes, when there is a need for more labor, such as at peak times of rice planting, weeding, and harvesting, lower and medium-income households often require the support of relatives and members of social institutions (neighbors, friends, etc.) to exchange labor. Exchange labor is a practice in which neighboring households’ team up and work in turns on each other's farms until all the members receive similar labor services. In addition, such kinds of social networks can help farmers access information about improved production packages and share their experiences. The result is consistent with previous studies reported by Kassie et al., (2015), which suggested that social capital and network variables are important for explaining the adoption decision of improved agricultural technologies. Moreover, upland rice-producing farmers use the row-planting method more than lowland rice growers, probably to ensure efficient use of water and fertilizer in the upland. The soil fertility status of the rice plot influenced the decision to adopt row-planting practices significantly and negatively. Farmers tend to adopt row planting more frequently on fertile land compared to infertile land. This preference might be driven by the expectation of higher yields from fertile soil, and the desire to maximize efficiency in agricultural practices. Implementing row planting on fertile land may also contribute to easing the workload, making it a preferred choice over infertile soil.

Urea fertilizer: Adoption of improved varieties alone is not sufficient to exploit the yield potential of rice varieties unless combined with the application of inorganic fertilizer (Urea and NPS/DAP). Obviously, the simultaneous adoption of improved varieties and inorganic fertilizer was the core technology of the green revolution in Asia and Latin America (Takahashi et al., 2020). The gender of the household head and average education level of family members significantly and positively increase the probability of applying the recommended rate of urea fertilizer to rice fields. Male-headed households are more likely to adopt the recommended urea fertilizer than female-headed households. This might be attributed to the greater chance of male-headed households being exposed to information and improved agricultural technologies than female-headed households. Bezu et al. (2014), Aryal et al. (2018), and Donkoh et al. (2019) found that a male headed household head has a positive and significant influence on the adoption of improved agricultural technologies. The positive contribution of education to the use of the recommended rate of urea fertilizer could be related to the awareness and knowledge related to the benefits of applying urea fertilizer. These results corroborate the findings of Donkoh et al. (2019) and Kassie et al. (2015), which revealed that education has a positive contribution to farmers' decisions to apply fertilizer at the recommended rate. In addition, total cultivated land, crop rotation practice in rice fields, and rice ecosystem are significantly and negatively associated with the adoption of the recommended rate of urea application in rice plots. Larger farms have higher costs for applying the recommended rate of fertilizer. Therefore, farmers might opt to apply below the recommendation rate. This result is in line with the studies of Kassie et al. (2015) and Donkoh et al. (2019), who suggested that land scarcity can induce agricultural intensification through the adoption of improved technologies. Farmers who have experience with crop rotation practices in rice plots have a lower probability of adopting the recommended rate of urea fertilizer. Crop rotation is the planting of different crops sequentially on the same plot to improve soil fertility and soil health. Crop rotation as a means to enhance soil fertility status can be seen to have a negative relationship with the use of urea fertilizer. Framers in the lowland rice ecosystem have a higher probability of applying the recommended rate of urea fertilizer than those in the upland ecosystem. This may be due to the abundant availability of water and flooding in lowland rice fields, which require more than an upland rice ecosystem.

DAP/NPS fertilizer: Crop rotation practices, membership in social institutions, and rice plot distance have a significant and positive effect on the adoption of the recommended rate of DAP/NPS fertilizer, whereas off-farm and non-farm income have a negative effect on the adoption of the recommended rate of DAP/NPS fertilizer on their rice plots. Rice plots found far from the resident might not receive farmyard manure because of the distance involved. This distance effect might be the reason for the application of the recommended rate of DAP/NPS fertilizer for distant rice plots. This finding is consistent with the study of Tesfay (2020a), which found that fertilizer adoption correlates negatively with plot distance. The positive effect of membership in social institutions on fertilizer application is understandable because they might be used as a source of information and funds for acquiring fertilizer. The total area of land covered by rice was significant and had a negative relationship with the adoption of the recommended rate of DAP/NPS fertilizer. This could be due to the extra cost required to manage larger rice farms. This result is in line with the studies of Kassie et al. (2015) and Donkoh et al. (2019).

Off-farm or non-farm income helps farmers to increase capital availability and financial resources to invest in new inputs, practices or technologies (Kassie et al., 2015). Hence, various studies indicate that off-farm income has a positive impact on the adoption of new technologies (Fernandez et al., 2007; Kassie et al., 2015). However, in our study, farmers who participate in non/off-farm income are less likely to adopt the recommended rate of DAP/NPS fertilizer. The findings of the negative non/off-farm income effect on fertilizer expenditure agree with the results reported by Feng et al. (2010) and Shi et al. (2011), which indicate that participation in off-farm/non-farm income tends to reduce the amount of fertilizer applied. The findings of the negative off-farm income effect on fertilizer expenditure also agree with the findings by Phimister and Roberts (2006) for England and Wales and Chang and Mishra (2012) for the United States, who showed that off-farm work tends to decrease expenditures on fertilizers. Moreover, non-farm income has a negative influence on demand for fertilizer use in Kenya (Mathenge et al., 2015). This negative effect could be attributed to the higher relative returns from other investments. If off-farm enterprises have higher returns, then households might prefer to invest in options that have better returns, given the risk involved in agriculture. In addition, increased participation in off-farm employment reduces the labor availability of households for farm production, and households may therefore restructure their farm production and consumption to adapt to the new situation.

Weeding: The family size of the household, and the average education level of the family members are positive drivers of decisions to apply the recommended frequency of weeding practices. Rice weeding is the most labor-demanding practice among rice cultivation activities. According to Abera and Assaye (2021), rice weeding activity takes up more than 40% of the total rice cultivation labor hour share. The justification could be that households with a larger family size have the necessary labor to apply the recommended frequency of weeding to their rice farm plots. Family members are the main source of household labor for rice cultivation. In this regard, the positive effects of family size on adopting the recommended frequency of weeding are expected. These results corroborate the findings of Genet and Feyso (2020), Teklewold et al. (2013), and Kassie et al. (2015), which established a positive correlation between the adoption of improved technologies and household size. Moreover, education helps a household to interpret complex data and information, thereby making appropriate decisions about the use of practices such as weeding. However, the age of the household head, access to irrigation, total cultivation land, and rice ecosystems negatively and significantly affect the implementation of the recommended rate of weeding frequency in the rice field. Access to irrigation helps a farmer to grow different crops two or more times in the same plot in a year. It increases crop rotation practices that can help to reduce weed infestations. Farmers with large cultivated land size had a lower probability of adopting the recommended weeding frequency, likely due to increased labor costs incurred. Furthermore, upland rice growing farmers weed their rice plots more than lowland rice producers, as weed incidences are more likely in the latter as lowland rice grows under flooded land, which might help to suppress weeds, thereby reducing the need for frequent weeding.

Table 18. Multivariate probit simulation results for adoption of rice technology packages

Explanatory variables	**Improved seed** Coef. (Rob. S.E)	**Row Planting** Coef. (Rob. S.E)	**Recom Urea** Coef. (Rob. S.E)	**Recom DAP** Coef.(Rob. S.E)	**Recom Weeding** Coef.(Rob. S.E)
Gender (male)	0.302	0.100	0.572***	-0.156	0.303
	(0.230)	(0.204)	(0.203)	(0.200)	(0.198)
Age (years)	-0.008	0.008	-0.006	0.004	-0.012**
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Family size (number)	-0.054	-0.039	-0.008	-0.002	0.071**
	(0.034)	(0.032)	(0.032)	(0.030)	(0.031)
Family education	0.114***	0.067**	0.058*	-0.007	0.068**
	(0.035)	(0.034)	(0.032)	(0.032)	(0.032)
Credit (1=used)	0.070	0.176	-0.185	-0.118	-0.069
	(0.140)	(0.133)	(0.132)	(0.130)	(0.127)
Irrigation access (1=yes)	0.018	0.094	0.045	0.126	-0.219*
	(0.125)	(0.123)	(0.114)	(0.113)	(0.113)
Inform asset (mobile &/	0.421***	0.240*	0.144	0.200	-0.065
radio ownership (1=yes)	(0.143)	(0.139)	(0.126)	(0.125)	(0.126)
Extension frequency	0.009*	0.004	-0.005	0.006	-0.004
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Non/ off farm income	0.005	0.190	-0.110	-0.384***	0.009
	(0.152)	(0.145)	(0.137)	(0.138)	(0.134)
Rice area (ha)	0.201	0.017	-0.128	-0.126	0.181
	(0.141)	(0.147)	(0.149)	(0.143)	(0.126)
Sqr of Plot distance	-0.084**	0.036	-0.024	0.097***	0.012
(minute)	0.035)	(0.033)	(0.031)	(0.031)	(0.031)
Soil fertility	0.030	-0.220**	-0.095	0.121	-0.134
	(0.099)	(0.102)	(0.091)	0.090	(0.090)
Crop rotation	-0.158	0.224	-0.348***	0.270**	0.009
	(0.144)	(0.132)	(0.128)	(0.126)	(0.126)
Livestock ownership	0.036***	0.011	0.009	0.011	-0.023
(TLU)	(0.013)	(0.014)	(0.014)	(0.014)	(0.015)
Log cultivated land	-0.249**	0.061	-0.524***	0.071	-0.545***
	(0.115)	(0.111)	(0.113)	(0.103)	(0.120)
Social capital	0.443	0.732**	-0.356	0.736***	0.152
	(0.286)	(0.295)	(0.277)	(0.266)	(0.274)
Rice ecosystem	-0.355**	0.256**	-0.297**	0.006	-0.291**
(1=lowland)	(0.142)	(0.122)	(0.125)	(0.120)	(0.118)
Main market distance	-0.002*	-0.001	0.001	0.001	0.001
(Km)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Coop membership	0.087	-0.208	0.086	0.062	0.042
(1=yes)	(0.129)	(0.131)	(0.117)	(0.118)	(0.118)
Constant	-0.638	-1.713***	0.441	-1.454***	0.427
	(0.498)	(0.442)	(0.434)	(0.432)	(0.435)

Wald test of overall coefficient significance χ^2 (95) = 338.29, Prob > χ^2 = 0.000
Robust standard errors in parentheses, *** p<0.01, ** p<0.05, and * p<0.1

After running the MVP regression, we did post estimation to look at the pairwise correlation among the dependent variables (adoption of rice production technologies). The correlation matrix of the technologies from the MVP model also showed that farmers have adopted a number of improved rice technology packages simultaneously. This finding was tested using pairwise correlation coefficients across the residuals of the multivariate probit model. The coefficients measure the correlation between the adoption decisions of rice technologies considered, after the influence of the observed factors has been accounted for (Greene, 2002). The results support the hypothesis that error terms of multiple improved rice technology adoption decision equations are correlated. All pairwise coefficients were positively correlated and significant, indicating complementarity among the improved rice production technologies (Table 18).

Table 19. Correlation matrix of the technologies from the MVP model (Robust S.E)

Improved technologies	**Improved seed** Coef. (Rob. S.E)	**Row Planting** Coef. (Rob. S.E)	**Recom Urea** Coef. (Rob. S.E)	**Recom DAP** Coef. (Rob. S.E)	**Recom Weeding** Coef. (Rob. S.E)
Row Planting	0.588^{***} (0.088)				
Recom Urea	0.451^{***} (0.083)	0.303^{***} (0.076)			
Recom DAP	0.269^{***} (0.080)	0.549^{***} (0.080)	0.396^{***} (0.071)		
Recom Weeding	0.396^{***} (0.079)	0.307^{***} (0.078)	0.347^{***} (0.072)	0.273^{***} (0.072)	
Predicted probability	0.1988	0.1922	0.3870	0.3737	0.5193
Joint probability (success)			3.9%		
Joint probability (failure)			20.2%		
Number of observations			594		
Number of simulations			100		
Log-likelihood			-1589.3638		
Wald Chi2 (degree of freedom)			338.29^{***}(95)		

LR test of overall significance of correlation coefficients χ^2 (10) = 138.249, Prob > χ^2 = 0.000
Robust standard errors in parentheses, *** p<0.01, ** p<0.05, and * p<0.1

3.7. Conclusions and Policy Implications

3.7.1. Conclusions

The adoption of improved agricultural technology packages is a major tool for increasing the production and productivity of the agricultural sector in Ethiopia. Therefore, research and the adoption of improved production technologies are crucially important for increasing productivity, lowering poverty levels, and ensuring the food security of farmers. The study assessed the likelihood of smallholder farmers adopting improved rice technologies and practices and its determinant factors in Ethiopia using primary data collected from a sample of 594 rice-producing farm households. The findings show that the average landholding size for the sample households is about 1.44 ha, with considerable variability across rice-producing areas. Moreover, the average livestock holdings of sample households in Amhara, Oromia, SWEP, and Benishangul Gumuz regional states were 5.39, 5.83, 4.05, and 11.18 TLU, respectively. Adopters of improved rice varieties had higher livestock ownership in all regional states than non-adopters.

Rice is the dominant crop, covering 39% of the area and 54% of total production in the study location. Other important crops include maize, grass peas, soybeans, and millet, in that order. The average area that a household allocated for rice production was 0.74 ha of land, with an average yield of 3475 kg from a hectare of land. Rice growing environments in the country are classified into three categories: rain fed lowland, rain-fed upland, and irrigated rice. Lowland rice is a type of rice grown in flooded and wetland areas, whereas upland rice is rice grown on vertisols like other cereal crops. The lowland rain-fed rice ecosystem is the most dominant rice production system, covering 74.7% of the total production in the study area. The corresponding share of the upland rice ecosystem was 25.3%. The distribution of rice varieties across and within regional states is different due to the ecological difference of the locations. Looking at the across region comparison, X-Jigna, Gumara, and NERICA-4 were widely cultivated (in that order) in the Amhara region. The varieties known as Superica-1 and Chewaka are more popular in the Oromia region, whereas Pawe-1 and Nerica-4 are widely cultivated in the Benishangul Gumuz and SWEP regions respectively. The limited involvement of formal rice seed-producing institutions significantly affects the accessibility and availability of improved rice seeds in the study area. Moreover, the presence of more improved varieties on the shelf than on farmers' hands also implies how slow the diffusion of new varieties is. This can be related to the performance of both the seed and the extension system.

The improved rice production technology packages used by the farmers were improved rice variety, row planting, recommended rate of Urea, recommended rate of DAP, and recommended weeding frequency. The result showed that weeding is the most widely adopted practice (52.4%), followed by the use of other improved practices/technologies, viz., Urea (40.9%), DAP (38.6%), improved rice varieties (24.4%), and row planting (23.4%). About 79% of sample farmers had adopted at least one improved rice technology in their rice production system. Farmers decide to adopt a particular variety based on the traits (attributes) of the variety which they value most. Grain yield, grain color, and straw yield are the most preferred varietal attributes. The result showed that the mean productivity of rice for improved rice variety adopters was 4144.3 kg/ha and the corresponding figure for non-adopters was 3244.9 kg/ha. Adopters get an extra yield of 900 kg/ha over non-adopters. Similarly, there was a significant mean difference in the average income of rice between adopters and non-adopters of improved rice varieties. The results also revealed that the adoption of row planting, recommended frequency of weeding, and recommended rate of fertilizer (Urea and DAP/NPS) had a significant mean difference in rice productivity and income from the sale of rice between adopters and non-adopters.

The study found that variables affecting farmers' decisions to adopt improved technology packages differ among technologies and practices. Some of the explanatory variables are strongly significant in affecting the decisions made by farmers about particularly improved rice technology packages and it may be insignificant for the other technology packages. Thus, the multivariate probit analysis result revealed that the decision of each rice technology package was influenced by different factors and at different levels of significance, by the same factor. Results also showed that most of the estimated parameters conformed to the expectations in influencing the adoption of improved rice technology packages in the study area. Furthermore, the result demonstrated the existence of complementarity among the technologies, suggesting that the adoption of one will reinforce the adoption of the others. In addition, adopting a combination of improved rice technology packages significantly boosted rice productivity and income.

The MVP regression results show that the demographic and institutional characteristics of the households, including gender, age, average education level of family members, extension services, membership in social institutions, credit use, and distance to the main market are key factors affecting decisions to adopt improved rice technology packages. In addition, resource ownership, and plot characteristics of the households, such as rice area, distance to rice plots, crop rotation practices, soil fertility status, access to irrigation, livestock ownership, access to non-farm or off-farm income, information related asset (mobile & rsdio) ownership, total cultivated land, and ecology of rice play significant roles with different signs in adoption decisions across improved rice technology packages.

3.7.2. Policy implications

The findings of this study offer valuable insights that can play a pivotal role in encouraging the adoption of agricultural technology among smallholder farmers. The complementarity observed among improved rice technologies underscores the importance of policy instruments that affect one technology, potentially influencing other related technologies. Therefore, promoting agricultural technologies as comprehensive packages is a strategic approach to scaling their adoption. The cumulative benefits derived from using a combination of improved technologies far outweigh those from using individual technologies. Consequently, extension services should prioritize the promotion of technology bundles over single technologies. Such effort should also be complemented by access to important inputs such as capital and other market infrastructure, which are limited in areas like Amhara, where much of the total national production comes from. It should also be recognized that other institutional and economic factors might affect the adoption of improved technology packages, such as the price of inputs (improved rice seed, urea, NPS, and daily labor wage) and the availability of institutional structures that facilitate the accessibility of the inputs.

Promoting labor-saving technologies as well as offering opportunities to increase farmers' social capital by way of strengthening existing social networks can help to enhance the adoption of labor-intensive practices such as row planting, especially when dealing with larger plots. In this regard, farmers need to gain enough knowledge on optimal farm management decisions to maximize their return from available resources. Therefore, the governmental and developmental partners must strive not only to promote improved rice technology packages and support the accessibility of improved technologies at affordable prices but also to improve farmers' skills in farm management practices.

The national rice research program should also focus on developing rice varieties that can meet the preferences of farmers, considering factors such as yield, marketability (including color), straw yield, and other crucial traits. Additionally, apart from addressing the traits demanded in the market, researchers should work on improving varieties following the farmer-preferred characteristics embedded in the local varieties.

Providing ease of access to information will contribute to the better probability of adoption, and the government should improve not only the access but also the content and quality of the extension services. For example, services to improve post-harvest practices need to be given proportional weight. In addition, the extension service needs to devise ways to make use of existing social networks to enhance learning as well as the flow of information across farmers. Moreover, capital constraints remain crucial to the use of improved inputs. In this regard, efforts need to be made to improve access to and availability of credit facilities at lower interest rates, for example, through microfinance institutions.

CHAPTER FOUR

4. Impact Assessment of Adopting Improved Rice Variety on Farm Household Welfare in Ethiopia

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Abstract

This article presents the evaluation of the impact of the adoption of improved rice varieties on yield, commercialization, multidimensional poverty, and subjective poverty using data collected from 594 rice producing smallholder farmers in Ethiopia. We adopted an endogenous switching regression model complemented with a propensity score matching methodology to test robustness and reduce selection bias, restricting both observed and unobserved characteristics. The analysis results are consistent across models, indicating that adoption of improved rice varieties has a robust and positive impact on rice yield, and commercialization. Controlling the variations in household characteristics, the average effect of improved rice variety adoption on productivity was 0.564 t/ha. Similarly, the econometric result showed that improved rice variety adoption decreased multidimensional poverty and subjective poverty by 1.7% and 12.4%, respectively. The government should work with development partners and NGOs to ease the accessibility and expansion of improved rice varieties in rice producing areas of the country. Therefore, policymakers and development organizations should consider improved rice variety adoption as the main strategy to increase productivity, commercialization, and reduce poverty of the rice farm households.

Keywords: Improved varieties adoption, Impact, Endogenous switching regression, Propensity score matching

4.1. Introduction

The agriculture sector is the mainstay of the Ethiopian economy and the people at large. The sector contributes 32.8% of the country's GDP, produces 90% of its exports, and provides employment for 72.7% of the total population. The official data for Ethiopia show that the country's economy experienced strong and broad-based growth, averaging 9.2% per year, and the agriculture sector has grown on average by 5.3% per year from 2010 to 2020 (PDC (FDRE Planning and Development Commission), 2021). This consistent and higher economic growth in general, and agricultural growth in particular, has been a major contributor to the important poverty reduction observed during the last decade in Ethiopia. Enhancing the productivity of this sector is, therefore, crucially important not only for the development of the sector itself but also for the development of other sectors in the economy.

Rice is among the targeted commodities that received due attention in transforming agricultural production in the country. The Ministry of Agriculture has recognized the importance of rice in agriculture and designated it as the "millennium crop" to ensure food security and import substitution (MoA, 2020). The cultivation of rice in Ethiopia is a recent phenomenon. It is linked with the introduction and testing of improved varieties in the early 1970s in different parts of the country to address various challenges related to settlement and food security during the Derge regime (Alemu et al., 2018). Since its introduction, rice production has expanded rapidly in various parts of the country. The expansion has been substantial since the mid-1990s, following rice research initiatives and the consequent generation of high-yielding improved varieties. The total area under rice production has increased from about 35,088 ha in 2009 to over 85,289 ha in 2021, and the national production has increased from 71,394 tons in 2009 to 268,224 tons in 2021 (CSA, 2021). Among cereals, rice ranked second after maize in terms of productivity. Between the years 2005 and 2021, the productivity of rice increased from 1.8 t/ha to 3.14 t/ha. The contribution of new technologies disseminated to farmers, in this case, is instrumental.

The Ethiopian government has pushed rice research to a new level since the 1990s. The launch of rice improvement research at Abobo and Pawe Agricultural Research Center during the late 1990s marked the beginning of advancements in rice production technologies (MoA, 2020; Alemu et al., 2018). To date, different technologies have been developed, including improved varieties. About 43 improved rice varieties with associated agronomic and crop protection practices have been released for different rice ecologies. Regarding varieties released between 1998 and 2020, there have been about two new varieties released every year. Most of the varieties developed to date (44%) are upland types. Lowland and irrigated varieties, respectively, make up 29% and 27% of the total varieties.

To evaluate investment in the development and dissemination of improved rice technologies, one can examine the returns on that investment. In Ethiopia, despite considerable efforts put into the development and dissemination of improved rice varieties, their contributions to productivity gain and welfare have been addressed only slightly in the literature. Most earlier studies have emphasized non-rice crops such as tef, maize, and wheat to assess the impact of technology adoption on agricultural productivity and household welfare (Asmelash, 2014; Genet & Feyso, 2020; Getahun, 2019; Giziew & Mebrate, 2019; Jaleta et al., 2018; Kotu et al., 2000; Leake & Adam, 2015; Shiferaw et al., 2014; Teklewold et al., 2013; Yirga et al., 2015; Yu et al., 2011). This study was therefore conducted to elucidate the adoption and impact of rice varieties using a range of indicators.

This work contributes to the existing body of literature on the impact assessment of agricultural technologies in two ways. First, we used comprehensive and nationally representative household-level survey data from all major rice-growing areas of the country. It has a wider application to all rice production systems in the country, unlike previous studies, which relied on small samples and were limited to specific locations (Asmelash, 2014; Belayneh & Tekle, 2017; Hagos & Zemedu, 2015). Second, little is known about the impacts of the adoption of improved rice varieties on smallholder farmers' welfare, which need to be assessed to ascertain how they influence household welfare. The scarcity of such empirical investigations has created a knowledge gap on the impact of improved rice varieties in the country. This report is the first of a study of Ethiopian rice production at the national level that links the adoption of improved rice varieties with its impact on yield, commercialization, multidimensional and subjective poverty. Our results could help policymakers to design effective food security and poverty reduction measures in Ethiopia, which faces enormous food insecurity challenges.

4.2. Review of empirical literature

The adoption of improved agricultural technology is a decision that is determined by different factors. Various studies examined the factors which influence agricultural technology adoption and its subsequent effect on welfare and poverty reduction (Asfaw, Kassie, et al., 2012; Bannor et al., 2020; Becerril & Abdulai, 2010; Bezu et al., 2014; Habtewold, 2021; Jaleta et al., 2018; Kassie et al., 2011; Khonje et al., 2015; Mansaray & Jin, 2020; Sileshi et al., 2019; Yokamo, 2020). As it is suggested by the literature, household demographic, economic, technological attributes, and institutional factors significantly affect the decision of the household to adopt a technology. Households' demographic, economic, farm and institutional variables are some of the factors that affect smallholder farmers' adoption behavior. Under demographic characteristics, researchers such as Baiyegunhi et al. (2022); Jaleta et al. (2018); Mansaray & Jin (2020); Sileshi et al. (2019); and Yokamo (2020) have modeled age, sex, household size, farming experience, and education as the determinants of agricultural technology adoption. Access to extension services, credit, market, irrigation, information, and membership in farmers organizations are some of the institutional variables that have been extensively modeled as factors influencing the adoption of agricultural technologies (Bannor et al., 2020; Jaleta et al., 2018; Khonje et al., 2015). A research study by Baiyegunhi et al. (2022), Mansaray & Jin (2020), and Shiferaw et al. (2014) demonstrated that soil fertility status, area planted, plot distance, total cultivated land, non-off farm income, farm assets, and livestock ownership are some of the farm and resource related variables that determine the adoption of improved agricultural technologies.

On the impact of adoption, most empirical studies have shown that improved agricultural technology has significantly contributed to increased production and farm-level efficiencies, improved incomes, reduced poverty, and the overall wellbeing of farm households. Research by Shiferaw et al. (2014) employed an endogenous switching regression treatment effects approach complemented with propensity score matching to analyze the impact of improved wheat varieties on farmers' food security status in Ethiopia. The two econometric techniques produced consistent results, suggesting that the use of an improved variety of wheat improves the food security status of farm households. That is, adopters were found to be better off because of adoption, and non-adopters would have been more food secure had they adopted. A study conducted by Jaleta et al. (2018) using an endogenous switching regression approach to detect the impact of adoption of improved maize varieties on the food security of adopters indicated positive and significant payoffs in terms of food security outcomes. Becerril and Abdulai (2010) examined the adoption of different types of maize varieties and its impact on household welfare in two regions of Mexico using a propensity score-matching model. Their findings indicated that the adoption of improved maize varieties had a positive and significant impact on farm household welfare.

Jaleta et al. (2016) assessed the productivity, labor, and draft power saving impacts of minimum tillage practices in maize production using an endogenous switching regression model. Their findings indicated a considerable increase in maize productivity and a reduction in labor and draft power use under minimum tillage practice compared to conventional practices. Lokossou et al. (2022) addresses the welfare impacts and food security implications of adopting improved groundnut varieties in the semi-arid areas of three West African countries, including Ghana, Mali, and Nigeria using a fixed-effects instrumental variable approach. The study concluded that the adoption of improved groundnut varieties is a promising pathway for rural economic development and poverty reduction.

In the mid-1960s, high yielding improved varieties of wheat and rice were developed and distributed to farmers in Latin America and Asia to increase agricultural productivity. These high yielding varieties of wheat and rice had 20% or more grain than its earlier cultivars and were more responsive to nitrogen fertilizers (Evenson & Gollin, 2003). This study also reveals how improved rice varieties contributed tremendously to enhancing rice production and reducing large numbers of rural poor and food insecurity. A study conducted by Islam (2018) states evidence on how the adoption of improved rice varieties can induce food security by directly influencing output levels, food availability, and incomes of farm households and indirectly by raising employment, and wage rates of functionally landless laborers in Bangladesh. Likewise, a study conducted in Nigeria, Sri Lanka, Ghana and Indonesia revealed that smallholder farmers with higher improved rice technology adoption rates had higher yields and lesser levels of food insecurity (Awotide et al., 2016; Evenson & Gollin, 2003; Islam, 2018; Yokamo, 2020). In the Ethiopian context, where unlike most other African countries, rice is a recent introduction, the estimation of the gains from the use of improved varieties in a more robust setting can stimulate investments. Despite considerable efforts put into the development and dissemination of improved rice varieties in Ethiopia, their contributions to productivity gain and welfare have been addressed only slightly in the literature. Most earlier studies have emphasized non-rice crops and examined the factors which influence agricultural technology adoption and its subsequent effect on welfare and poverty reduction (Genet & Feyso, 2020; Getahun, 2019; Giziew & Mebrate, 2019; Jaleta et al., 2018; Kotu et al., 2000; Leake & Adam, 2015; Shiferaw et al., 2014; Teklewold et al., 2013; Yirga et al., 2015; Yu et al., 2011). On the other hand, little is known about the impacts of the adoption of improved varieties on smallholder farmers' welfare using both multidimensional poverty and subjective measures in Ethiopia. Whether improved rice variety adoption leads to better welfare outcomes is a question of great relevance to policy and development in the country. This study was therefore conducted to elucidate the adoption and impact of rice varieties using a range of indicators.

4.3. Research Methodology

4.3.1. Study area

The study was conducted in the major rice-producing areas of the country. The area allocated for rice in 2018 was considered to determine the share of sampled households to be drawn from the study area. The target population for this study was all agricultural households that participated in rice production in 2018 and were permanent residents of the selected *kebeles*[11] in the study districts. Farm households that produced rice in the Amhara, Benishangul Gumuz, Oromia, and SWEP regional states constituted the population (N) from which the sample was drawn. The study was conducted in eight zones [12]and eleven districts of Amhara, Benishangul Gumuz (BG), Oromia, and SWEP national regional states (Figure 7).

[11] *Kebele* is the smallest administrative unit in Ethiopia.
[12] Zone is the next lower administrative tier after regional states. The highest tier is the Federal state.

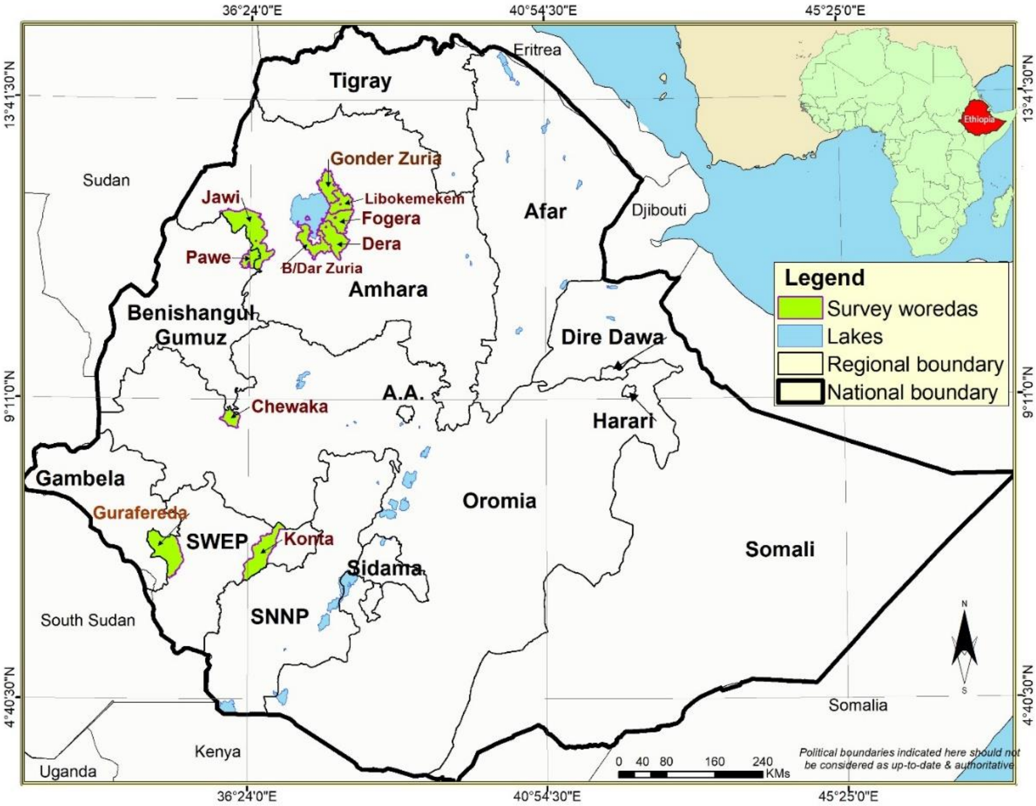


Figure. 7. Map of study areas of the impact of improved rice variety adoption

The main rice producing regional states are Amhara, Benishangul Gumuz, Oromia, and SWEP, which account for 99% of the rice area cultivated by smallholder farmers in the country (Table 19).

Table 20. Status of rice production in Ethiopia

Region	Area (ha)	Production (Quintals)	Area share (%)	Production share (%)
Amhara	49,361.04	1,689,037.08	57.9	62.97
Benishangul Gumuz	18,953.94	517,298.96	22.2	19.29
Oromia	11,263.46	319,578.01	13.2	11.91
SWEP	5,094.74	139,666.28	6.0	5.21
Tigray	392.30	10,203.71	0.5	0.38
Gambela	223.37	6,451.10	0.3	0.24
Total	85,288.85	2,682,235.14	100.0	100.00

Source: CSA 2020

4.3.2. Data and survey design

The study relied on cross-sectional data obtained from rice-based farming systems across Ethiopia's four regional states in the year 2018. The primary data were collected from sample households using a structured questionnaire with the interview method. Additionally, relevant secondary data were also collected from various sources, including the Ministry of Agriculture, the Central Statistical Agency (CSA), FAOSTAT, and the International Trade Center (ITC), as well as from published and unpublished sources.

The sampling technique employed to select sample households for the study involved both purposive and random sampling techniques. The four regional states were selected purposely based on the share of area allocated for rice production and were used as strata. A multistage sampling approach was followed to identify farm households in which districts were the primary sampling unit: *kebeles* the secondary, and farming households the tertiary sampling unit. The sampling frame includes information about the list of rice growing districts in each of the strata, a list of *kebeles* in the sample districts, and a roster of rice producing farm households in the sample *kebeles.* The proportions of the sample households assigned to each stratum were based on the density of the rice production area.

Accordingly, 11 out of 26 rice-growing districts were selected using a random sampling technique. Then 35 *kebeles* were selected randomly from the sampled districts. Finally, a systematic random sampling technique was used to identify 594 households' respondent farmers from the list of household rosters at the *kebele* level. Sampled households who participated in the study were asked to sign the consent form regarding their participation and the confidentiality of the responses they provided. Expecting unavailability and rejection of participation in the survey, we included five extra sample households as a reserve from each *kebele* (Table 20).

Table 21. Study area and its sampling distribution of sample households

Region	Zone* share (%) from the total rice	Sampled district	Number of *kebeles*	Households	
				Number	(%)
	South Gondar (68.86%)	Fogera	13	269	45.3
		Libokemkem	6	109	18.4
Amhara		Dera	2	31	5.2
	Central Gondar (5.05%)	Gonder Zuria	2	30	5.1
	West Gojam (2.36%)	Bahir Dar zuria	1	14	2.4
	Awi (6.23%)	Jawi	2	37	6.2
BG	Metekel (8.08%)	Pawe	3	48	8.1
Oromia	Ilu Aba Bora (3.2%)	Chewaka	2	19	3.2
	Benchi Maji (2.86%)	Guraferda	2	17	2.9
SNNP	Konta Woreda (3.37%)	Konta	2	20	3.4
Total			35	594	100.0

** Zone is the next lower administrative tier after regional states*
Source: Survey result, 2019

Data were collected using a structured questionnaire administered to sampled farmers. Before the actual survey, the questionnaire was pretested in non-sampled villages. The data collected from the household survey included rice variety knowledge and adoption, input use, and production during the 2018 production year. The questionnaire also captured household, farm, and plot-level characteristics, as well as the institutional environment. Additional data were also collected from secondary sources and community surveys. The community survey was aimed at collecting community level data from focus group discussions with community leaders and key informants. Information from the community survey provided useful insight into the community level variables. Data collection was done using computer-assisted personal interview (CAPI) after the questionnaire was converted to CSPro: data collection application software that had been loaded on the data collection machines.

4.4. Analytical Framework and Estimation Procedure

Impact assessment requires proper counterfactuals to ensure correction of self-selection bias and controlling for non-observable farm and household characteristics. Getting proper counterfactuals has been the main challenge for impact assessment using non-experimental cross-sectional data (A. Abdulai & Huffman, 2014; Jaleta et al., 2016, 2018; Sileshi et al., 2019). Specifically, the challenges are related to unobserved heterogeneity and possible endogeneity. For instance, PSM only controls for observed heterogeneity, whereas instrumental variables capture only unobserved heterogeneity and assume that the parallel shift of outcome variables can be considered as a treatment effect (Jaleta et al., 2016, 2018; Sileshi et al., 2019; Teklewold et al., 2013). In contrast, using regression models to analyze the impact of a given technology using pooled samples of users and non-users might be inappropriate because it imparts a similar effect on both groups (Ahmed & Mesfin, 2017; Bidzakin et al., 2019; Kassie et al., 2011). However, estimating the impact of technology adoption on productivity, income, and poverty without accounting for the potential endogeneity bias might lead to an overestimation or underestimation of the actual impact. The endogenous switching regression (ESR) framework relaxes this assumption by estimating two separate equations (for adopters and non-adopters) along with the selection equation (Jaleta et al., 2018; Shiferaw et al., 2014; Sileshi et al., 2019). As described herein, we adopt both the ESR model and PSM to verify the robustness of the result across different measurement techniques.

4.4.1. Endogenous switching regression (ESR)

Rice technology adoption might result in increased yield, commercialization, and reduced poverty status. Moreover, increased commercialization and welfare can enhance the extent of technology adoption. The main objective of this study was to explore the impacts of adopting improved rice varieties on yield, commercialization, and reduced poverty status (MPI and subjective poverty), measured by the average treatment effect on the treated (ATT). The ATT computes the average difference in outcomes of adopters with and without improved technology. To examine these effects, we apply a switching regression model in a counterfactual framework, in which we consider differences in outcome variables (yield, commercialization, multidimensional poverty index (MPI), and subjective assessment of poverty) between those households adopting and not adopting improved rice varieties.

The ESR analysis was applied using a probit model as a selection equation in the first stage. In the second stage, a linear regression model was used as an outcome equation for yield, commercialization, and MPI, and an ordered probit model for subjective poverty was used as an outcome equation. The observed outcomes of the adoption of improved rice varieties can be modeled following a random utility formulation. Consider the i^{th} farm household facing a decision on whether or not to adopt improved rice varieties. A farmer (i) adopts improved rice varieties if the expected utility from adoption (U_a) is higher than the corresponding utility from non-adoption (U_{na}), i.e., $U_a - U_{na}$), >0.

Let A_i^* be the latent variable that captures the benefit from adopting improved rice varieties by the i^{th} farmer, and be given as

$$A_i^* = Z_i\alpha + \varepsilon_i \quad \text{where} \quad A_i = \begin{cases} 1 \text{ if } Z_i\alpha + \varepsilon_i > 0. \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

Where A_i is a binary indicator variable equal to 1 if a farmer adopts an improved variety and zero otherwise. Also, Z is a vector of households, and farm-level variables that affect the decision to adopt or not adopt improved rice varieties, α is a vector of parameters to be estimated; and ε is an error term that is distributed normally and independently with a mean of zero and a variance σ^2.

The adoption of new agricultural technologies can help to increase productivity and farm incomes, and reduce poverty, thus improving household welfare. Assuming that the outcome variables of yield, commercialization, MPI, and subjective poverty have a linear function of a dummy variable for improved rice variety adoption, along with a vector of other explanatory variables (X), leads to the following equation:

$$Y_i = X_i\beta + \gamma A_i + u_i \qquad (2)$$

Where X_i is a vector of variables related to household-level demographics, resource ownership, production characteristics, access to services, and social capital that affect the extent of rice productivity, commercialization, multidimensional poverty, and subjective poverty. γ represents the effects of improved rice variety adoption on rice productivity, commercialization, multidimensional poverty, and subjective poverty.

The outcome equations for both adopters and non-adopters can be written as an endogenous switching regime model:

$$Regime\ 1: \quad Y_{1i} = X_{1i}\beta_1 + \sigma_{1\varepsilon}\hat{\lambda}_{1i} + \eta_{1i} \quad if\ A_i = 1\ (Adopters) \qquad (3a)$$
$$Regime\ 0: \quad Y_{2i} = X_{2i}\beta_2 + \sigma_{2\varepsilon}\hat{\lambda}_{2i} + \eta_{2i} \quad if\ A_i = 0\ (Non\ adopters) \qquad (3b)$$

Where Y_{1i} represents outcome variables representing yield, commercialization, MPI and subjective poverty of household i for adopters and Y_{2i} for non-adopters, X_i represents a vector of farm and socioeconomic characteristics of the household that affects outcome variables, $\hat{\lambda}_{1i} = \frac{\phi(Z_i\hat{\alpha})}{\Phi(Z_i\hat{\alpha})}$ and $\hat{\lambda}_{2i} = \frac{\phi(Z_i\hat{\alpha})}{1-\Phi(Z_i\hat{\alpha})}$ are the inverse Mill's ratios (IMRs) computed from the selection equation (Eq. 1) to correct for selection bias in the second-stage estimation (outcome equations), β_i and σ_i are vectors of parameters to be estimated and η is an independently and identically distributed error term with mean zero and constant variance. The standard errors in Equations (3a) and (3b) are bootstrapped to account for heteroscedasticity arising from the generated regressors ($\hat{\lambda}$).

According to Jaleta et al. (2018), if the selection equation (first stage) is endogenous in the outcome equation (second stage), then results are expected to be biased and inefficient. Therefore, it is crucially important to use instrumental variable methods to identify the second-stage equation from the first-stage equation. The instrumental variable is expected to affect the adoption of improved rice varieties, but the outcome variables do not. Whereas we acknowledge that the selection of instrumental variables is empirically challenging, we excluded two explanatory variables from the outcome equations. Extension service and local event attendance (field days, demonstration days, extension visits, etc.) are taken as instrumental variables used for the identification of the impact of adoption on the outcome variables. The adoption behavior of farmers can be strongly influenced by access to certain sources of information because the diffusion process and content of information about the technology might differ among information sources (Adegbola & Gardebroek, 2007). Different scholars used information-related variables as instruments to assess the impact of adopting improved seeds and adaptation to climate change (Adegbola & Gardebroek, 2007; Di et al., 2012; Shiferaw et al., 2014; Sileshi et al., 2019). Using a falsification test, we checked the admissibility of these instruments (Di et al., 2012; Jaleta et al., 2016, 2018; Sileshi et al., 2019). A falsification test is one way of ascertaining whether instrumental variables are valid instruments if they affect the selection equation (adoption of improved rice variety) but not the outcome variable (rice productivity). Accordingly, a falsification test applied to selected instrumental variables shows that they are jointly significant in the adoption decision (in the selection equation: Chi2 = 16.17; p-value = 0.0003) but not in the outcome equations (in the outcome equation: F= 1.20; p-value = 0.3018).

The above ESR framework can be used to estimate the average treatment effect of the treated (ATT) and the untreated (ATU) by comparing the expected values of the outcomes of adopters and non-adopters in actual and counterfactual scenarios. Following (3a) and (3b), we calculate the ATT and ATU as follows:

Conditional Expectations

(a) $E[Y_{1i}|X, A_i = 1] = X_{1i}\beta_1 + \sigma_{1\varepsilon}\hat{\lambda}_{1i}$ $(adopters)$ (4a)

(b) $E[Y_{2i}|X, A_i = 0] = X_{2i}\beta_2 + \sigma_{2\varepsilon}\hat{\lambda}_{2i}$ $(Non\ adopters)$ (4b)

(c) $E[Y_{2i}|X, A_i = 1] = X_{1i}\beta_2 + \sigma_{2\varepsilon}\hat{\lambda}_{1i}$ $(Adopters\ had\ they\ decided\ not\ to\ adopt)$ (4c)

(d) $E[Y_{1i}X, A_i = 0] = X_{2i}\beta_1 + \sigma_{1\varepsilon}\hat{\lambda}_{2i}$ $(Non\ adopters\ had\ they\ decided\ to\ adopt)$ (4d)

Equations (4a) and (4b) are observed from the rice household survey data, while equations (4c) and (4d) are the counterfactual outcomes. Using these conditional expectations, the counterfactual outcomes are defined as the expected level of rice yield, commercialization, multidimensional perversity index (MPI), and subjective poverty on adopter households if their characteristics (X_{1i}) had the same return as non-adopter households' characteristics (β_2) and vice versa.

Table 22. Expected conditional and average treatment effects

Outcome variable	Category	Decision stage		
		To adopt	Not to adopt	Effect of adoption
Yield, RCI, MPI & Subjective poverty	ATT	(a) $E[Y_{1i}|X, A_i = 1]$	(c) $E[Y_{2i}|X, A_i = 1]$	$a - c$
	ATU	(d) $E[Y_{1i}|X, A_i = 0]$	(b) $E[Y_{2i}|X, A_i = 0]$	$d - b$

	TH	$BH_1 = a - d$	$BH_2 = c - b$	$BH_1 - BH_2$

Note: (a) and (b) represent observed expected outcomes (yield, RCI, MPI & poverty); c) and (d) represent counterfactual expected outcomes (yield, RCI, MPI & poverty);

$A_i = 1$ if the household i adopted improved rice varieties;

$A_i = 0$ if the household i did not adopt improved rice varieties;

Y_{1i} = Rice yield/RCI/ MPI/poverty if a household adopted improved varieties;

Y_{2i} = Rice yield/RCI/MPI/poverty if a household did not adopt;

ATT = Average Treatment Effect on treated;

ATU = Average Treatment Effect on untreated;

BH_1 = The effect of base heterogeneity for adopter households (a-d);

BH_2 = The effect of base heterogeneity for non-adopter households (c – b);

TH = Transitional heterogeneity $(ATT - ATU)$

As explained in Table 21, the expected change in the mean outcome of adopters, the average treatment effect on the treated households (ATT), is computed as the difference between (4a) and (4c):

$$ATT = (a) - (c) = E[Y_{1i}|X, A_i = 1] - E[Y_{2i}|X, A_i = 1] = X_{1i}(\beta_1 - \beta_2) + \hat{\lambda}_1(\sigma_{1\varepsilon} - \sigma_{2\varepsilon}) \tag{5a}$$

Similarly, the expected change in the mean outcome of non-adopters, the average treatment effect on the untreated (ATU) is given by the difference between (4d) and (4b):

$$ATU = (d) - (b) = E[Y_{1i}|X, A_i = 0] - E[Y_{2i}|X, A_i = 0] = X_{2i}(\beta_1 - \beta_2) + \hat{\lambda}_2(\sigma_{1\varepsilon} - \sigma_{2\varepsilon}) \tag{5b}$$

4.4.2. Propensity score matching (PSM)

Propensity-score matching is a non-experimental method for estimating the average effect of technology or programs. The method compares the average outcomes of participants and non-participants, conditioning on the propensity score value. The average comparison measures the average impact of the technologies. Since results from ESR may be sensitive to its model assumptions, i.e., the selection of instrumental variables, we also used the PSM approach to check the robustness of the estimated treatment effect results from ESR. Takahashi and Barrett (Takahashi & Barrett, 2014), the ATT can be defined as:

$$\text{ATT} = E\{Y_1 - Y_0|P = 1\} = E(Y_1|P = 1) - E[Y_0|P = 1) \tag{6a}$$

We can observe the outcome variable of adopters $E(Y_1|P = 1)$, but we cannot observe the outcome of those adopters had they not adopted $E[Y_0|P = 1)$, and estimating the ATT using

Eqn. (6a) may therefore lead to biased estimates. Propensity score matching relies on an assumption of conditional independence where, conditional on the probability of adoption, given observable covariates, an outcome of interest in the absence of treatment, Y_1 and adoption status, P are statistically independent (Abdulai & Huffman, 2014; Takahashi et al., 2020).

Another important assumption of PSM is the common support condition, which requires substantial overlap in covariates between adopters and non-adopters. This means that each household being compared has an equal probability of being both an adopter and a non-adopter, such that $0 < p(X) < 1$ (Baiyegunhi et al., 2022; Becerril & Abdulai, 2010; Habtewold, 2021; Jaleta et al., 2018). If the two assumptions are met, then the PSM estimator for ATT can be specified as the mean difference of the adopters matched with non-adopters who are balanced on the propensity scores and fall within the region of common support, defined as:

$$\text{ATT} = E(Y_1|P = 1, p(X)) - E[Y_0|P = 1, p(X)) \quad (6b)$$

Generally, PSM technique is also a two-step procedure. Firstly, the probability (either logit or probit) model for adoption of improved rice varieties is estimated to calculate the propensity score for each observation. Secondly, each adopter is matched to a non-adopter with similar propensity score values, in order to estimate the ATT. In addition, we employed the nearest neighbor matching (NNM), kernel-based matching (KBM), and radius caliper matching (RCM) methods of the PSM to estimate ATT.

4.5. Empirical Results

4.5.1. Results of descriptive analyses

Household heads had an average age of 43.6 and 11.3 years of rice farming experience. The interviewed households' average education level of the family members was 2.6 years of schooling. The illiteracy level of rice-producing farmers' families is higher in the Amhara region than in others in the study area. Among the sample households, 89.6% of respondents were male-headed households. On average, each household had 5.6 family members. The average landholding size for the sample households is about 1.4 ha, with considerable variation across regions. The average landholding size is the greatest in Benishangul Gumuz and SNNP with 3.2 ha and 2.6 ha per household, whereas land pressure is more evident in Amhara and Oromia regions, respectively, with 1.2 and 1.6 ha per household.

Rice growing environments are classifiable into three rice ecosystems: rain-fed lowland, rain-fed upland, and irrigated rice. Lowland rice is grown in flooded and wetland areas, whereas upland rice is grown in vertisol, similar to other cereal crops. Lowland rain-fed rice ecosystem production is the most dominant rice production system. It covers a 73.0% share, whereas upland rice ecosystem production accounts for the remaining 27.0% share of the total rice production share in the country. There were no irrigated rice production practices in the study area at the time the survey was administered.

The average number of plots allocated to rice production per household is 2.13. The average area of land that a household cultivated for rice production was 0.735 ha ranging between 0.0625 ha and 3.5 ha of land. Rice is the dominant crop, followed by maize and grass pea. Rice has the highest share of total production, contributing 54% of the total grain production of the households. Maize follows rice with an 11% share of grain production. Soybean and grass pea respectively made up 4.9% and 4.7% shares of the grain production. Almost a quarter (24.4%) of the interviewed sample households in the study area were adopters: they used improved rice seed from a known source.

Table 22 presents descriptive statistics of the explanatory variables used for the impact analysis. They are disaggregated by improved rice variety adoption. Accordingly, the survey results show that adopters have more area allocated for rice cultivation, livestock ownership, more farm assets, and received better extension service as compared to non-adopters. Non-adopters travel greater distances to get to the main market. The average size of total cultivated land was found to be significantly different between adopter and non-adopter households.

Table 23. Descriptive statistics of households by adoption status

Variable	Total (N=594)	Adopters (N=145)	Non adopters (N=449)	Test-statistics (t-test/ χ2)
Demographic variables				
Sex of household head (*1=male*)	0.896 (0.306)	0.938* (0.242)	0.882 (0.323)	3.6730
Age of household head (*years*)	43.58 (11.83)	42.16 (11.27)	44.04* (11.99)	1.6652
Education of household head (*years of schooling)*	1.88 (2.63)	2.31** (2.80)	1.74 (2.57)	-2.2676
Rice cultivation experience (*years*)	11.30 (6.43)	12.12* (6.49)	11.03 (6.40)	-1.7669
Household size (*number*)	5.56 (2.05)	5.68 (2.02)	5.52 (2.06)	-0.8011
Average family members education (*years of schooling*[13])	2.61 (1.90)	3.11*** (2.15)	2.45 (1.78)	-3.6631
Production related variables				
Area covered by rice (ha)	0.735 (0.470)	0.820*** (0.570)	0.708 (0.430)	-2.5005
Access to irrigation (*1=yes*)	0.401 (0.490)	0.428 (0.496)	0.392 (0.489)	0.5786
Soil fertility status (*1=fertile*[14])	1.53 (0.60)	1.52 (0.61)	1.53 (0.60)	0.1359
Plot distance (*walking minutes*)	18.50 (15.99)	15.86 (12.81)	19.36 (16.82) **	2.2976
Qty of UREA applied *(kg/ha)*	117.82 (80.05)	133.16** (79.29)	112.87 (79.75)	-2.6672
Qty of DAP applied *(kg/ha)*	44.09 (58.14)	52.40** (58.02)	41.46 (57.99)	-1.9846
Weeding frequency (number)	2.62 (0.75)	2.78*** (0.75)	2.56 (0.75)	-3.0784
Planting method (1=row)	0.234 (0.424)	0.469*** (0.501)	0.158 (0.365)	59.0797
Pesticide use *(1=yes)*	0.38 (0.49)	0.45* (0.50)	0.36 (0.48)	3.1938
Resource related variables				
Own land (ha)	1.439 (1.264)	1.428 (1.268)	1.443 (1.265)	0.1222
Total land cultivated (ha)	1.787 (1.441)	1.876 (1.532)	1.759 (1.410)	-0.8485
Farm Asset (value in birr)	6066.72 (9324.74)	7794.07*** (10324.85)	5508.89 (8919.12)	-2.5778
Off/non-farm income (*1=yes*)	0.237 (0.426)	0.262 (0.441)	0.229 (0.421)	0.6462
Livestock ownership (TLU)	9.18 (7.17)	10.32** (7.53)	8.81 (7.02)	-2.2064
Social capital variables				
No. of relatives who are traders	0.842 (1.366)	0.897 (1.383)	0.824 (1.362)	-0.5552
Social capital (index)[15]	0.420 (0.243)	0.475*** (0.244)	0.403 (0.240)	-3.9573
Access to services variables				
Distance to main market *(minute)*	100.60 (65.48)	91.09 (64.49)	103.67** (65.57)	2.0162
Land market participation(*1=yes*)	0.424 (0.495)	0.448 (0.449)	0.416 (0.494)	0.4536
Cooperative membership (*1=yes*)	0.498 (0.50)	0.572** (0.496)	0.474 (0.50)	4.2129
Credit (*1=received*)	0.234 (0.424)	0.248 (0.434)	0.229 (0.421)	0.2179
Extension service (*1=received*)	0.717 (0.451)	0.834*** (0.373)	0.679 (0.467)	13.0149
Frequency of extension contact (*number*)	11.94 (12.66)	15.30*** (13.48)	10.86 (12.20)	-3.7065

Note: Figures in parentheses indicate the standard deviations
***, ** and * respectively denote significant mean differences at 1%, 5%, and 10% level.

The average rice productivity calculated from the survey data was 3.46 tons per hectare, which is more than the national average productivity of rice (2.84 tons per hectare) during the 2018

[13] Average family members' education level is the average of all years of schooling of the household members. It is calculated by the sum of years of schooling of the household members divided by the family size.

[14] Soil fertility status: we used farmers' subjective assessment of soil fertility (fertile, average (medium) and infertile) as a proxy measure for soil fertility

[15] The social capital is an index number calculated using the membership of the households in local and social institutions or organizations (*Equb, Edir, Debo, Kebele* administration, development committee, and religious group) ranging from zero to one. We used a simple formula to calculate social capital index, ($Social\ capital = \frac{\sum_0^6 (Membership\ in\ social\ groups)}{Total\ number\ of\ social\ groups\ (6)}$)

production season (CSA, 2018). A significant rice productivity difference was found between adopters and non-adopters (Table 23). The average productivity of rice for adopter farm households was 4.14 tons per hectare, whereas the average rice productivity for non-adopter households was about 3.24 tons per hectare. We cannot exclusively attribute this yield difference only to the improved rice varieties adoption based on this simple descriptive mean comparison between adopters and non-adopters. These data are not sufficient because one must account for the contribution of other factors to single out the contribution of varietal adoption. Other demographic, farm resource and institutional factors can also affect rice productivity. The actual impact of adopting improved rice varieties on rice productivity, accounting for all other factors, is reported in the subsequent section using ESR analysis.

Table 24. Descriptive statistics of outcome variables among adopters and non-adopters

Outcome Variable	**Total (N=594)**	**Adopters (N=145)**	**Non-adopters (N=449)**
Rice productivity *(kg/ha)*	3464.43*** (1528.15)	4144.33 (1603.69)	3244.87 (1437.52)
Rice income *(USD/ha)*[1]	319.22*** (259.78)	425.85 (284.66)	284.78 (241.69)
RCI[16] *(total volume sold/total prod)*	0.353*** (0.231)	0.420 (0.223)	0.331 (0.230)
MPI[17]	0.341*** (0.158)	0.306 (0.136)	0.352 (0.163)
Subjective poverty[18]	1.961***(0.660)	1.733 (0. 614)	2.036 (0.658)

Source: Computed results

[1] 1 USD = 29.21 Birr when the survey was conducted.

4.5.2. Improved rice variety adoption

Table 24 presents results from the first stage of the endogenous switching regression model. The dependent variable is binary for the adoption of improved rice varieties. The maximum likelihood estimates of the probit model result indicated that twelve variables were significant in explaining the adoption of improved rice varieties. A positive estimated coefficient in the model implies an increase in the likelihood of adoption of improved rice varieties for every additional unit of the value of the explanatory variable, whereas a negative estimated coefficient in the model implies decreasing the likelihood of adoption with the increase in the

[16] Rice commercialization index of the farmers is calculated as a ratio of the rice sales over the total value of rice production

[17] Multidimensional Poverty Index (MPI) is a multidimensional measure of poverty developed by the Oxford Poverty and Human Development Initiative (OPHI) at the University of Oxford. It is composed of ten indicators corresponding to the same three dimensions as the Human Development Index: Education, Health and Standard of Living. The MPI ranges from 0 to 1, and higher values imply higher poverty (Alkire & Foster, 2011). Results indicate that 46.63% of rice-producing farm households in the country are living in a cute poverty.

[18] Subjective poverty was measured using household interviews to describe their poverty status (Rich (having more than adequate food access), Medium (adequate food access), and Poor (food insecure)

value of a continuous explanatory variable. Resource ownership and information-related variables are positively correlated with the probability of adopting improved rice varieties for rice production. The estimated model results indicate that the education level of the household, livestock ownership, farm asset ownership, agricultural extension service, and attending local events (field days, demonstration days) have a significant and positive effect on the adoption decisions of improved rice varieties.

The positive effects of education, agricultural extension services, and attending local events on the decision to adopt improved rice varieties are expected given the importance of awareness and access to various forms of information from different sources, which enhances farmers' willingness to use improved rice varieties. The result is consistent with the findings reported earlier in the related literature (Bezu et al., 2014; Donkoh, 2020; Donkoh et al., 2019; Giziew & Mebrate, 2019; Kumar et al., 2020). Livestock ownership, and farm asset ownership help the farmers to adopt improved seed technology by reducing the financial constraints of households to purchase seed of improved rice varieties. Allocating more land to rice encourages the farmers to experiment with new practices to get the maximum possible yield from the technology. This finding is also consistent with many reports of earlier work (Donkoh, 2020; Kassie et al., 2015; Leake & Adam, 2015; Yokamo, 2020). In general, the marginal effect results showed that a unit increment in education, livestock ownership, rice area, farm asset, extension service, and attending a local event increased the probability of adopting improved rice verity by 3.4%, 0.5%, 10.5%, 3.8%, 9.1%, and 12.9%, respectively.

In contrast, the probability of adoption of improved rice varieties is negatively associated with the age of the household head, distance to rice plots, total farm size cultivated and distance to the nearest main market. Non-adopters are relatively older household heads with larger family sizes because of living costs and risk related issues. When farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. On the other hand, younger farmers are typically less risk-averse and are more willing to try new technologies (Bezu et al., 2014; Donkoh et al., 2019; Donkor et al., 2016; Kassie et al., 2015). The total farm size cultivated was significant and had a negative relationship with the adoption of improved rice varieties. This might be due to the tendency to either thinly spread the limited resources or competition from other enterprises. The result is in line with the studies reported by Kassie et al. (2011) and Donkoh et al. (2019), suggesting that land scarcity motivates agricultural intensification through the adoption of improved technologies. The results contradict earlier reported findings by Donkor et al. (2016), a large farm provides sufficient space for farmers to experiment with the technology and to assume some risks of adoption, but this holds when the household can afford to invest extra resources. Distance to rice plots from the homestead increases the cost of production because of the time spent commuting to the plot. This finding seems reasonable in terms of saving labor and draft power used for rice cultivation. As the distance to the main market increases, the likelihood of the adoption of improved rice varieties declines, suggesting that enhancing market access is crucially important to expand adoption. The marginal effect results showed that a unit increment in age, distance to plot, and total farm size cultivated translated to a decreased probability of adopting improved rice verity by 0.5%, 0.2%, and 4.5%, respectively. The result is consistent with the earlier findings reported in the literature (Assefa & Gezahegn, 2010; Donkoh et al., 2019; Giziew & Mebrate, 2019; H. Hagos et al., 2018). The aggregate adoption rate of improved rice varieties was 24.4% in Ethiopia.

Table 25. Decision to adopt improved rice varieties: a probit model

Explanatory variables	Coefficient	Robust Std. Err.	Marginal Effects
Sex of the household head	0.161	0.233	0.045
Age of the household head	-0.016***	0.006	-0.005
Education level of the household head	0.116***	0.033	0.034
Household size	-0.055	0.034	-0.016
Area covered by rice	0.358***	0.133	0.105
Rice plot distance	-0.008*	0.005	-0.002
Access to irrigation	-0.043	0.128	-0.013
Livestock ownership (TLU)	0.017*	0.010	0.005
Total farm size cultivated	-0.153***	0.051	-0.045
Non or off farm	0.086	0.146	0.026
Farm asset (log)	0.131**	0.057	0.038
Extension service	0.329**	0.147	0.091
Cooperative membership	0.065	0.130	0.019
Distance to main market	-0.002	0.001	0.0004
Received credit	0.035	0.142	0.010
Attending local events (filed day, etc.)	0.4215***	0.142	0.130
Constant	-1.518***	0.519	
Number of observations	594		
LR chi2 (16)	71.50		
Prob> chi2	0.000		
Pseudo R2	0.1074		
Log-likelihood	-294.68		

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

4.5.3. Impact of improved rice variety adoption on outcome variables

Results obtained from the ESR treatment effect model (Table 25) show that rice productivity is higher by 0.564 tons per hectare for adopters of improved rice varieties compared to their counterfactuals. Similarly, on average, the productivity of rice for non-adopters would have increased by 0.373 tons per hectare if they had decided to adopt improved rice varieties. The transitional heterogeneity effect is positive, and the productivity effect is greater for households that adopt improved rice varieties. Furthermore, the expected conditional average treatment effect of improved rice variety adoption on income from rice production was positive and significant. Had the adopters decided not to adopt, their average income from the sale of rice would have decreased by 64.8 USD per hectare. Whereas, the income from the sale of rice (USD) for the non-adopters would have increased by 21.2 USD per hectare if they decided to adopt improved rice varieties.

The results also revealed that improved rice variety adoption increases household level rice commercialization (RCI). Specifically, the causal effect of improved rice variety adoption is about 0.04 RCI for the adopters, and the causal effect for non-adopters is about 0.02 RCI if they practice it. Similarly, the results indicate that improved rice variety adoption has a positive effect on poverty, where for adopters, the MPI decreases by about 1.7%. However, if non-adopters had adopted, their MPI would have decreased by 3%. Furthermore, subjective poverty decreased by 12.4% for adopters of improved rice varieties compared to their counterfactuals, and subjective poverty for the non-adopters would have decreased by 13.4% if they had decided to adopt improved rice varieties.

The results reported here confirm the strong positive impacts of improved rice varieties on smallholder farm households' welfare. In general, the adopters of improved rice varieties were better off in different welfare indicators than the non-adopters. These results are consistent with other related studies on the impact of agricultural technologies on poverty and household welfare(Ahmed & Mesfin, 2017; Bezu et al., 2014; Chilot & Dawit, 2016; Jaleta et al., 2016, 2018; Kassie et al., 2015). The adoption of improved rice varieties helps to increase crop productivity and household commercialization, which have vital importance in reducing poverty. Therefore, adoption of improved rice varieties can be seen as one way to lift out smallholder rice farm households from poverty.

Table 26. Expected conditional and average treatment effects

Outcome variable	Category	Farmer's decision		
		To adopt	Not to adopt	Adoption effect
Rice productivity *(kg/ha)*	ATT	(a) 4144.33 (88.12)	(c) 3580.45 (80.22)	563.81***(119.17)
	ATU	(d) 3617.98 (41.18)	(b) 3244.87(37.97)	312.63***(58.03)
	HE	BH_1= 526.35	BH2= 335.64	TH= 220.71
Rice income *(USD/ha)*	ATT	(a) 425.85 (14.74)	(c) 361.05 (10.73)	64.80***(18.63)
	ATU	(d) 305.99 (8.12)	(b) 284.78 (5.89)	21.21**(10.03)
	HE	BH_1= 119.86	BH2= 76.27	TH= 43.59
Rice Commercialization Index	ATT	(a) 0.420 (0.010)	(c) 0.383 (0.007)	0.037*** (0.013)
	ATU	(d) 0.346 (0.006)	(b) 0.331 (0.005)	0.015**(0.008)
	HE	BH_1=0.074	BH_2= 0.052	TH=0.022
MPI	ATT	(a) 0.306 (0.006)	(c) 0.323 (0.005)	-0.017**(0.008)
	ATU	(d) 0.322 (0.003)	(b) 0.352 (0.003)	-0.030***(0.004)
	HE	BH_1=-0.016	BH_2= -0.029	TH=0.013
Subjective poverty	ATT	(a) 1.733 (0.029)	(c) 1.856 (0.022)	-0.124*** (0.037)
	ATU	(d) 1.902 (0.022)	(b) 2.036 (0.014)	-0.134*** (0.026)
	HE	BH1=-0.169	BH2= -0.18	TH= 0.01

Note: Figures in parentheses denote the standard errors:
*** and ** respectively denote significance levels at 1% and 5%

The results obtained from the endogenous switching regression model provide valuable insights regarding rice variety adoption and its impact on various dimensions of agricultural outcomes. Notably, the regression model sheds light on the relationships between the improved rice variety adoption and its influence on key agricultural outcome indicators, such as rice yield, income, and commercialization, as well as broader socio-economic dimensions, including multidimensional poverty and subjective poverty. The model also offers a nuanced understanding of the factors influencing farmers' decisions to adopt improved rice varieties in relation to the outcome variables (Table 26). These findings contribute to a better understanding of the complex dynamics that shape rice cultivation practices, providing valuable insights for policymakers, researchers, and practitioners seeking to improve sustainable agricultural practices and alleviate poverty in rice farming communities.

Table 27 Endogenous switching regression results for rice variety adoption and its impact

Explanatory variable	Yield				RCI				MPI				Poverty			
	Adopter		Non-adopter		Adopter		Non-adopter		Adopter		Non-adopter		Adopter		Non-adopter	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E	Coeff.	S.E	Coeff.	S. E	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Sex	-499.30	508.6	611.6***	207.3	-0.071	0.071	-0.051	0.032	-0.083*	0.043	-0.057**	0.029	-1.210***	0.445	-0.052	0.198
Age	-3.75	11.99	-25.23***	6.99	0.004**	0.002	-0.002*	0.004	0.003***	0.001	0.002**	0.001	0.037***	0.013	-0.001	0.007
Education	85.36	75.94	59.26	44.44	-0.025**	0.011	-0.026***	0.007	-0.006	0.006	-0.009*	0.005	-0.127*	0.074	0.053	0.044
Household size	6.67	72.42	-12.93	36.28	0.006	0.010	0.010	0.007	0.017***	0.006	0.017***	0.005	-0.108*	0.060	0.010	0.035
Rice area	-328.80	340.5	-6.40	154.2	0.001	0.046	0.021	0.035	0.044*	0.024	-0.018	0.024	-0.064	0.283	-0.335*	0.179
Plot distance	2.62	11.41	-10.88***	4.30	0.003***	0.001	0.003***	0.001	0.002**	0.001	-0.001**	0.000	0.021**	0.009	-0.004	0.005
Irrigation	21.64	235.4	58.43	129.9	0.081**	0.035	0.020	0.022	0.003	0.022	-0.014	0.016	0.042	0.228	-0.296**	0.127
TLU	7.04	21.19	35.04***	11.82	-0.006**	0.003	0.002	0.002	-0.003	0.002	0.001	0.001	-0.039**	0.018	-0.019**	0.011
Total farm	-186.40	134.6	-286.9***	58.04	0.039**	0.019	0.001	0.010	-0.009	0.010	0.001	0.007	0.088	0.111	-0.103*	0.053
Non or off farm	-192.50	276.9	-275.6*	156.2	-0.059	0.042	-0.059	0.024	-0.039	0.024	-0.008	0.018	-0.538*	0.311	0.235*	0.132
Farm Asset (log)	-56.67	124.5	63.80	54.46	-0.040*	0.022	-0.031	0.010	0.010	0.012	-0.002	0.006	-0.218*	0.129	0.072	0.069
Coop member	-387.70*	231.6	85.90	142.0	-0.138***	0.041	-0.033	0.022	-0.058**	0.022	-0.024	0.018	-0.676***	0.246	-0.355***	0.127
Received credit	-164.70	267.8	88.74	156.9	-0.041	0.041	0.028	0.025	0.020	0.023	0.029	0.018	0.547**	0.261	0.224	0.139
Dis main market	3.53	2.48	1.62	1.10	0.001*	0.000	0.001	0.002	-0.000	0.000	-0.000	0.000	-0.001	0.001	-0.003***	0.001
DAP_ha	0.36	2.91	0.24	1.12	-0.000	0.000	0.000	0.000	0.000	0.000	-0.000	0.000	0.002	0.002	0.000	0.001
UREA_ha	2.19	1.52	2.16***	0.96	-0.000	0.000	-0.000**	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.001
Planting mtd	671.20***	251.0	647.6***	186.3	0.119***	0.040	0.141	0.027	-0.017	0.022	-0.064***	0.020	-0.505	0.222	-0.440***	0.152
Weeding	543.20***	173.7	497.5***	85.71	0.049*	0.028	0.017	0.015	0.002	0.017	-0.002	0.011	0.261*	0.150	-0.069	0.087
No Stress	143.40	227.3	233.60	130.7	-0.032	0.039	0.003	0.024	-0.018	0.023	-0.023	0.016	-0.045	0.200	-0.053	0.123
Hired labor	12.60***	3.76	0.95	2.07	0.001	0.001	0.000*	0.000	-0.001**	0.000	0.000	0.000	-0.005	0.004	-0.004	0.002
Mills1	-564.7	659.1	696.7**	329.2	-0.290***	0.080	-0.291***	0.037	0.202	0.134	-0.006	0.032	-0.362	0.604	0.738**	0.221
Constant	3501.0**	1586.0	654.6	825.3	0.826***	0.231	0.928***	0.118	0.351	0.178	0.364***	0.089				
Number of Obs	145		449		145		449		145		449		145		449	
F value/ Wald X^2	6.43		9.84		4.26		52.93		5.52		3.57		59.94		99.32	
R/PseudoR2	0.4378		0.2810		0.3183		0.4269		0.3085		0.1264		0.2328		0.1184	
Prob>F/ X^2	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
Root MSE	1301		1248.6		0.1989		0.2118		0.1225		0.1561					
Log ps likelihood													-96.48		-381.27	

Note: ***, ** and * are significant at 1%, 5% and 10% level respectively

4.5.4. Propensity score matching (PSM) estimation results

In addition to the ESR model, the PSM technique was used in this research work to test the robustness of the ESR model's results. Propensity scores (the probability of adopting improved rice varieties) are estimated using a probit model. The matching variables used are the same as the variables presented in Table 24. The matching techniques all passed various quality assurance tests. Figure 8 presents the distribution of adopter and non-adopter households related to estimated propensity scores. Moreover, after estimating the propensity scores for the adopters and non-adopters, we verified the common support condition. Based on the results, the predicted propensity scores for adopters ranged from 0.037 to 0.842 with a mean of 0.342 and from 0.003 to 0.699 for non-adopters with a mean of 0.212. The common support region would then be expected to lie between 0.037 and 0.699.

Accordingly, the total off-support samples were from the control groups. It was 4.5% of the total sample and was discarded from the analysis in estimating the ATT in both groups. Consequently, about 96% of the non-adopters and all adopters were in the common support area, showing a substantial overlap between the two groups. As presented in Figure 6, a visual inspection of the density distribution of the estimated propensity scores for the two groups indicates that the common support condition is satisfied and there is substantial overlap in the distribution of the propensity scores for adopters and non-adopters. The treatment groups' propensity score distribution is shown in the upper half of the graph, while the control groups are shown in the lower half. The predicted propensity score densities are presented on the y-axis.

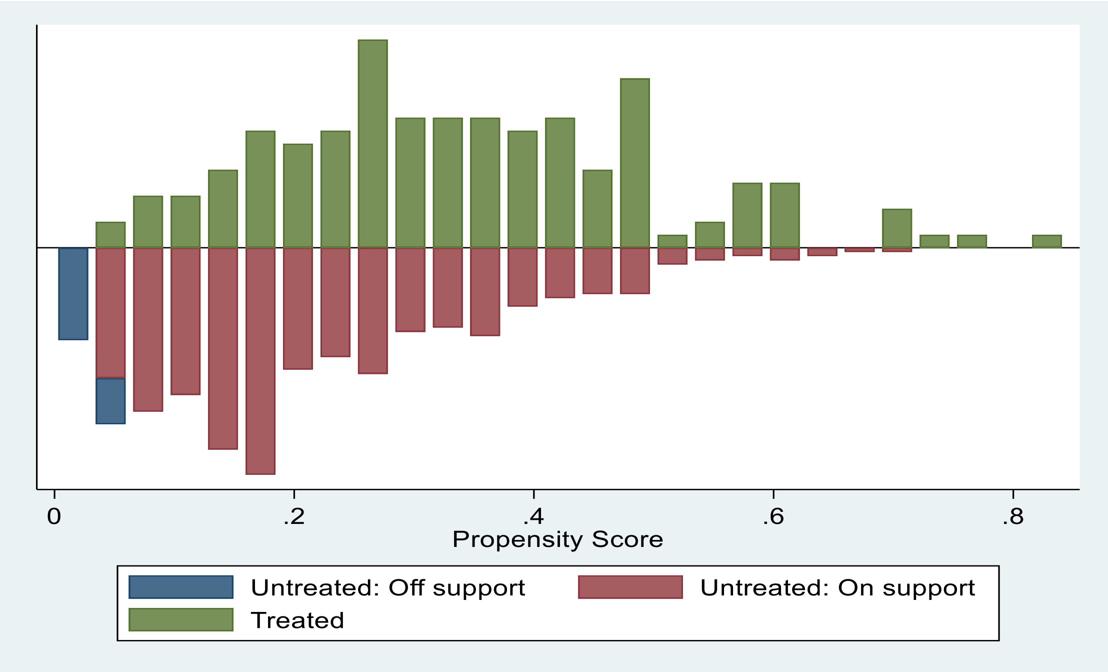


Figure 8. Propensity score distribution and common support area

Table 27 presents the covariate balancing test results of each matching algorithm before and after matching. The mean standardized bias was reduced after matching (2.1 to 9.0%) compared to 19.3% before matching. The balancing test results also reveal that pseudo-R^2 declines considerably, from 12.3% to a range of 0.2 to 3.6%. On the other hand, the likelihood ratio test (*p*-value) indicates the joint significance of all covariates with a probability level of less than 1% before matching, but it was insignificant after matching. Furthermore, the total bias declined significantly in the range of 53.37 to 89.12 through matching. Generally, low mean standardized bias, low pseudo-R^2, high total bias reduction, an insignificant level of likelihood ratio test (*p*-value), and a greater total bias decline after matching suggest that the proposed specification of the propensity score was successful in terms of balancing the distribution of covariates between the two groups.

Table 28. Propensity scores matching quality test

Matching algorithm	Pseudo-R^2		LR $\chi2$ (*p*-value)		Mean standardized bias		Total % |bias| reduction
	Before	After	Before	After	Before	After	
NNM[a]	0.123	0.036	81.19 (0.000)	14.47 (0.756)	19.3	9.0	53.37
NNM[b]	0.123	0.007	81.19 (0.000)	3.00 (1.000)	19.3	3.5	81.87
KBM[c]	0.123	0.003	81.19 (0.000)	1.06 (1.000)	19.3	2.3	88.08
KBM[d]	0.123	0.003	81.19 (0.000)	1.35 (1.000)	19.3	2.4	87.56
RCM[ae]	0.123	0.002	81.19 (0.000)	0.93 (1.000)	19.3	2.1	89.12

Note: Standard errors in parenthesis (bootstrapped only for KBM and radius matching): *, **, and *** respectively denote significance at 10%, 5%, and 1%.
NNM[a] = single nearest neighbor matching with replacement and common support
NNM[b] = five nearest neighbor matching with replacement and common support
KBM[c] = with bandwidth 0.06 and common support
KBM[d] = with bandwidth 0.03 and common support
RCM[e] = radius caliper at 25% of SD matching

Table 28 reports the estimated value of the average adoption effect based on PSM technology using the nearest neighbor matching method (NNM), kernel-based matching (KBM), and radius matching methods. The PSM results are based on the single and five nearest neighbor methods with replacement and the Epanechnikov kernel estimator with 0.03 and 0.06 bandwidth and bootstrapped standard errors, with 50 replications reported. The result reveals that, on average, the adoption of improved rice varieties increased the rice productivity, rice income, and rice commercialization index (RCI) of the households, respectively, to ranges of 23.57–25.09%, 34.18–42.60%, and 6.32–14.44%. In addition, the adoption of improved rice varieties reduced the probability of multidimensional poverty index and subjective poverty, respectively, to the ranges of 8.93–11.05% and 7.51–7.93%. It can therefore be concluded that, apart from slight differences in the magnitude of the impact between the PSM and ESR estimates, the adoption of improved rice varieties had positive impacts on rice productivity, income, and RCI, indicating the robustness of the finding from the ESR model. Furthermore, the adoption of improved rice varieties reduced the level of MPI and subjective poverty status significantly. It is possible that the effects of unobserved heterogeneity, which are not taken into account in the PSM method, are the reason why the PSM approach gives higher estimates of impact than the ESR results. Results obtained through this study are consistent with the findings reported by Jaleta et al. (2016), Jaleta et al. (2018), Takahashi et al. (2020), and Takahashi & Barrett (2014).

Table 29. PSM estimates of the impact of rice variety adoption on outcome variables

Outcome variable	**Category**	Mean of outcome variables based on matched observations		Mean standardized bias
		Adopters	Non-adopters	ATT (SE)
Rice productivity *(kg/ha)*	NNM[a]	4144.33	3334.23	810.10*** (216.57)
	NNM[b]	4144.33	3312.95	831.38*** (166.89)
	KBM[c]	4151.39	3343.68	807.71*** (162.77)
	KBM[d]	4119.72	3333.84	785.88*** (161.66)
	RCM[e]	4146.86	3339.93	806.93*** (162.89)
Rice income *(USD/ha)*	NNM[a]	425.85	298.63	127.22*** (32.31)
	NNM[b]	425.85	313.34	112.51*** (29.39)
	KBM[c]	428.51	317.51	111.00*** (28.23)
	KBM[d]	428.51	319.36	109.15*** (28.70)
	RCM[e]	428.51	317.83	110.68*** (28.37)
	NNM[a]	0.420	0.395	0.025 (0.030)

Rice Commercialization Index (RCI)	NNM[b]	0.420	0.367	0.053** (0.024)
	KBM[c]	0.420	0.372	0.047** (0.024)
	KBM[d]	0.422	0.370	0.051** (0.024)
	RCM[e]	0.417	0.373	0.049** (0.024)
Multidimensional Poverty Index (MPI)	NNM[a]	0.306	0.342	-0.036* (0.021)
	NNM[b]	0.306	0.344	-0.038*** (0.016)
	KBM[c]	0.306	0.337	-0.031** (0.015)
	KBM[d]	0.307	0.336	-0.030* (0.016)
	RCM[e]	0.307	0.337	-0.030* (0.015)
Subjective poverty	NNM[a]	1.733	1.767	-0.034 (0.0881)
	NNM[b]	1.733	1.878	-0.145** (0.069)
	KBM[c]	1.731	1.880	-0.149** (0.066)
	KBM[d]	1.736	1.877	-0.141** (0.066)
	RCM[e]	1.736	1.880	-0.144** (0.066)

Note: ***, **, and * significant at the 1, 5, and 10% probability levels, respectively
Standard errors are in the parentheses

4.6. Conclusions and Implications

4.6.1. Conclusions

This study used primary data collected from a sample of 594 farm households to analyze the determinants and welfare impacts of the adoption of improved rice varieties in Ethiopia. This paper employed the ESR model to estimate the impact by reducing the effects of self-selection bias due to unobservable effects. Non-parametric (PSM) methods were also used to test the robustness of the findings from the ESR.

The results obtained from both the ESR and PSM models were consistent, indicating that the adoption of improved rice varieties generated a significant and positive impact on rice yield, commercialization, and income. The results further show that improved rice varieties had a positive welfare effect in the form of reduced multidimensional poverty and subjective poverty status in the major rice-producing area of the country. One can infer that improved rice variety adoption has made a significant contribution to the welfare of smallholder rice-producing farmers. Therefore, improving and maintaining agricultural growth depends primarily on the adoption of improved agricultural technologies, such as improved rice varieties.

4.6.2. Policy implications

The findings of this study have important implications for agricultural policy in Ethiopia related to rice. To further promote the adoption of improved rice varieties and maximize their impact, policymakers should target farmers' access to information, markets, extension services, and other inputs, which enhances farmers' willingness to use improved rice varieties. It could also be necessary to develop appropriate linkages between research institutions, farmers, and extension service agents. In addition, demonstrating and scaling out the improved rice technologies through field days and demonstration sites are also important avenues to show the effectiveness of improved rice varieties to farmers and enhance their adoption.

Information-sharing platforms such s agricultural extension services should be strengthened to provide farmers with updated information on improved rice varieties, best farming practices, and market opportunities. Extension workers should actively engage with farmers to facilitate the adoption of these technologies. Furthermore, rural infrastructure, including roads and transportation networks, should be improved to reduce the cost and time required for farmers to access markets. This will encourage commercialization and boost farmers' income. Additionally, efforts should be made to enhance market access for rice farmers, as this can play a crucial role in encouraging adoption and increasing rice commercialization.

The national rice research program should also work on the development of varieties that can meet the preferences of farmers. Furthermore, improving the rice seed system across regional states (availability, accessibility, and affordability of seeds) could enhance the uptake of improved rice varieties and lead to higher welfare impacts. Therefore, governmental and non-governmental organizations should devote more attention to the provision of an enabling environment for the adoption of improved varieties to ensure a positive change in the livelihood of rice farm households. Gains at the household level are expected to contribute to the wider economy in the form of tax and employment opportunities in the long run.

CHAPTER FIVE

5. Commercialization of smallholder rice producers and its determinants in Ethiopia

(Presented in the 6th International Rice Congress held in Manila, Philippines from October 16-19)

Abstract

In Ethiopia, rice holds significant importance as a strategic agricultural commodity aimed at enhancing national food security and reducing reliance on imports. To foster the growth and advancement of the rice sector, various measures and initiatives have been implemented to promote domestic production and self-sufficiency in rice supply. This study assessed factors that influence smallholder farmers' level of rice commercialization in Ethiopia on the output and input sides. The required data were generated from 594 randomly sampled rice producers using multi-stage sampling techniques from four major rice-producing regional states. Both descriptive and econometric methods were used to analyze the data. We adopted the Tobit model to analyze factors determining output and input commercialization in the rice market. The Tobit model result for rice output commercialization showed that the educational status of the household head, credit use, the share of irrigated land cultivated, membership in social groups, and land dedicated to rice production were found to influence significantly and positively the level of rice commercialization. Conversely, total cultivated land, and distance to the main market were found to have a negative influence. On the other hand, the Tobit model results of rice input commercialization indicated that farming experience of the household head, credit, irrigated land, extension service, and land allocated for rice was found to influence significantly and positively the degree of input commercialization, while distance to the main market affected the degree of input commercialization negatively. These findings suggest that promoting productivity-increasing technologies, developing irrigation facilities, strengthening social institutions, and facilitating access to credit are crucial for enhancing the commercialization of rice in the study area. Since agricultural lands are limited, intensified farming through the promotion of improved rice technologies and mechanized farming could be an option to enhance marketable surpluses and increase the level of rice market participation.

Keywords: Rice, Commercialization, Input, Output, Tobit, Ethiopia,

5.1. Introduction

Improving the agricultural production systems and marketing infrastructures of smallholder farmers is becoming a key strategy for agricultural commercialization and poverty reduction. Smallholder farmers' market participation has been recognized as crucial for transforming agriculture from subsistence-oriented to market-oriented and achieving expected agricultural growth. Consequently, as smallholder farmers begin to produce an agricultural surplus for the market, the farmers are more likely to increase productivity through intensification and then through their market participation (Abdullah et al., 2019; Block, 1999; Wiggins, 2014). Thus, their commercialization can be considered as an indicator of a step toward a market-oriented farming system.

Commercial-oriented farm households make production decisions based on market signals and comparative advantages in the market. While semi-commercial and subsistence farm households make production decisions based on their subsistence requirements and participate in marketing the surplus left after they meet their household's consumption requirements. Hence, the production decisions vary among smallholder farmers based on their level of commercialization, the demographic, socio-economic, and farm-level variables (Abdullah et al., 2019; Barrett, 2008; Gebre et al., 2021; Gebremedhin & Hoekstra, 2007; Ogutu & Qaim, 2019; Pingali, 2012). Therefore, improving agricultural marketing facilities, access to improved technologies, productive assets, and rural infrastructure could enable the farm households to plan their production more in line with market signals, schedule their agricultural product processing, and decide which markets and to whom to sell their products (Barrett, 2008). Moreover, a proper agricultural marketing system could also enable farm households to increase production and market efficiency.

Rice production has become an essential aspect of agriculture in Ethiopia, bringing significant changes in the livelihoods of farmers and other stakeholders involved in the rice value chain. According to Alemu et al. (2018), rice production has contributed to the development of smallholder farmers, increased food security, and improved the overall economic growth of the country. The country has ample resources to expand its rice production. According to recent estimates, there are about 30 million hectares of land suitable for rice production, out of which 5.6 million hectares are highly suitable (MoARD, 2010). However, despite the significant untapped potential of land, only 1.5% (85, 289 ha) of the most suitable land for rice production was dedicated to rice in the year 2020 (CSA, 2021). This suggests that there is a significant untapped potential for rice production in the country, which could contribute to rice self-sufficiency. Moreover, by utilizing 9.1% of the highly suitable land (509,600 hectares) for rice cultivation, Ethiopia can produce enough rice to meet the domestic demand for rice. This indicates a great opportunity for the country to increase its rice production, improve food security, and reduce the reliance on rice imports.

Enhancing the commercialization of rice sector is a vital pathway toward ensuring food security and import substitution for smallholder farmers in Ethiopia. Commercialization stimulates agricultural productivity by increasing the opportunity to use the obtained income for input purchases, and hence increased agricultural productivity also leads to surplus production for the market. The commercialization of rice is believed to lead smallholder rice producing farmers to a more specialized rice production system based on the comparative advantage of rice in resource utilization. Because the productivity of rice is by far better than most cereal crops except maize, and the market price of rice is also the highest among cereals next to tef (CSA, 2021; Assaye et al., 2022).

There have been studies in different specific districts or zones of the country on rice commercialization and agrarian change, rice profitability, market participation, and rice value chain (Abera, 2021; Abera & Assaye, 2021; Alemu et al., 2018; Alemu & Assaye, 2021; H. Hagos et al., 2018; Sabates-Wheeler et al., 2021; Takele, 2017; Workye et al., 2019). However, to the best of the researchers' knowledge, little or no study has been done on smallholder rice commercialization and its determinant factors at the national level in Ethiopia. Development initiatives and policymakers require information on rice commercialization to address the existing development gaps and opportunities that help to boost economic contribution and secure the national self-sufficiency of rice. Therefore, the main focus of this paper is to assess smallholder farmers' rice commercialization and factors affecting rice commercialization in major rice-producing areas of Ethiopia.

5.2. Methodology

5.2.1. Description of the study area

The study was conducted in major rice-producing areas of the country. The area allocated for rice in the year 2018 was considered to determine the share of sampled households to be drawn in the study area. The target population for this study is all agricultural households in the districts who were permanent residents of the selected *kebeles*[19] and participated in rice production in the year 2018. Farmers from the Amhara, Benishangul Gumuz, Oromia, and SWEP (Southern West Ethiopia People) regional states who produced rice constituted the population (N) from which the sample was drawn.

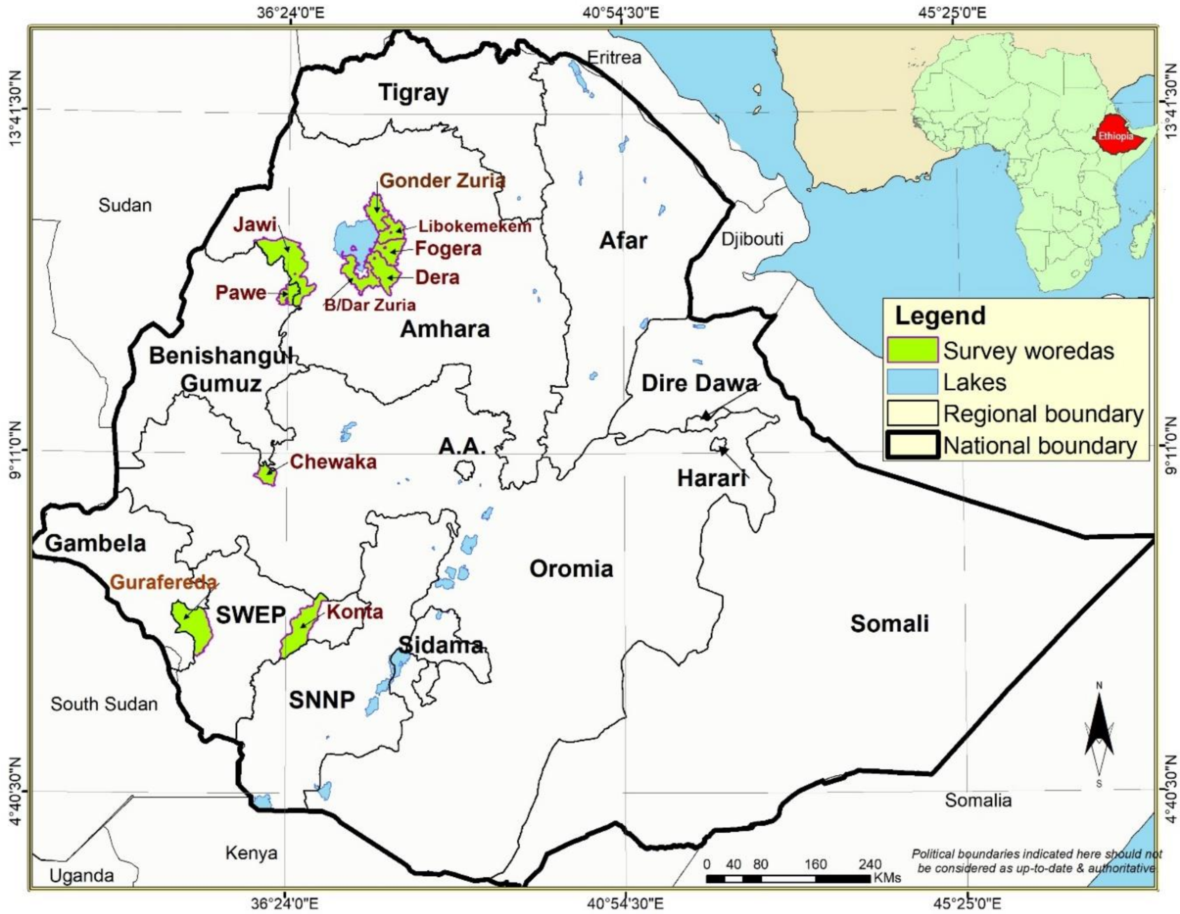


Figure 9. Study area map of rice commercialization

The main rice-producing regions are Amhara, Benishangul Gumuz, Oromia, and SWEP which account for 99% of the rice area cultivated by smallholder farmers in the country (CSA, 2020) (Table 29). The rice farming system in Ethiopia comprises complex production units involving

[19] *Kebele* is the smallest administrative unit in Ethiopia. It is equivalent to a village in some countries

a diversity of interdependent mixed cropping and livestock activities. In the rice farming system, farmers grow diverse crops in the country. Rice is the dominant crop, followed by maize and grass pea. According to this study's results, rice, maize, grass peas, soybean, and millet took up 39%, 12%, 10%, 7%, and 7% of the cultivated crop area, respectively. As to total production, rice has the highest share and contributes 54% of the total grain production of households. Maize is next in production and has an 11% share of grain production. Soybean and grass peas made up 4.9% and 4.7% of the grain production, respectively.

Table 30. Details of Rice production in Ethiopia

Region	Area (ha)	Production (tons)	Area share (%)	Production share (%)
Amhara	49,361.04	168,903.71	57.9	62.97
Benishangul	18,953.94	51,729.90	22.2	19.29
Oromia	11,263.46	31,957.80	13.2	11.91
SNNP	5,094.74	13,966.63	6.0	5.21
Tigray	392.30	1,020.37	0.5	0.38
Gambela	223.37	6,45.11	0.3	0.24
Total	85,288.85	268,223.51	100.0	100.00

Source: CSA 2020

5.2.2. Data type and sampling procedure

This study was based on cross-section data collected from rice-based farming systems at the community, household, and plot levels during the production year 2018. The primary data were collected through a questionnaire-based survey of a smallholder rice farmer and through focus group discussions and key informant interviews using checklists prepared to guide the discussions. Relevant secondary data were also collected from different organizations, including the Ministry of Agriculture, CSA, FAOSTAT, ITC, and other published and unpublished sources.

A multistage sampling technique was employed to select sample households for the study. Four regional states (Amhara, Oromia, Benishangul Gumuz, and SNNP) were purposively identified, and 11 and 35 rice-growing districts and kebeles were selected using a random sampling technique. Finally, 8-28 rice-growing households were randomly selected from each survey kebele based on the weighted scale of the area covered by rice. This procedure yielded a sample of 612 households’ data from the sampling frame of rice-producing farmers at the kebele level. Data from each household were collected through face-to-face interviews using a structured questionnaire administered to sampled farmers. All details of agricultural production and marketing were collected for 12 months and we used 594 sampled households data for analysis.

5.2.3. Analytical framework

Descriptive analysis was used to analyze the demographic, institutional, and farm resource ownership characteristics and the commercial orientation typology of farm households. Further, descriptive statistics such as means, proportions, and standard deviation were used to describe the socio-economic characteristics of the sample respondent households and their rice commercialization orientation. These analyses were also used as inputs for the econometric analysis in the subsequent sections.

Measuring Rice Commercialization

The agricultural commercialization index was used to evaluate the degree of commercialization at the household level, which has been used in many studies to measure the extent of output commercialization among smallholders (Awotide et al., 2016; Gebre et al., 2021; Gebremedhin & Jaleta, 2010; Jaleta et al., 2009; Ogutu & Qaim, 2019; Tesfay, 2020a; von Braun, 1995). Commodity-specific output and input side commercialization can help to understand the details of commercialization for a specific commodity. Commercialization can be studied on the output side of production with an increased marketed surplus, but it can also occur on the input side with increased use of purchased inputs.

In measuring household-specific levels of commercialization, Jaleta et al. (2009), Govereh et al. (1999), and Strasberg et al. (1999) used a household commercialization index (HCI), as a ratio of the total value of all crop sales to the total value of all crops produced per household per year. We measure commercialization based on farmers' rice production and marketing activities over the 12 months of the year 2018. Therefore, we compute the household level of rice commercialization as the share of the total value of rice marketed by the total value of rice produced during the 12 months covered by the survey. The commercialization index is continuous and ranges between zero and one. The same type of commercialization index was also used in previous studies (Alelign et al., 2017; Ogutu & Qaim, 2019; Otekunrin et al., 2022; von Braun, 1995).

Input market participation indices for rice were calculated using the share of the value of agricultural inputs purchased to the total value of agricultural inputs used to produce rice and considered as an important indicator of the commercial behavior of sample households (von Braun, 1995). Thus, chemical fertilizer, seed, and agrochemicals were used as input side commercialization since those are the most commonly used agricultural inputs purchased by the farmers in the study area. Agricultural input market participation stimulates agricultural productivity, and hence increased agricultural productivity also leads to surplus production for the market. In addition, higher investment in agricultural inputs for the production of rice can indicate the farmers' motivation to increase the return from rice cultivation. In general, agricultural inputs are expected to boost crop production and the possibility of smallholder farmers engaging in output markets.

In this paper, we both used the output and input side rice commercialization index as a proxy for the degree of agricultural commercialization for the households which had grown rice in the year 2018. Hence, the output side commercialization index for a household (RCI) was computed as:

$$RCI_h = \frac{Value\ of\ rice\ Sold_h}{Value\ of\ rice\ produced_h}; Value\ of\ rice\ produced_h \geq Value\ of\ rice\ sold_h \quad \text{Output side} \quad (1)$$

Where RCI_h is the proportion of the value of rice sold ($Value\ of\ rice\ Sold_h$) to the total value of rice produced ($Total\ value\ of\ rice\ produced_h$) per household. The index measures the extent of farm households' market participation. The index value closer to zero signifies a subsistence-oriented household while closer to 1, indicates the higher degree of rice commercialization.

In addition, the input side commercialization index for a household (RCI) can be computed as:

$$RCI_i = \sum_{i=1}^{n} \frac{Total\ value\ of\ inputs\ purchased_i}{Total\ value\ of inputs\ used_i} \quad \text{input side} \quad (2)$$

Where, RCI_i is the proportion of the value of agricultural inputs purchased for rice production ($Total\ value\ of\ inputs\ purchased_i$) to the total value of inputs used for rice production ($Total\ value\ of\ inputs\ used_i$). A value closer to zero would indicate a subsistence-oriented household and a value closer to one imply a highly commercialized household.

Methodologically, one needs to apply a two-step analytical approach for output commercialization, considering participation and intensity of participation. However, almost all sample farm households participated in rice output marketing (about 87%), and hence there is no need to estimate the decision to participate in rice input and output marketing. Therefore, we employed the Tobit model to analyze the determinate factors of both output and input commercialization, as this model was used by different researchers in agricultural commercialization studies (Alelign et al., 2017; Gebremedhin & Tegegne, 2012).

Tobit model specification

The censored regression model is an option for handling these limited dependent variable applications where the dependent variable is observed to be zero for some individuals in the sample. Therefore, the Tobit regression model was applied to quantify the magnitude and direction of the effects of the factors influencing smallholder rice producers' participation in input marketing. The general formula defining the Tobit model is specified as follows:

$$y_i^* = \beta x_i + \varepsilon_i \qquad i = 1, 2, 3, \ldots . n$$
$$y_i = \begin{cases} 0, & if\ y^* \leq 0 \\ y^*, & if\ y^* > 0 \end{cases} \tag{6}$$

where: y_i^* is a latent variable (agricultural input commercialization index), which is unobserved for values less than 0 and greater than 1, that represents subsistence or fully commercial index, y_i is the observed dependent variable, x_i is a vector of independent variables which includes factors affecting the level of commercialization. β is a vector of unknown parameters to be estimated; ε_i is a disturbance term assumed to be normally distributed with zero mean and constant variance σ^2 ; and i= 1, 2, 3… n (n is the number of observations).

The Tobit model is estimated using maximum likelihood estimation. Let f (.) and F (.) be the density and the cumulative density functions of y*. Then the model implies that the probabilities of observing a non-zero y and a zero y are f(y) and p(y*<0) =F (0), respectively. The log-likelihood function for the model is:

$$\ln L = \ln\left(\prod_{y_i>0} f(y_i) \prod_{y_i=0} F(0)\right) = \sum_{y_i>0} lnf(y_i) + \sum_{y_i=0} lnF(0) \tag{7}$$

Since the error terms of y* are assumed to be normally distributed, f(.), F(.) and hence the log-likelihood functions can be written in the form of the density function and cumulative density function of the standard normal distribution. As for the standard normal distribution: $\emptyset$(.) and Φ(.) and the log-likelihood function is rewritten as:

$$lnL = \sum_{y_i} - ln\sigma + ln\phi\left(\frac{y_i - \chi_i\beta}{\sigma}\right) + \sum_{y_i} ln\left(1 - \Phi\left(\frac{\chi_i\beta}{\sigma}\right)\right) (3)$$

To identify factors affecting smallholder rice commercialization (input and output commercialization), different variables were hypothesized based on economic theories and the findings of different empirical studies. The explanatory variables that are expected to influence the dependent variable(s) are summarized in Tables 30 and 31.

Table 31. Summary of variable description hypothesized to influence rice output commercialization

Description of variables	Description	Values	Sign
Demographic Characteristics			
Sex	Sex of the household head	0=female, 1=male	+/-
Age	Age of the household head	Years	+/-
Rice experience	Experience of the household in rice farming	Years	+
Education status	Education status of the household head	1= literate, 0= illiterate	+
Household size	Number of family members	Number	+/-
Asset Ownership			
Total cultivated land	Cultivated area	Area in ha	+/-
Rice area	Total area covered by rice	Area in ha	+/-
TLU	Livestock ownership	TLU	+
Non/off-farm	Non or off-farm income	1=Yes, 0=No	+/-
Institutional Variables			
Extension	Frequency of extension contact in a year	Count	+
Received credit	Did you receive credit last year	1=Yes, 0=No	+
Share of irrigated land	Share of land that has access to irrigation	Percent	+
Market distance	distance to the main market	Kilometers	-
Social Capital index	Index of membership in social institutes	Index	+

Table 32. Description of variables hypothesized to influence the input side rice commercialization

Description of variables	Measurement	Expected sign
Rice farming experience	Continuous (years)	+
Sex of the household head	Dummy (1. male, 0. Female)	-
Education status of the household head	Dummy (1. Literate, 0. Illiterate)	+
Dependency ratio	Continuous (%)	-
Distance to the nearest main market	Continuous (kilometers)	-
Received credit	Dummy (1= yes, 0=no)	+
Access to extension service for agricultural inputs	Dummy (1. yes, 0. no	+
Share of land that has access to irrigation	Continuous (%)	+
Membership in social association	Index (0 to 1)	+
Livestock holding	Continuous (TLU)	+
Land allocated to rice	Continuous (hectare)	
The total land cultivated	Continuous (hectare)	
Off/non-farm income	Birr	+/-

5.3. Result and Discussion

5.3.1. Status of Rice commercialization and households' characteristics

Rice market participation indices were calculated using the share of rice sold from the value of total rice produced and considered as an important indicator of the commercial behavior of sample households. The descriptive results of commercialization level considering the value of rice marketed derived from the ratio of the value of sales to the value of rice produced expressed in percent is summarized in four categories of commercialization level in Table 32. The category of rice commercialization was made based on the extent of the share of rice marketed. Non-commercial farmers are those households who didn't participate in rice marketing and low-commercial farmers are those farmers who participated in rice marketing up to 25% of the total produce. Both non-commercial and low-commercial farmers are grouped under subsistence farmers. In addition, semi-commercial farmers are farmers who produce a marketable surplus between 25% to 50% of total production. Commercial farmers are those farmers who produce a marketable surplus above 50% of the total production.(Birhanu et al., 2021; Gebre et al., 2021; Zewditu et al., 2020).

Table 33. Household's Rice commercialization category

Rice commercialization	Freq.	Percent	Cum.
Non-commercial	78	13.13	13.13
Low commercialization	108	18.18	31.31
Semi commercialization	236	39.73	71.04
Commercialization	172	28.96	100
Total	594	100	

Source: Computed from the survey data

The rice farmers' market orientation index was computed by using the land allocation share of the households weighted by the marketability index of rice. The average market orientation index of rice was about 21%, indicating a moderate market orientation of smallholders in the study area, while the average rice output commercialization was 36%, also indicating moderate market participation (Table 33). Rice has become one of the most important market-oriented crops among cereals, with about 87% of households participating in rice marketing and allocating approximately 57% of the total cultivated land for rice.

Table 34. Market participation across regional states (mean and sd)

REGION	Amhara	Oromia	SWEP	Benishangul	Total
Rice output commercialization	0.35 (0.21)	0.56 (0.29)	0.46 (0.32)	0.30 (0.23)	0.36 (0.23)
Market orientation of rice	0.22 (0.17)	0.22 (0.16)	0.19 (0.19)	0.10 (0.1)	0.21 (0.17)
Land share (rice)	0.62 (0.30)	0.44 (0.22)	0.34 (0.21)	0.30 (0.170	0.57 (0.30)
Rice output market Participation	0.89 (0.32)	0.89 (0.32)	0.78 (0.42)	0.75 (0.44)	0.87 (0.34)

Source: Own survey result

5.3.2. Demographic and socioeconomic characteristics of the households

The average age of household heads was 43.6 years with 11 years of experience in rice farming. About 10% of household heads in the sample were female-headed and sampled households on average have a family size of 5.56. About 47.0% of sampled household heads were illiterate and the average livestock holdings of the sample households were 5.79 TLU (Table 34).

The average productivity of rice was about 3.15 tons, which is very close to the national average yield (3.14 tons). Chemical fertilizers are known for their responsiveness in increasing rice productivity in the study area. Thus, about 87.5% and 49.5% of the households applied Urea and DAP/NPS fertilizer among those farm households 41% and 39% of the farmers applied recommended rate of Urea and DAP/NPS fertilizer in the rice field respectively. The average land allocated for rice cultivation was about 0.74 ha and the share of land for rice from the total cultivated land was 57%. The average value of rice produced per household was 35,820 birrs. In addition, rice commercialization demands daily laborers from the market, and around 51% of the farm households used hired labor for rice production (Table 34).

Households in the study area on average travel for 108.4 minutes to get to the nearest main market and about 23% of the respondents received credit in the year 2018. Most of the advice that the farmers received from the extension workers was mainly on rice pre-harvest operations, especially on land preparation, fertilizer application, varietal choice, and seed rate in that order. The extension service is not that strong in providing advice on post-harvest processing and marketing. The smallholder farmers on average contact 11 times with extension workers in a year.

For the descriptive comparisons, we subdivided the sample into quartiles according to the household level of rice output commercialization and compared the most commercialized (highest quartile, MC25%) with the least commercialized (lowest quartile, LC25%) households. On average, sample households sold 36% of their rice output, while the most and the least commercialized quartiles sold 68% and 7%, respectively (Table 34). Commercialization is positively associated with several demographic, and socioeconomic variables, as well as with farm input use and productivity.

Table 35. Summary statistics of variables by the level of rice commercialization (mean & sd)

Variables	Total sample	MC25%	LC25%	t-value
Rice commercialization (share of rice sold, 0-1)	0.36 (0.23)	0.68 (0.11)	0.07 (0.08)	-0.61***
Age of the household head (years)	43.58 (11.8)	41.78 (12.2)	45.71 (12.6)	3.94***
Sex of household head (male=1)	0.89 (0.31)	0.94 (0.23)	0.90 (0.3)	-0.04
Rice farming experience (years)	11.3 (6.43)	11.04 (6.3)	10.85 (6.7)	-0.20
Household size	5.56 (2.05)	5.70 (2.19)	5.52 (1.98)	-0.17
Education status of the head (l=literate)	0.53 (0.50)	0.59 (0.49)	0.48 (50)	-0.118***
Received credit (yes=1)	0.23 (0.42)	0.24 (0.43)	0.18 (0.39)	-0.06
Ownership of livestock (TLU)	5.79 (4.91)	6.48 (5.79)	6.0 (5.88)	-0.48
Productivity of rice in a ton	3.15 (1.54)	3.60 (1.45)	2.88 (1.49)	-0.72***
Non/off-farm income (yes)	0.24 (0.43)	0.21 (0.41)	0.26 (0.44)	0.04
Total cultivated land (ha)	1.69 (1.32)	1.77 (1.32)	1.88 (1.55)	0.11
Irrigation access (yes=1)	0.4 (0.49)	0.43 (0.5)	0.34 (0.47)	-0.10*
Main market distance (walking minute)	108.4 (66.6)	101.9 (71.6)	103.0 (66.3)	1.11
Social capital index	0.4 (0.24)	0.42 (0.23)	0.37 (0.24)	-0.05*
Frequency of extension contact	11.94 (12.6)	12.88 (13.3)	11.64 (12.5)	-1.246
Improved seed (used)	0.24 (0.43)	0.36 (0.48)	0.17 (0.37)	-0.19***
Recommended Urea (used)	0.41 (0.49)	0.42 (0.5)	0.32 (0.47)	-0.10*
Recommended DAP/NPS (used)	0.39 (0.49)	0.46 (0.5)	0.28 (0.45)	-0.18**
Land allocated for rice (ha)	0.74 (0.47)	0.86 (0.61)	0.59 (0.37)	0.26***
Observations	594	138	149	287

Notes: Standard deviations are shown in parentheses.
MC25%, 25% most-commercialized households; LC25%, 25% least-commercialized households; ETB is Ethiopian birr, and
*, ** and *** are significance levels at 10%, 5% and 1% level.

5.3.3. Rice production across regions

Based on interviewed households estimate, the average area that a household allocated for rice production was 0.473 ha of land and harvested 3475 kg of rice from a hectare of land (Table 35). The average productivity of rice is much higher in the Oromia region as compared to the national average yield while the average productivity of rice in Benishangul Gumuz and SWEP regions is below the national average. The quantity of rice consumed at home is comparably equal to that supplied to the market in the Amhara and Benishangul Gumuz regions while the quantity of rice supplied to the market is too high as compared to the quantity of rice consumed at home in Oromia and SWEP regions. Farmers of Oromia and SWEP regions are highly commercial as compared to Amhara and Benishangul Gumuz regions in rice production.

According to the CSA 2021 report, most of the cereal crops produced in the country were used for household consumption (63%) whereas nearly 25% and 11% were used for sale and seed, respectively. The remaining 4% of the cereals produced were used for other purposes like wages, animal feed, etc. About 46% to 72% of the crops produced in the cereals group were used for home consumption while 14% to 36% of these crops were used for marketing. Among cereal crops, rice (36%) was the most commercial crop as compared with other cereals in the country (Table 35). The CSA report on the rice commercialization index is the same as our survey findings (Table 36).

Table 36. Utilization of rice

	Total production (quintal)	The ratio of utilization					
		consumption	Sale	seed	In-kind payment	animal fed	Others
Ethiopia	2,682,235.1	47.1	35.6	13.8	1.0	0.4	2.1
Amhara	1,689,037.1	49.6	34.3	12.5	0.7	-	3.0
Oromia	319,578.0	44.3	36.8	15.4	0.7	0.9	2.0
SNNP	139,666.3	34.4	43.8	14.7	3.4	1.3	2.4
Benishangul	517,299.0	56.7	27.9	15.4	-	-	-

Source: Computed from CSA 2021 report

Table 37. Rice production and utilization across regions

REGION	Yield (kg/ha)	Area (ha)	Produced (kg)	Commercialization %
Amhara	3632	0.686	2468	34
Oromia	4582	0.828	3511	56
SWEP	2509	0.853	2166	45
Benishangul	2181	1.215	2521	29
Total	3475	0.743	2487	35

Source: Own survey result

5.3.4. Access to market

Smallholder farmers struggle to access paddy rice markets in different parts of the country. Access to rice marketing demands road and marketing infrastructure to mobilize resources. The government, development organizations, and farmers' cooperatives have to invest resources to facilitate the equitable access of producers to input and output markets. This could increase the bargaining power of producers and reduce transaction costs. The analysis result showed that sampled households traveled on average for 80 and 42 minutes to get the rice output and input markets respectively (Table 37). This indicated that rice output markets are less accessible for the producers than the input market. Interestingly, rice farmers of the Amhara regional state, who contribute the largest share of national production are further away from the output as well as input market. Efforts have to be made to improve the accessibility of markets to the producers to enhance rice commercialization.

Table 38. Access to market

REGION	Distance (walking minute) to	
	Output market	Input market
Amhara	90.47	44.75
Oromia	26.53	11.05
SWEP	21.00	15.95
Benishangul G.	37.42	43.73
Total	79.96	41.82

Source: Own survey result

The provided data in Figure 10, sheds light on the primary rice marketing places for rice across different regions, revealing distinct marketing patterns that have significant implications for the rice industry. Notably, the data reveals distinctive patterns of rice marketing strategies in each region. In the Amhara Region, district markets serve as the predominant marketplace, accounting for a substantial 61.7% of rice sales because of the availability of rice processors and wholesalers in the nearby district. This highlights the pivotal role of district markets in connecting rice producers with a broader consumer base. Conversely, the Oromia Region primarily relies on farm gate sales, with a substantial 68.8% of rice sold directly by farmers. In contrast, the South West Ethiopian People (SWEP) Region exhibits a more balanced distribution of rice across farm gate, village, and district markets. Benishangul, similar to Amhara, places a significant emphasis on district markets (66.2%) and village markets (30.8%). These regional variations underscore the need for tailored marketing strategies and infrastructure development to ensure efficient rice distribution and better access to markets, ultimately benefiting both producers and consumers.

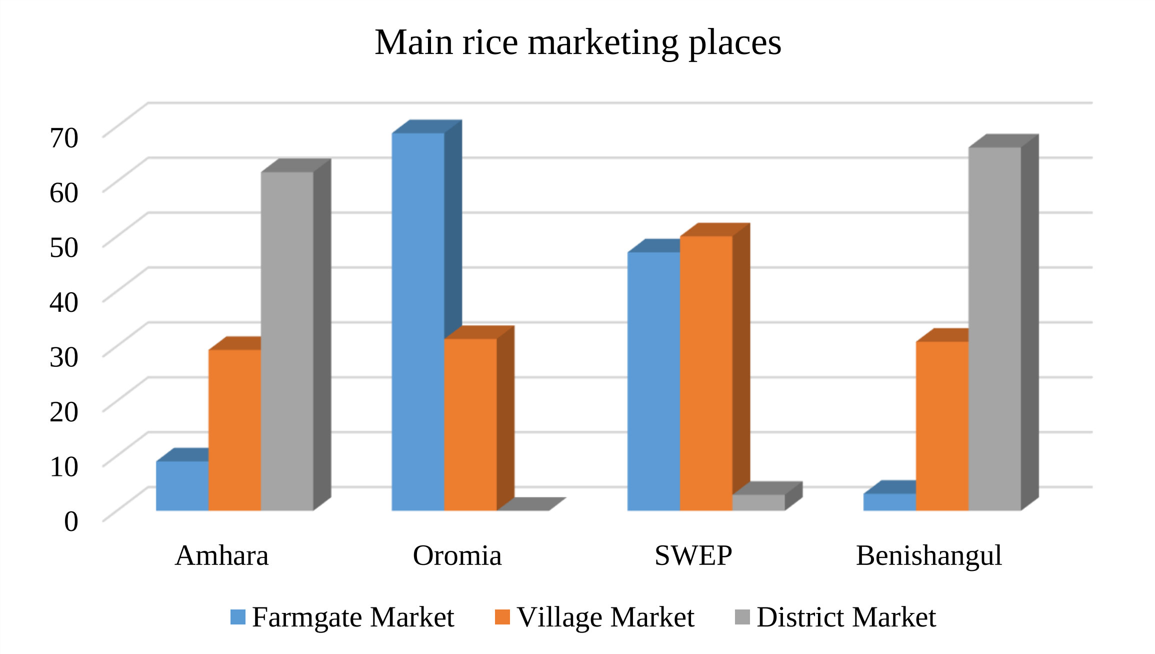


Figure 10. Smallholder farmers' main rice marketing places across regions

5.3.5. Seasonal market variability and price trends

Harvesting and threshing of rice take place between October and January in the country depending on the cropping calendar of the area. As indicated in Table 38, more than 63% of the total marketed rice was sold immediately after harvest in December, January, and February. On the other hand, the proportion of rice marketed becomes lower in later seasons during which the price rises, such as June to September. Smallholder rice farmers of Oromia and SNNP regional states sell their rice immediately after harvest at the lowest selling price as compared to Amhara and Benishangul Gumuz regional state farmers. The price of rice became highest in July, June, and August respectively while the lowest price was recorded in December, January, and February. There are also unusual price fluctuations due to the flush of rice imports which causes some market distortion in the country (Table 38).

The key findings of this study revealed that smallholder farmers in practice do not have a comprehensive marketing strategy with regards to the timing of sales, even though they are much aware of price movement and sales are made purely based on the cash needs of farmers (Table 38). Most of the social events and religious holidays are celebrated from December to February, the farmers need cash to celebrate those social events and holidays, this could be one factor that farmers sell their produce immediately after harvest. In addition, storage and transport accessibility problems have driven the farmers to sell a large quantity of rice immediately after harvest (63% of the total sale). Furthermore, the unavailability of rice milling machines in the nearby cities makes the farmers sell paddy rice immediately after harvest for collectors. Thus, the farmers cannot make use of price advantages that occur in the later season. Encouraging the private sector to participate in investing in rice processing in the main rice-producing areas of the country could be an option. Additionally, governmental and non-governmental organizations, cooperatives, and other private investors can invest in a warehousing system to enable farmers to store their products as inventory that would serve as collateral for consumption loan access during periods of peak season (immediately after harvest at which the price is low). Furthermore, most farmers used local seed (77%), and almost all farmers in the study areas threshed rice on the bare ground resulting in adulteration, all of which goes to affect the quantity and quality of rice production. Therefore, enhancing domestic quality rice production and marketing has become an urgent policy issue in Ethiopia.

Table 39. Rice marketing calendar of the farmers with average selling price (ETB/kg)

Months	**Amhara**		**Oromia**		**SNNP**		**BG**		**Overall**	
	Share of sell (%)	Selling price	Share of sell (%)	Selling price	Share of sell (%)	Selling price	Share of sell (%)	Selling price	Share of sell (%)	Selling price
January	33.0	10.5	5.1	5.0	17.7	6.8	19.7	8.3	29.2	10.3
February	16.6	10.6	57.4	7.2	32.1	6.7	11.3	8.5	19.9	10.1
March	7.5	11.4	15.3	7.3	3.7	7.2	10.0	8.4	7.8	10.9
April	7.0	11.1	15.9	7.8	13.0	7.8	14.6	8.8	8.5	10.9
May	3.6	11.5	0.0	-	0.7	7.0	14.6	9.4	4.0	11.0
June	4.8	12.6	0.0	-	0.0	-	6.9	8.7	4.3	12.3
July	1.7	11.4	0.0	-	0.0	-	0.3	9.0	1.4	11.0
August	4.2	12.6	0.0	-	0.0	-	11.0	8.9	4.1	11.6
September	1.9	11.9	0.0	-	1.6	8.0	2.3	8.5	1.8	11.2
October	1.2	10.9	0.0	-	4.2	7.0	0.0	-	1.3	10.5
November	4.8	10.8	0.0	-	0.5	8.0	0.0	-	3.8	10.6
December	13.7	10.3	6.4	6.0	26.6	6.3	9.5	8.7	14.0	10.0
Total	100	10.8	100	7.3	100	6.9	100	8.6	100	10.5

Source: Own household survey result

5.3.6. Determinant factors of rice output market participation of households

As indicated in Table 39, smallholder farmers' extent of rice output commercialization was influenced by educational status, credit use, the share of irrigated land cultivated, membership in social groups, and land under rice production were found to influence significantly and positively the probability of being commercial-oriented while total cultivated land, and distance to the main market influences negatively.

Distance to the nearest main market had a negative and significant effect on the level of rice output commercialization, probably because of high transportation costs for shipping the agricultural outputs to the market. Thus, households who are far away from the marketplace places expected to have lower output market participation, or households closer to market outlets are more likely to participate in marketing activities. This finding suggests that rural road infrastructure and transportation facilities are crucially important to promote agricultural commercialization in the study area. Several authors agreed that agricultural marketing costs are directly related to distance to the market and road access which can determine the level of commercialization and smallholder market participation (Atinafu et al., 2022; Barrett, 2008; Isinika et al., 2020; Tafesse et al., 2020).

The total size of the cultivated land is a crucial factor in determining commercialization for farmers. A larger cultivated land enables farmers to produce different types of crops for sale. Studies have shown that as the size of cultivated land owned by a household head increases, the decision to produce rice for sale decreases while the decision to produce other cash crops increases. This is because households with larger land sizes can allocate their land for both food crop production and cash crop production. When farmers cultivate more land, they can produce a variety of crops, which increases the probability of producing different cash crops for sale rather than food crops like rice. Consequently, the tendency of farmers to produce rice for sale decreases. This finding is consistent with previous studies conducted by Alelign et al. (2017) and, Sabates-Wheeler et al. (2021).

The significant role of social capital in market participation suggests the need for establishing and strengthening local institutions and service providers to enhance rice output commercialization. In a country where there is information asymmetry and where both input and output markets are incomplete, local institutions can play a critical role in providing farmers with timely information, inputs, and technical assistance (Kassie et al., 2015; Shiferaw et al., 2014; Teklewold et al., 2013). Access to credit services increases the likelihood of participation in rice commercialization. A farmer might use credit to purchase inputs for rice production, and then repayment of the credit could encourage households to increase their supply of rice to the market. This result is in line with the works of Getachew et al. (2011), Shikur (2020), Isinika et al. (2020), Kim et al. (2016), and Hailu & Fana (2017).

The education status of the household head was found to be of positive influence on the extent of rice output commercialization. A possible explanation for this would be that education enhances the likelihood of getting market-related information which would help smallholder farmers to make the appropriate decision to participate in rice output commercialization. It may also be the reason that education enables household heads to understand market dynamics in a better way than uneducated household heads. This result was in line with the findings of (Belay et al., 2021; Endalew et al., 2020; Meleaku et al., 2020; Nega et al., 2022; Tafesse et al., 2020), who found that the education level of smallholder farmers increased the probability of crop commercialization.

The share of land allocated for rice had a positive and significant effect on the level of rice output commercialization because the households with a higher share of land allocated for rice could probably lead to produce more rice. The framers who allocated more land for rice can produce surplus production which could help them to increase the probability of rice market participation. This finding is in line with the research works reported by (Alelign et al., 2017; Getahun, 2019; Meleaku et al., 2020), who reported that the share of land allocated for specific crops positively influenced the level of that specific crop commercialization. The total area of land cultivated had a negative and significant relationship with rice output commercialization. The farmers with larger cultivated land might have more probability of planting different crops with different purposes so that they might have multiple crops to supply to the market than rice.

Access to irrigation contributes to a significant increase in the volume of rice marketed. market participation, the volume of rice marketed produce, and, hence, income. Smallholder farmers who have access to irrigation, supply more rice to the market than those farmers operating only under the rainfed production system. Farmers need more cash to purchase agricultural inputs and to operate farming activities under irrigation. This might force the farmers to participate in rice marketing in a better way than farmers who have no access to irrigation. This result is in line with the works of (F. Hagos et al., 2007; Haile et al., 2022; Hailu & Fana, 2017).

Table 40. The marginal effect of Tobit estimation results of output commercialization

Variable	Coefficient (S.E)	Marginal effect (S.E)
Age of the household head	-0.001 (0.001)	-0.001 (0.001)
Sex of the household head	0.016 (0.037)	0.012 (0.027)
Household size	0.004 (0.006)	0.003 (0.004)
Education status	0.011^{**} (0.004)	0.008 (0.003)
Credit	0.047^{*} (0.024)	0.036 (0.019)
Livestock ownership	0.003 (0.003)	0.002 (0.002)

Non/off-farm income	-0.035 (0.025)	-0.026 (0.018)
Total cultivated land	-0.052*** (0.011)	-0.038 (0.008)
Irrigated land share	0.096* (0.051)	0.071 (0.038)
Main market distance	-0.006*** (0.002)	-0.005 (0.002)
Membership in social groups	0.111** (0.045)	0.083 (0.033)
Frequency of extension contact	-0.0002 (0.0002)	-0.0002 (0.001)
Land allocated for rice	0.150*** (0.025)	0.112 (0.019)
Constant	0.307*** (0.059)	
Var(e.output comm.)	0.059*** (0.004)	
Prediction	0.3800	
Observation	594	

Note: ***, ** and * represents statistical significance of the factors at 1%, 5% and 10% respectively

5.3.7. Determinants of rice input commercialization of smallholder farmers

The definition of input-side commercialization given by von Braun, (1995) was adopted in computing the commercialization index of agricultural input purchased for agricultural production. The common approach used for measuring household commercialization from the input side is to take the ratio of the value of inputs purchased to the total value of crops produced in a particular production period (Alelign et al., 2017; Jaleta et al., 2009; Ogutu & Qaim, 2019). Thus, the value of agricultural inputs (seed, fertilizer, and agrochemicals) purchased as a proportion of the value of rice produced has been used as a basis to assess the agricultural input commercial orientation of the smallholder farmers.

There are limitations in setting a cutoff point for defining the commercial orientation of smallholder farmers in terms of agricultural input purchases (seed, pesticide, and fertilizer). About 24.4%, 90.6%, and 48.6% of farm households in the rice farming system participated in purchasing seed, fertilizer, and agrochemicals respectively. Thus, the total cost spent for agricultural input purchase was used as input side commercialization since it indicates the motive of the farm household to cultivate rice for commercial purposes. Almost all sample households participated in input marketing, no need to estimate the input market participation. To estimate the level of input market participation, we employed the Tobit regression model. The Tobit model is commonly used in such kinds of data where the dependent variable is observed to be zero for some individuals in the sample.

Before the estimation process, an appropriate test such as the Lagrange Multiplier (LM) or score test suggested for the normality assumption in the Tobit model was performed. The LM-statistic test was applied to test the Tobit model specification against the alternative nonlinear models in the regressor and contains an error term that can be heteroscedastic and non-normally distributed. Assuming the regressors are stochastic, the critical values are obtained via parametric bootstrapping. The result revealed that bootstrap critical values displayed for 1%, 5%, and 10% level tests are 7.01. 4.01, and 2.73, respectively, and these values are less than the LM statistic (268.51). Hence, the LM test suggests that the Tobit model is appropriate for the data.

The average value of agricultural inputs used for rice production was estimated at 2,666.2 birr of which about 52% (1,395.3 birr) came from rice seeds (Table 40). Agricultural inputs such as fertilizer, seed, and agrochemicals took 74%, 17.7%, and 8.3% of the total value of purchased inputs respectively. This figure shows that the farmers are spending more money on fertilizer than other inputs.

Table 41. The average value of inputs used for rice production

Variable	Obs	Mean	Std. Dev.	Min	Max
Agricultural input value (ETB)	594	2666.2	1805.2	155	11807.8
Purchased input value (ETB)	594	1545.5	1372.9	0	9050.0
Purchased fertilizer value (ETB)	594	1144.2	1033.5	0	7475.0
Purchased seed value (ETB)	594	273.3	605.5	0	3300.0
Purchased agrochemical value (ETB)	594	128.0	257.4	0	2000.0
Used Seed value (ETB)	594	1395.3	934.2	141	6240.0

Source: Own survey data

The model result indicated in Table 41 showed that, out of 13 independent variables used in the model, farming experience of the household head, credit, irrigated land share, extension service, land allocated for rice, and distance to the main market were found to influence significantly the degree of rice input commercialization.

Irrigation is a very important resource for market-oriented agricultural production. Farmers who have more access to irrigation could have more exposure to use of agricultural inputs. Share of irrigated land was positively influenced rice input commercialization. This is because if a household had more irrigated land, they might earn more cash income from the sale of crops produced by irrigation and their tendency to purchase agricultural input would increase. In addition, farmers could be motivated to produce cash crops using irrigation which can increase their cash reserves. This result is consistent with the findings of Sileshi et al., (2019), Joshi & Piya, 2021; Oluwatayo & Rachoene, (2017), and Shikur, (2020) who reported that irrigation significantly contributes to market participation by enabling smallholder farmers to grow marketable crops.

Distance to the nearest main market negatively affects the probability of smallholder farmers' participation in the agricultural input market due to high transaction costs that farm households incur in terms of transportation and marketing. Thus, as the distance to the main market increases, the transaction cost of input purchased increases, which may lead to discouraging smallholder farmers from participating in the input market. The result is consistent with the hypothesized sign and earlier findings reported by Bekele et al., (2022), Gebremedhin & Jaleta, (2010), Belay et al., (2021), Tafesse et al., (2020) and Hailu & Fana, (2017) which indicated that market distance detracts from crop input market participation due to its effect on increasing marketing costs.

Access to credit services increases the likelihood of participation in agricultural input commercialization by reducing the financial constraints of the households to purchase inputs for rice production. Furthermore, repayment of the credit could encourage households to increase their supply of rice to the market. This result is in line with the works of Getachew et al., (2011), Shikur, (2020), Isinika et al., (2020), Kim et al., (2016), and Hailu & Fana, (2017). The positive effects of the frequency of extension contacts on the decision to participate in rice input marketing are expected, given the importance of awareness and access to various forms of information, which enhances farmers' willingness to use agricultural inputs for rice production (Zeleke et al., 2021, Ogutu & Qaim, 2019, Endalew et al., 2020).

Farming experience was believed that household heads with higher experience in rice farming would have more knowledge and skills about rice production, input application, weather forecasting, and rice marketing. Farming experience was found to be significantly and positively influencing input market participation in the study area. The result is consistent with the findings reported by (Afolami et al., 2015; Chandio & Jiang, 2018; Zeleke et al., 2021) that farming experience increases the farmers rationality in use of improved agricultural inputs.

Agricultural extension services aim to support and facilitate individuals engaged in agricultural production by providing information, skills, and technologies to address problems and improve the productivity of farmers. Frequent extension visits provide technical advice on productivity-enhancing inputs, encouraging farmers to consider acquiring these inputs and understand the benefits of using improved agricultural inputs. The Tobit model's results revealed that the frequency of extension visits had a positive and statistically significant effect, indicating that farm households that received a large number of extension contacts were more likely to use purchased agricultural inputs

The land allocated for rice positively influenced the smallholder rice producers' agricultural input market participation. This could be because the income that the farmers earn from the sale of rice would increase the probability of agricultural input purchase. This result is consistent with the findings of Meleaku et al., (2020), Getahun, (2019), and (Atinafu et al., 2022) who reported that the larger the land size allocated, the higher would be the output which in turn increases the volume of supply to the market and increase the tendency of participating in the input market.

Table 42. The marginal effect of Tobit estimation results of input commercialization

Variable	Marginal effect	Standard Error
Farming experience	0.001**	0.0003
Sex of the household head	-0.0294	0.0207
Dependency ratio	0.0015	0.0028
Education status	-0.0116	0.0081
Credit	0.0333**	0.0158
Livestock ownership	0.0008	0.0009
Non/off-farm income	0.0086	0.0109
Total cultivated land	-0.0008	0.0008
Irrigated land share	0.0412**	0.0162
Main market distance	-0.0201**	0.0101
Membership in social groups	0.00179	0.0028
Frequency of extension contact	0.0224***	0.0080
Land allocated for rice	0.0166*	0.0085
Constant	0.0482	0.0306
Sigma	0.0941***	0.0109
Prediction	0.11268524	

Note: ***, ** and * represents statistical significance of the factors at 1%, 5% and 10% respectivily

*** p<0.01, ** p<0.05, * p<0.1

5.4. Conclusion and recommendations

This study was conducted to measure the level of rice commercialization and examine determinant factors that affect rice commercialization. The descriptive result of the study indicated that the majority of smallholder farmers are semi-commercial rice producers. On average, 31%, 40%, and 29% of the households were under subsistence, semi-commercial, and commercial-oriented categories respectively. Rice has become one of the most important market-oriented crops among cereals, with about 87% of households participating in rice marketing and allocating approximately 57% of the total cultivated land for rice. In general, smallholder farmers in the rice farming system have a great potential to be commercial-oriented in rice farming than other cereal crops in the country. Therefore, special emphasis should be given to rice to promote rice commercialization through implementing rice productivity increasing technologies and agricultural mechanization technologies to enable smallholder farmers to produce a marketable surplus.

Promoting rice commercialization could have a multiplier effect on the whole rice value chain and economy as well. Because rice is a crop that requires further processing that demands different actors to participate before being sold to the consumers. It can create job opportunities for different members of the community. Agricultural input suppliers, rice millers (processors), transporters, traders, laborers, and others can directly benefit from rice commercialization. Therefore, rice commercialization can promote income distribution among rural community members and other stakeholders in the rice value chain beyond rice production and can help to link rural with urban communities.

The key findings of this study also revealed that smallholder farmers in practice do not have a comprehensive marketing strategy about the timing of sales, even though they are much aware of price movement, sales are made purely based on the cash needs of farmers. In addition, storage and transport accessibility problems have driven the farmers to sell a large quantity of rice immediately after harvest. Furthermore, the unavailability of rice milling machines in the nearby cities makes the farmers to sell paddy rice immediately after harvest for collectors. Thus, the farmers cannot make use of price advantages that occur in the later season. Encouraging the private sector to participate in rice processing in the main rice-producing areas of the country could be an alternative option. Additionally, governmental and non-governmental organizations, cooperatives, and other private investors can invest in a warehousing system to enable farmers to store their products as inventory that would serve as collateral for consumption loan access during periods of peak season (immediately after harvest at which the price is low).

Moreover, the econometric model results revealed that different demographic, socioeconomic, and institutional variables have a significant and differential effect on rice commercialization. The result indicated that educational status, share of irrigated land, credit use, land allocated to rice, distance to the nearest main market, membership in social institutions, total cultivated land, and farming experience had a statistically significant effect on rice commercialization.

Furthermore, special emphasis should be given to productivity-increasing technologies, irrigation facilities, social institutions, and credit-providing institutions to enhance rice commercialization in the study area. Since agricultural lands are limited, intensified farming through promoting improved rice technologies and mechanized farming should be implemented to enhance rice productivity and a high degree of rice commercialization.

Additionally, access to rice marketing demands road and marketing infrastructure to mobilize resources. The government, development organizations, and farmers' cooperatives have to invest resources to facilitate the equitable access of producers to market. This could increase the bargaining power of producers and reduce transaction costs. Surprisingly, rice farmers of the Amhara regional state, who contribute the largest share of national production are further away from the output as well as input market. Efforts have to be made to improve the accessibility of markets to the producers to enhance rice commercialization.

CHAPTER SIX

6. Analysis of Consumer Preferences for Rice Quality Attributes in Ethiopia

Abstract

This study explores consumer preferences and behaviors within the Ethiopian rice market, providing insights into the evolving dynamics of rice consumption and demand. We used data collected from 200 consumers using a semi-structured questionnaire in 2023. As per capita rice consumption, steadily increased in the last 15 years in the country, it becomes evident that consumers' choices are shaped by a combination of factors, including socioeconomic factors, affordability, perceived quality, convenience, cultural compatibility, and others. The findings reveal a dynamic interplay between urban and rural consumers, highlighting their distinct patterns in rice type preferences, consumption habits, and quality attribute perceptions among consumers. Urban consumers lean towards imported rice due to perceived quality and packaging advantages, while rural consumers often opt for locally produced rice for its affordability and compatibility with traditional dishes. Key quality attributes, including color, selling price, level of impurities, and breakage play pivotal roles in shaping consumer choices, varying in importance across regions. These findings highlight the importance of having diverse marketing strategies, better quality of locally produced rice, initiatives to educate consumers, innovative packaging, sustainable agricultural practices, developing value-added products, and improved market access for rural producers as essential ways to build a strong and sustainable rice sector.

Keywords: Rice, consumers, preferences, consumption, quality attribute, Ethiopia

6.1. Introduction

Marketing is the process of identifying and addressing the human and social needs of consumers. It is both an art and a science, involving the identification and targeting of specific markets, the development of strategies using the marketing mix elements, and the establishment, communication, and promotion of consumer value (Kotler & Keller, 2021). Consumer preferences can vary based on factors such as income levels, lifestyles, culture, and other influences. Satisfying consumer demands and preferences requires innovative approaches to maintaining the existing customer base while also attracting new ones (Carreras-Simó et al., 2023; Custodio et al., 2019; Sgroi et al., 2022). Therefore, the study of consumer preference and behavior is the starting point for the definition of marketing strategies and choices regarding a product, price, communication, and distribution policies.

Consumer preferences for rice exhibit considerable variation across communities and countries, reflecting the influence of socioeconomic, historical, and cultural factors. Usually, consumers are very concerned about the quality, price, and safety of the commodity when they make decision to purchase a product (Diako et al., 2010). For instance, consumers in the United States preferred rice varieties associated with specific cooking quality, menus, and processing characteristics. In the Middle East, there is a preference for long grain rice that is well-milled and has a strong aroma, while Europeans tend to prefer long grain rice without any scent. Japanese consumers highly prioritize well-milled, freshly processed, short-grain Japonica rice. In addition, imported rice also are mostly preferred by restaurants in Africa due to its quality as compared with locally produced rice (Aoki et al., 2017; Custodio et al., 2019; Vroegindewey et al., 2021).

Furthermore, consumers might prefer to buy locally produced rice over imported rice due to its compatibility with local foods, low price, freshness, and other reasons. On the other hand, consumers might prefer to purchase imported rice over local rice due to its quality, branding, and related issues. In general, consumers have their own set of preferences and their purchasing behavior could be influenced by different factors such as culture, education, lifestyle, and social and economic background of the society.

Quality plays a significant role in determining consumers' decision to purchase agricultural products in the market. However, defining rice quality in the rice sector remains a challenge, as there is no universally acceptable definition and consensus on rice quality measures. While agronomic traits of rice are measured based on their ability to increase yields and ability to resist stresses. Therefore, assessing quality attributes is more complex due to the relative and context-specific nature of rice quality. Additionally, the assessment of rice quality is context specific and subjective and relies on the consumer's perspective, taking into account the historical, geographical, and socio-cultural context of rice consumption. For instance, rice that is considered of low quality in one region may be regarded as premium quality in another region (Bairagi et al., 2021; Custodio et al., 2019; Demont & Ndour, 2015).

Consumers may prioritize their preferred rice quality attributes based on intrinsic or extrinsic characteristics to make decision to purchase rice. Intrinsic characteristics encompass grain quality traits such as color, cleanliness, purity, softness, aroma, size, uniformity, and shape of the grain. On the other hand, extrinsic attributes include packaging, labeling, and branding (Bairagi et al., 2021; Custodio et al., 2019). The preference for these quality attributes is influenced by the historical, geographical, economic, and socio-cultural context in which consumers are situated and where rice consumption takes place. Packaging plays a crucial role in the transition towards emphasizing extrinsic quality attributes in the advancement of the food retail industry. It serves as a facilitator for conveying extrinsic quality attributes, enabling consumers to acquire pertinent information about the product.

Given the increased production and consumption of rice in Ethiopia, it is essential for both locally produced and imported rice to meet the quality attributes desired by consumers. However, there is limited information available in the literature regarding Ethiopian rice consumption preferences. The review of existing literature indicates that the majority of research on consumer preferences is conducted in developed countries, leaving developing countries largely unexplored. Specifically, there is a lack of research on consumer preferences towards agricultural products, including rice, in Ethiopia. Additionally, the literature does not address consumers' preferences for specific quality attributes of rice, how rice is consumed and the factors that influence their purchasing behavior in Ethiopia.

This research aims to find out which type of rice Ethiopian consumers prefer among the many options available in the market. Understanding consumer preferences is important in guiding investment efforts to boost the rice sector in Ethiopia. The main objective of this study is to explore consumer preferences for rice quality attributes to enable demand-driven research and development activities in the rice industry. Additionally, the study seeks to shed light on the preferences of both urban and rural consumers for both local and imported rice. Generally, it is important to conduct a thorough investigation to comprehend how rice quality is perceived and consumed in Ethiopia.

6.2. Material and methods

6.2.1. Data collection procedure

To achieve the stated objective, a rice consumer survey was conducted between late December 2022 to early February 2023 through a semi-structured questionnaire, covering the primary rice-growing and consuming regions in Ethiopia. We employed a two-stage stratified sampling technique to ensure a fair representation of consumers. In the first stage, we classified the target population into two strata: rural and urban consumers. This classification aimed to represent the local rice production areas and the main consumer markets, respectively, in the country. Secondly, we selected 100 sampled respondents from each stratum using the snowball sampling method and conducted structured interviews using a questionnaire. The consumer survey covered 4 cities and 4 rural districts in Ethiopia. The surveys were complemented with key informant interviews. The data was collected using CSPRo software loaded onto iPads or smartphones through face-to-face interviews of consumers. The programmed questionnaire in the CSPRo software was pre-tested before the formal survey started.

Table 43. Sampled consumers across regions

		Consumer type		
Region	District	Urban consumer	Rural consumer	Total
Amhara	Fogera	19	32	51
	Libokemkem	0	14	14
	Bahir Dar	19	0	19
	Jawi	0	2	2
Benishangul	Pawe	25	32	57
SWEP	Guraferda	20	20	40
Addis Ababa	Addis Ababa	17	0	17
	Total	100	100	200

Source: Own survey data

6.2.2. Data analysis

The data was analyzed using descriptive analysis and factor analysis (FA). Descriptive analysis was employed to describe the socio-demographic characteristics of the population, rice quality attribute perceptions of consumers, drivers of increased rice consumption, rice consumption preference and frequency, and others in terms of mean, frequencies, percentages, etc.

Additionally, the study utilized clustering techniques, including hierarchical and k-means clustering, to identify distinct segments among Ethiopian rice consumers.

6.3. Result and Discussion

6.3.1. Sociodemographic characteristics of the consumers

The descriptive statistics of rice consumers in Ethiopia revealed that 70% of the surveyed household heads were male, with the remaining 30% being female. In terms of marital status, a significant majority (87%) were married, while a smaller proportion were divorced (8.5%), single (3%), or widowed (1.5%). Among the respondents, farming emerged as the most common occupation, representing for 42.5% of the household heads, followed by civil service at 23% and trading at 31.5%. Artisanship (handcraft) and other unspecified occupations each accounted for 1.5% of the household heads.

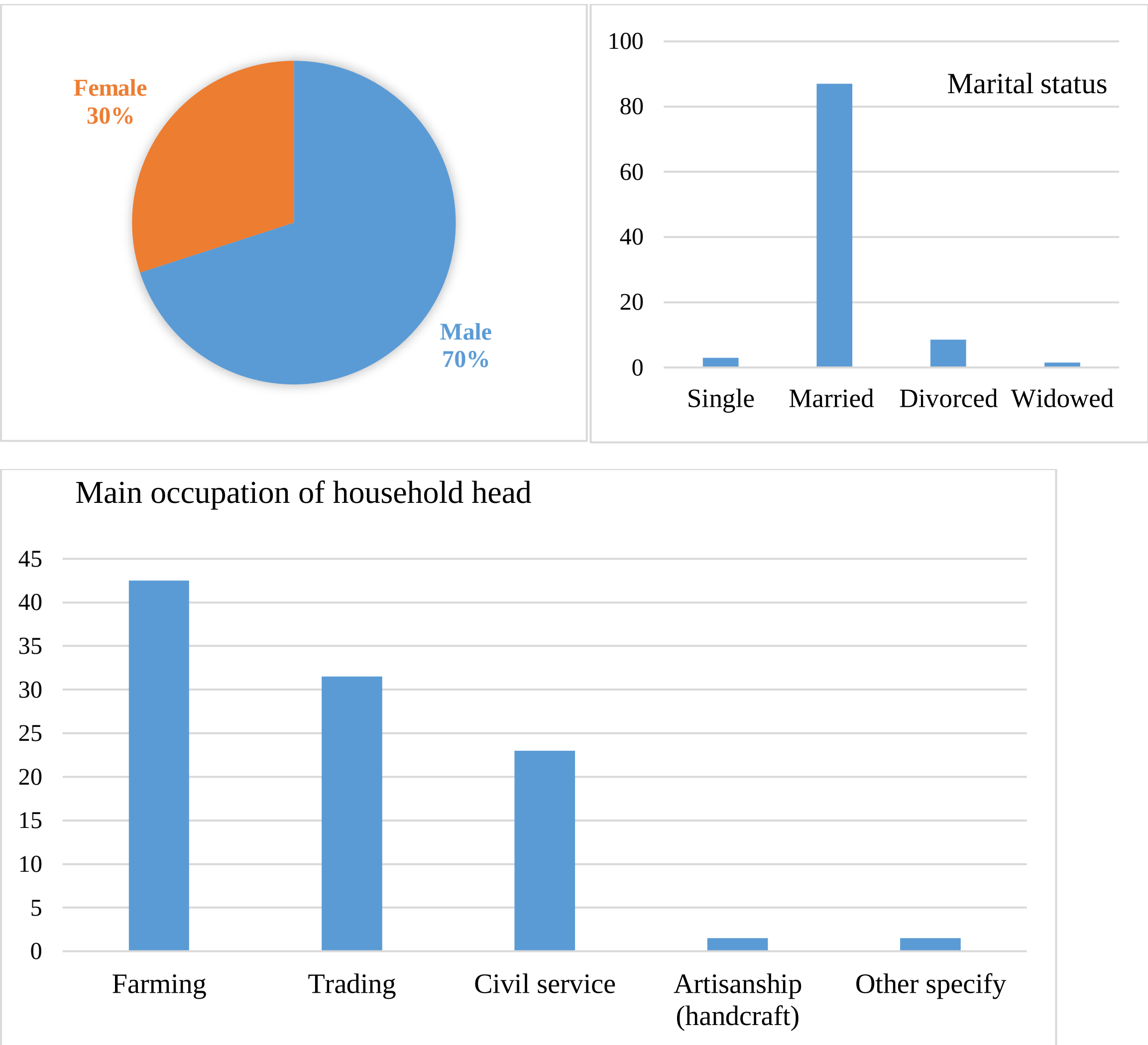


Figure 11. Sociodemographic characteristics of the consumers
Source: Own survey result (2023)

Furthermore, the age of the household heads ranges from 19 to 70 years, with an average age of 39.5 years. Their educational backgrounds vary from no formal education to up to 18 years of schooling, with an average of 7.6 years of schooling. The annual average household income spans from 16,000 to 1,000,000 birr, with an overall mean income of 164,989 birr. Household sizes range from 1 to 14 members, with an average household size of 4.7. Additionally, the households have been consuming rice for various periods, ranging from 3 to 45 years, with an average consumption duration of 18.3 years (Table 43). These characteristics could influence their choices in the rice market, such as the type and quality of rice they prefer and the factors that influence their purchase decisions.

Table 44. Sociodemographic characteristics of the respondents

Variables	Minimum	Maximum	Mean	Std. Deviation
Age of the household head in years	19	70	39.5	10.1
Education level of the head (years)	0	18	7.6	6.0
Annual average income in birr	16000	1000000	164989.0	139774.4
Household size	1	14	4.7	1.9
Rice consuming experience (years)	3	45	18.3	8.9

Source: Own survey result (2023)

The average income levels of rice consumers across different regions in Ethiopia vary significantly. In urban areas, rice consumers tend to have higher average incomes compared to their rural counterparts. Addis Ababa, the capital city, stands out with the highest average income among urban rice consumers. On the other hand, the SWEP region exhibits the largest income disparity between urban and rural rice consumers. In contrast, the Benishangul region shows a relatively smaller income gap (Table 44). These income differences can potentially influence rice consumption patterns and preferences, highlighting the need for targeted marketing strategies and interventions to address regional disparities and promote rice consumption in a way that aligns with the economic conditions of different areas in Ethiopia.

Table 45. Average annual income of rice consumers across regions

REGION	Urban	Rural	Overall
Amhara	217,212.00	171,340.40	191,545.80
SWEP	142,941.90	43,600.00	94,482.44
Benishangul	142,168.20	119,677.40	129,717.90
Addis Ababa	320,000.00		320,000.00
Total	200,328.30	128,928.60	164,989.00

Source: own survey result

6.3.2. Overview of rice consumption in Ethiopia

6.3.2.1. Rice consumption trend

Consumption of rice in Ethiopia is growing faster than domestic production, resulting in a significant decline in the rice self-sufficiency rate. Ethiopia's estimated annual rice demand was 1.6 million metric tons while annual production was about 0.27 million metric tons in the year 2020. The market gap for rice is more than five-fold of its rice production and is filled by imports ((FAO), 2022). Rice consumption has been increasing on average by 29.2% each year over the past decade from 2010 to 2020 (Figure 12).

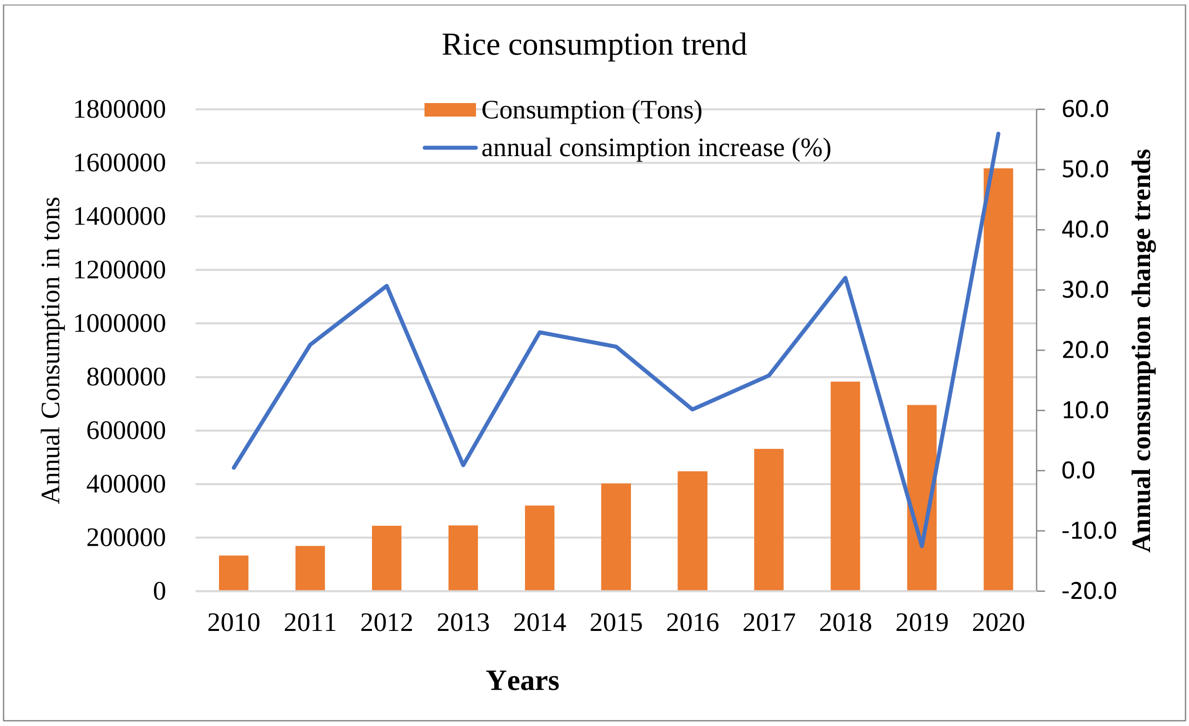


Figure 12. Rice consumption trend (2010-2020)
Source: Adopted from FASTAT and ITC, 2023

6.3.2.2. Per capita consumption trends (2005-2020)

Over the past 15 years (2005 to 2020), Ethiopia witnessed a significant transformation in its per capita rice consumption trends. As it is indicated in Figure 13, the per capita consumption of rice unveils a remarkable increase in rice consumption, offering valuable insights into the evolving dynamics of the rice market in the country. From the year 2005 to 2010, the per capita rice consumption in Ethiopia increased from 0.59 kg/person to 1.50 kg/person. The increase in per capita consumption might be attributed to factors such as expansion of rice production, population growth, economic development, and changes in urbanization patterns. This signifies the growing preference for rice as an essential staple in the Ethiopian diet, reflecting its gradual integration into the daily meals of consumers.

Subsequently, from 2010 to 2015, there was a notable surge in rice consumption, soaring from 1.50 kg/person to 3.93 kg/person, reflecting shifting consumer preferences and increased rice availability (Figure 13). However, the most transformative phase occurred between 2015 and 2020, during which per capita rice consumption experienced exponential growth, rising from 3.93 kg/person to an impressive 13.48 kg/person. This exponential surge indicated a fundamental shift in Ethiopian dietary habits, with rice becoming a staple food in the country. Compatibility of rice for making injera, rising awareness of the rice value and utility, increased price of teff, urbanization, increased rice imports, and government efforts to enhance food security likely played crucial roles in making the commodity more accessible and affordable to a broader segment of the population. This exponential growth also suggests a fundamental cultural acceptance of the commodity, as it became increasingly entrenched in the daily lives and preferences of consumers and its critical role in addressing food security challenges in the country.

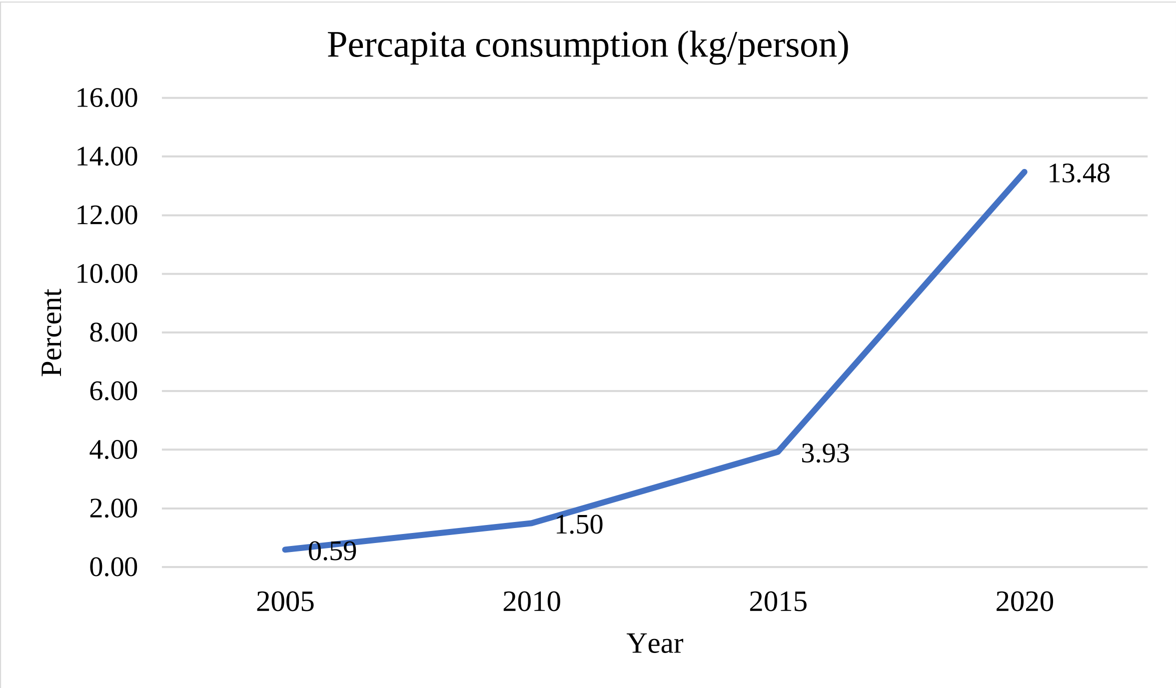


Figure 13. Per capita consumption trends (2005-2020)
Source: Adopted from FASTAT and ITC, 2023

6.3.2.3. Rice consumption habit

Rice consumption in Ethiopia exhibits variations between rural and urban communities, as well as among different regions within the country. In rural areas, the majority of consumers prefer locally produced rice due to several factors. Firstly, locally produced rice is favored for its affordable price compared to imported rice. Additionally, rural consumers appreciate the taste of locally grown rice, which aligns with their culinary preferences and traditional dishes such as *injera*, as well as local beverages like *tela* and *areke*.

In contrast, urban consumers living in the capital city, Addis Ababa, display distinct preferences. They lean towards imported broken rice, primarily due to its low level of impurity as compared with the local rice, making it more suitable for preparing *injera*. Moreover, urban consumers in Addis Ababa tend to opt for imported high-quality rice when consuming rice as table rice. On the other hand, urban consumers from other regions of the country prefer locally produced rice for making *injera* but choose imported rice for consumption as table rice.

Mixing rice with other cereal crops (*teff*, maize, finger millet, sorghum) for *injera* making has become a common practice in the country in both rural and urban communities. Moreover, as per the key informants of rice consumers, mixing rice with *teff* from 20 to 25% provides a 10 to 20% increased quantity of *injera*. Due to this reason, mixing rice with *teff* has become a common practice for making *injera* in most consumers who live in towns.

6.3.2.4. Drivers of increased rice consumption

The consumers were asked about the main reason for the increased consumption of rice in Ethiopia. The respondents listed various factors that contribute to the rising consumption of rice in the country (Table 45). Based on the consumers survey data, the most frequently cited reasons for the increased consumption of rice in Ethiopia include the higher price of *teff* (a local grain), which was listed by 23.9% of the respondents. This is followed by inflation (20.6%), population growth (19.4%), and expansion of rice production (18.1%). Other notable reasons include the suitability of rice for making injera (14.2%), awareness and knowledge about rice (12.9%), and the availability/accessibility of rice in the market (9.0%).

Additionally, respondents mentioned other factors influencing the rise in rice consumption including the changes in consumption habits and diets, improved income levels, and the perceived health benefits of rice as other factors influencing the rise in rice consumption. Moreover, some respondents pointed out that rice is highly demanded by children, and there has been an overall increase in demand for rice. Factors such as the ease of cooking, compatibility with various foods, lifestyle changes, globalization, and urbanization were also mentioned as contributing factors, albeit to a lesser extent.

Table 46. Possible reasons for increasing rice consumption in Ethiopia

Main reason for the increase in rice consumption	Percent
Price of teff	23.9
Inflation	20.6
Population growth	19.4
Rice production expansion	18.1
Good for making injera/ *wuha yanesal*	14.2
Awareness and knowledge about rice	12.9
Availability/accessibility of rice in the market	9.0
Consumption habit change (diet change)	6.5
Income increase	4.5
Good for health (nutritional value)	3.8
Highly demanded by kids	3.2
Demand increased	2.6
Easy to cook	1.9
Easy to eat with different foods	1.9
Lifestyle change	1.9
Globalization	1.9
Urbanization	1.3
I don't know the reason	3.2

Source: Own survey result (2023)

6.3.3. Consumers preference and consumption behaviour

6.3.3.1. Rice consumption preference and frequency

The findings of this study indicate that a significant proportion of the interviewed rice consumers (88%) incorporate rice into their daily dietary intake. Specifically, a majority of the respondents (76%) consume rice in the form of *injera* daily. Furthermore, a smaller percentage of respondents reported consuming rice at varying frequencies: 15.5% consume it 2-3 times a week, 2.5% consume it 1-3 times a month, 4.5% consume it once a week, and 1.5% consume it only a few days per year. The primary preference of the majority of consumers is to consume rice in the form of *injera*, primarily due to its ability to enhance the volume and improve the color of the *injera*. In Ethiopian households, children exhibit a greater inclination towards consuming rice in the form of table rice compared to other household members. This preference can be attributed to the convenience of cooking and packing rice as a school lunch, as well as the influence of globalization and social media. Typically, rice is consumed as table rice, often accompanied by vegetables and a meat stew prepared with various spices and ingredients such as onion, garlic, and tomato. In rural communities of rice producing areas, alternative methods of rice consumption include incorporating it into bread, porridge, and local beverages such as *Areke* and *Tela*. Most rice consumers exhibit a prevailing inclination towards consuming table rice mainly during breakfast, rather than during lunch and dinner (Figure 14). However, it is noteworthy that certain older household members choose to abstain from rice and wheat-based foods due to their perception that such foods may elevate their blood sugar levels.

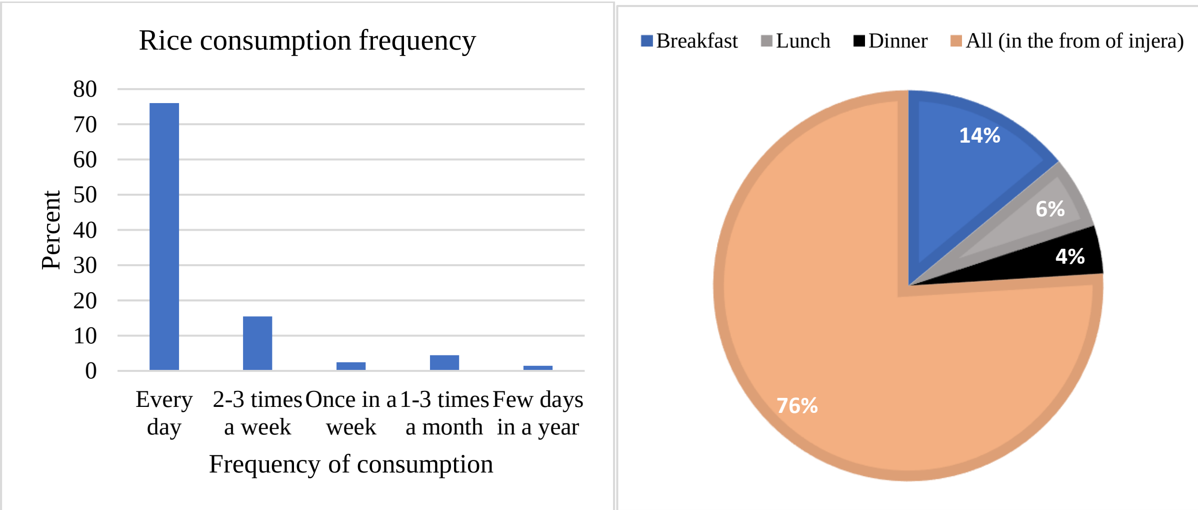


Figure 14. Rice consumption frequency and preferred time to consume rice
Source: Own survey result (2023)

6.3.3.2. Consumption behaviour of consumers: urban and rural

Urban and rural consumers in different regions of Ethiopia exhibit distinct patterns of preferences and consumption behaviors influenced by various factors, such as traditional foods commonly consumed in the area, economic conditions of the community, access to grains and resources. The data provide valuable insights into the cereal composition of *injera* consumed by urban and rural consumers in different regions of Ethiopia (Figure 15). In urban areas, the data highlights a significant reliance on teff as the primary cereal for making *injera*. For instance, in Addis Ababa, *teff* constitutes a substantial portion of 77.4% of the *injera* composition, aligning with its cultural significance and traditional culinary practices. Similarly, the Amhara (66.4%) and SWEP (61.8%) regions also show considerable *teff* usage, reflecting the preferences, popularity, and availability of this cereal in urban settings. Interestingly, in certain urban areas of the Benishangul region like Pawe, maize plays a more significant role (19.5%), potentially influenced by its accessibility and cost-effectiveness for urban consumers. The low or negligible percentages of maize and finger millet in the *injera*-making process in urban areas indicate that urban consumers tend to favor *injera* made primarily from *teff*. This inclination aligns with their exposure to diverse food choices and their preference for the color and soft texture of *injera*.

On the other hand, the figure also highlights a contrasting cereal composition for injera among rural consumers. In major rice producing rural areas, rice emerges as a predominant cereal, particularly in the Amhara and Benishangul regions, where it accounts for 63.6% and 61.2% respectively. This preference for rice usage among rural consumers may stem from their limited access to diverse food options and their reliance on locally grown commodities and staple crops. In general, rural consumers compared to their urban counterparts less prominently utilize *Teff*.

It's essential to recognize that food preferences and consumption patterns can also vary within regions based on factors like urbanization levels, access to markets, access to grains, income disparities and others. Understanding these variations can help policymakers and stakeholders in formulating targeted strategies to promote sustainable agricultural practices and preserve the traditional culinary heritage while addressing the unique dietary needs of both urban and rural populations.

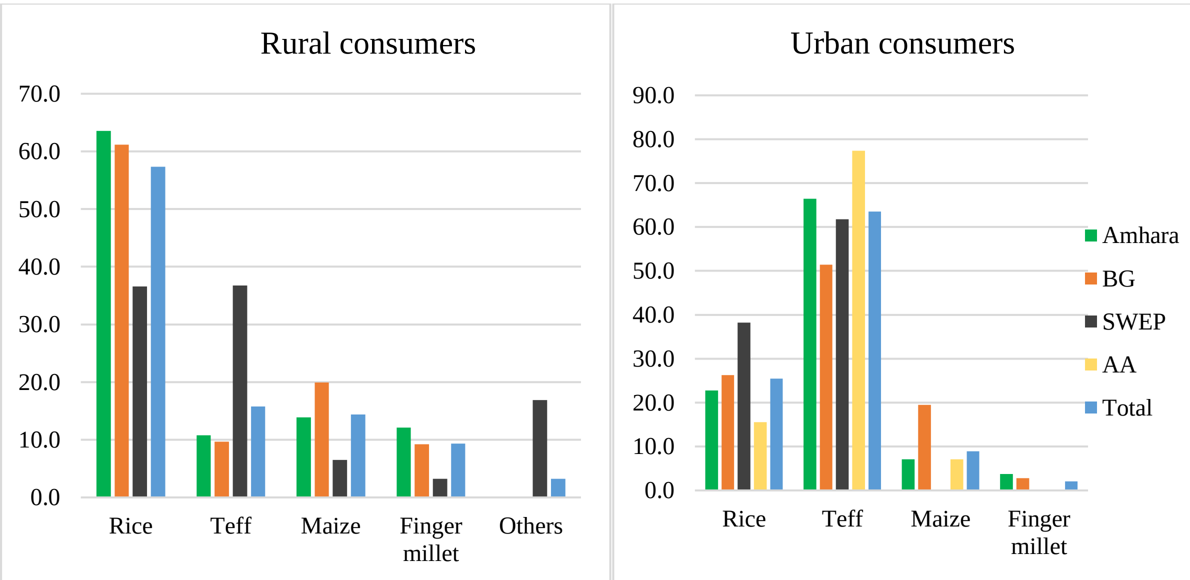


Figure 15. Rural and urban consumers' cereal composition used for making injera
Source: Own survey result (2023)

6.3.3.3. Composition of cereals in injera making process

The composition of cereals used in the *injera*-making process offers valuable insights into the dietary habits of both urban and rural consumers in various regions of Ethiopia. This exploration not only highlights the diversity in crop utilization for *injera* preparation but also underscores the cultural significance and variations tied to this traditional dish across different regions that produce and consume rice. In major rice-producing and consuming areas of Amhara region, rice (46.1%) and *teff* (35.1%) are the primary cereals used in injera making, comprising the majority of the composition. However, maize and finger millet are also incorporated, but to a lesser extent (10.9% and 8.4% respectively) (Table 46).

In the SWEP region, *teff* is the dominant cereal used for making *injera*, representing 48.9% of the composition. Rice is also commonly used (37.4%), while maize and finger millet have relatively smaller contributions (3.3% and 1.7% respectively). Interestingly, consumers used other crops (9.7%) in the SWEP region of Ethiopia to make *injera*. The Benishangul region exhibits a diverse combination of crops for making *injera*, with rice and *teff* as the primary components, representing 45.8% and 28.0% respectively. Maize is also a significant contributor (19.8%), along with a smaller percentage of finger millet (6.4%) in the region. On the other hand, Addis Ababa stands out with a distinct pattern, heavily relying on *teff* (77.4%) for making *injera*. Rice (15.6%) and maize (7.1%) are used to a lesser extent, while finger millet and other crops do not contribute to the *injera* composition in this region.

These cereal preferences for making *injera* are influenced by various factors such as access to diverse foods, culture, traditions, lifestyle, economic conditions and others. It's essential to acknowledge that preferences and consumption patterns can also differ within regions due to urbanization levels, market access, income disparities, and other factors. This highlights the importance of understanding consumer preferences and consumption patterns as the foundation for developing effective marketing strategies to better satisfy market needs.

Table 47. Ratio of crops used for making injera

REGION	Rice	*Teff*	Maize	Finger millet	Others
Amhara	46.1	35.1	10.9	8.4	0.0
SWEP	37.4	48.9	3.3	1.7	9.7
Benishangul	45.8	28.0	19.8	6.4	0.0
Addis Ababa	15.6	77.4	7.1	0.0	0.0
Total	41.6	39.5	11.7	5.7	1.4

Source: Own survey result (2023)

6.3.3.4. Prevalence of imported and locally produced rice in Ethiopia

Urban consumers in Ethiopia perceive locally produced rice to be inferior to imported rice, mainly due to several factors. Firstly, locally produced rice is often found to contain more impurities, higher breakage, and inconsistent grain sizes, which leads to a perception of lower quality. Additionally, the process of cleaning and sorting locally produced rice before milling and cooking is considered time-consuming and labor-intensive, deterring urban consumers from choosing it.

Another issue contributing to the preference for imported rice is its consistent availability in the market throughout the year, unlike locally produced rice, which may not be readily available at all times in some regions. Local rice producers tend to sell their harvest in bulk immediately after the harvest, limiting the year-round availability. Moreover, the lack of branding and diverse packaging options for locally produced rice poses a significant disadvantage. Imported rice offers various types of brands and packaging with different qualities to cater to diverse consumer preferences, enhancing its recognition and appeal in the market (Table 47).

In contrast, local rice lacks a distinct identity or recognizable brand, making it less attractive to consumers. The packaging and branding of rice play a crucial role in marketing and attracting consumers, and in this aspect, locally produced rice falls behind its imported counterparts. As a result, the value and appreciation of local rice among urban consumers remain relatively low. Rice consumption is primarily concentrated in urban areas compared to rural regions, leading to the higher consumption of imported rice in cities and locally produced rice being more prevalent in rural areas near production zones. The disparity in packaging, processing technologies, and branding contributes significantly to the varying consumer preferences between locally produced and imported rice in Ethiopia.

Table 48. Prevalence of imported and locally produced rice in Ethiopia

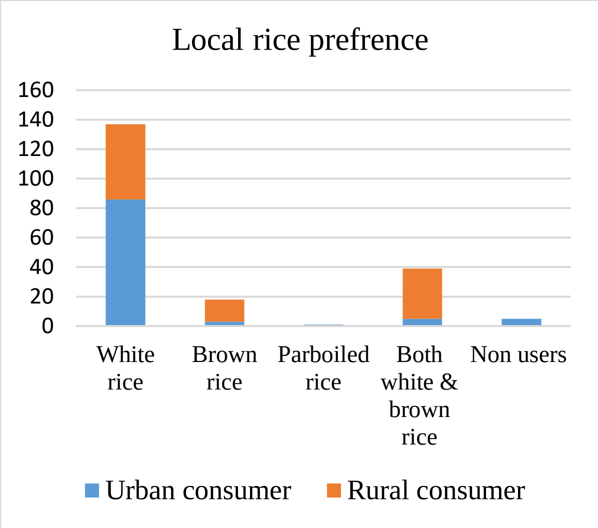
Consumer type	Rice type	Region			
		Amhara	SWEP	Benishangul	Addis Ababa
Urban consumer	Imported	43.2	52.4	36.0	70.6
	Local	54.1	47.6	64.0	29.4
	Indifferent	2.7	0.0	0.0	0.0
Rural consumer	Imported	4.2	0.0	6.3	0.0
	Local	89.6	100.0	62.5	0.0
	Indifferent	6.3	0.0	31.3	0.0
Overall	Imported	21.2	26.8	19.3	70.6
	Local	74.1	73.2	63.2	29.4
	Indifferent	4.7	0.0	17.5	0.0

Source: Own survey result (2023)

6.3.3.5. Rice consumers' affinity for different rice types

Consumers have different preferences and affinity to purchase and consume different rice types, as presented in Figure 16 and 17. Both urban and rural consumers in key rice-producing and consuming areas of Ethiopia exhibit varying affinities towards different rice types, indicating the diverse and nuanced consumer behavior within the rice market. In Figure 16, the local rice preferences of both urban and rural consumers are highlighted. Notably, white rice is the most favored local rice type, with 86% of urban consumers and 51% of rural consumers expressing their preference for it. Brown rice, known for its health benefits, is chosen by a smaller proportion of consumers, accounting for 3% of urban and 15% of rural respondents. Parboiled rice, on the other hand, has limited appeal, with only 1% of urban consumers indicating a preference for it, and none among the rural consumers. One possible reason for this could be that consumers in Ethiopia lack information about parboiled rice. It is interesting to note that 34% of rural consumers and 5% of urban consumers prefer both white rice for table consumption and brown rice for making *injera*. Additionally, a minor percentage of urban consumers (5%) abstain from using local rice in the study area.

Figure 17 highlights the preferences for imported rice types among urban and rural consumers. Among urban consumers, good quality rice stands as the most favored choice, with 35% of respondents selecting it. Basmati rice follows closely behind, being preferred by 27% of urban consumers. Broken rice is also moderately favored, chosen by 6% of urban consumers. It is worth noting that only 11% of rural consumers use imported rice. This could be due to their preference for local rice varieties for injera making and the affordability of local rice as compared to imported rice. On the other hand, 68% of urban consumers prefer to purchase imported rice because of low level of impurities as compared with local rice.



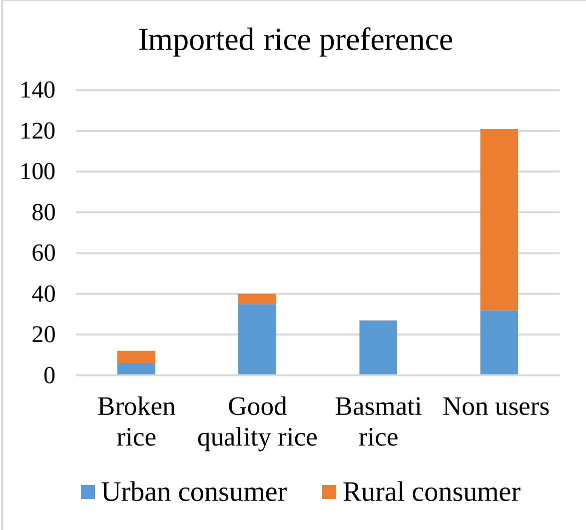


Figure 16. Preference of local rice type

Figure 17. Preference of imported rice type

Source: Own survey result (2023)

6.3.4. Rice quality attribute perceptions of consumers

6.3.4.1. Consumer preferences and ranking of rice quality attributes

Consumers were asked to list the most preferred quality attributes of rice from a set of pre-defined rice quality attributes. A noteworthy observation is that consumers do not uniformly perceive a single quality attribute as completely distinct from other quality attributes. There is a considerable overlap between quality attributes in terms of the features that define it. In most cases, the respondents list five to six quality attributes and ignore others because a single attribute may be considered as a representative of other quality attributes. The quality attributes are ranked based on their perceived importance in influencing rice preferences among consumers. Table 48 presents a comparative analysis of rice quality attributes in different regions, including Amhara, Southwest Ethiopia (SWEP), Benishangul (BG), and Addis Ababa (AA).

Color emerges as the most significant quality attribute, securing the top rank in Amhara, BG, and the overall assessment. This suggests that consumers in these regions highly value the visual appearance of rice when making their purchasing decisions. Marketability (price) is another crucial attribute, achieving the second rank in Amhara, SWEP, and BG. This indicates that consumers across these regions prioritize rice varieties that are highly demanded in the market. Compatibility for making injera, is ranked third in Amhara, SWEP, and BG, indicating its importance in the regions where injera is an essential part of the local food. However, it ranks seventh in AA, suggesting that consumers in the capital city seem to be less concerned with this attribute when selecting rice (Table 48).

Level of impurities is another prominent quality attribute, ranked first in AA, second in BG, and third in SWEP. This implies that consumers in AA and BG prioritize rice with minimal impurities, while SWEP consumers also consider this attribute important but to a slightly lesser extent. Taste, a fundamental aspect of rice quality, receives varied preferences across all consumer groups, with Amhara ranking it fifth and the other groups ranking it lower. The rate of breakage is ranked differently, with SWEP and AA consumers placing it second, while Amhara and BG consumers ranking it sixth and fifth, respectively.

Almost all consumers listed grain size, grain cohesion, aroma, perceived freshness, and compatibility for making local beverages as the least preferred attribute, with a minor difference across regions. Lastly, the origin of rice holds the lowest preference among all consumer groups.

Table 49. Ranks of rice quality attributes

Quality Attributes	Rank				
	Amhara	SWEP	BG	AA	Overall
Color	1	3	1	3	1
Price (marketability)	2	1	3	4	2
Compatibility for making injera	3	4	4	7	3
Level of impurities	4	5	2	1	4
Taste	5	6	6	6	6
Rate of breakage	6	7	5	2	5
Swelling capacity (Flour density)	7	2	8	8	7
Grain shape	8	8	9	5	8
Grain size	9	9	7	10	9
Grain cohesion (sticky nature)	10	11	10	11	10
Texture	11	10	11	9	11
Aroma	12	13	13	13	12
Perceived Freshness	13	12	12	12	13
Compatibility for making local beverages	14	14	15	15	14
Origin of rice	15	15	14	14	15

Source: Own survey result (2023)

6.3.4.2. Understanding consumer priorities: Exploring criteria for rice purchase

Consumer perceptions of rice quality vary depending on the context, and consumers have diverse opinions on what constitutes good quality rice. Various studies, including those by (Bairagi et al., 2021; Custodio et al., 2019; Demont & Ndour, 2015; Sgroi et al., 2022; Tomlins et al., 2005), have highlighted how consumer preferences for grain quality attributes differ based on geographical, social, and economic factors. To cater to this heterogeneity, the rice industry tends to supply a wide range of quality classes, offering rice options that suit different market segments.

To understand consumers' key criteria when purchasing rice, they were asked to prioritize attributes that they considered to be "very important," "important," "Neutral," "Not important," or "Not very important" in terms of rice quality. The bar diagrams illustrate the proportions of consumers who classified each attribute according to its level of importance in their rice buying decisions.

Among the criteria, price, attractiveness, taste, expansion and availability in the market are regarded as significant factors in consumers' decision-making process. Price holds a crucial position for consumers, influencing their choices in rice selection. They prioritize affordable options that fit within their budget. Attractiveness plays a key role, with consumers being drawn to visually appealing rice products. Taste is highly valued, as consumers seek rice that satisfies their palate and culinary preferences. Additionally, expansion, refers to how much the rice increases in volume during cooking. Availability is also another important criterion that consumers consider when purchasing rice (Figure 18). It influences their decision-making process, as consumers tend to prioritize rice that is easily accessible and readily available in the market. They prefer options that are consistently stocked and can be purchased conveniently whenever needed.

In contrast, packaging, flavor, and texture are given less emphasis by consumers when choosing rice. Packaging may not heavily influence their decision, as long as the rice is stored securely and conveniently. Flavor is not a top concern, suggesting that consumers may be more focused on other factors when making their rice selections. Similarly, texture may not be a major consideration, as long as the cooked rice is of acceptable quality. In general, understanding these consumer criteria is vital for the rice industry to meet the diverse demands of their customers. Companies can use this information to develop marketing strategies and product offerings that cater to the specific preferences of their target consumer segments, ultimately enhancing customer satisfaction.

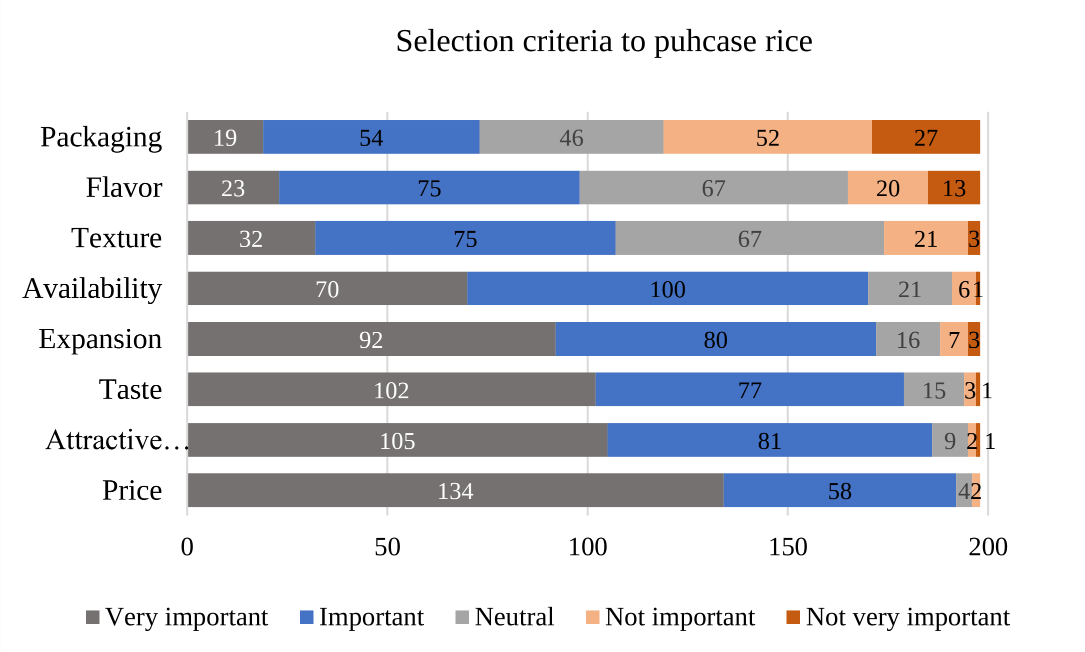


Figure 18. Key selection criteria to purchase rice

6.4. Conclusion and policy recommendation

6.4.1. Conclusion

In conclusion, this study offers a comprehensive insight into the complex landscape of consumer preferences and behaviors within the Ethiopian rice market. The finding highlights the dynamic interplay between consumer preferences, product attributes, and market dynamics in the Ethiopian rice industry, demonstrating their distinct preferences for rice types, consumption habits, and quality attributes. In addition, the per capita rice consumption trend over the last 15 years shows a steady and substantial increase, reflecting changing consumer behavior and preferences. This highlights the significance of understanding the consumption patterns of rice to anticipate future demand and identify opportunities for sustainable growth in the commodity market.

Furthermore, the exploration of quality attributes and purchasing criteria provides valuable guidance for stakeholders in the rice industry. Understanding which attributes are most influential in driving rice preferences enables producers, researchers, and traders to develop strategies that align with consumer demands. In addition, the study identifies critical criteria that guide consumer purchasing decisions, encompassing price, attractiveness, taste, expansion during cooking, and product availability. These criteria underscore the multifaceted nature of consumer behavior and provide valuable guidance for market players seeking to tailor their offerings to consumer demands

Urban consumers predominantly favor imported rice due to perceived higher quality, attractive packaging, and consistent availability. This preference highlights the role of branding, packaging, and year-round supply in influencing urban consumers' choices. In contrast, rural consumers exhibit a stronger affinity for locally produced rice, driven by affordability, compatibility with traditional foods like injera, and trust in local products. These insights emphasize the role of consumer awareness in promoting locally produced rice and reshaping perceptions of its quality and value. This divergence highlights the need for customized marketing approaches that address the distinct preferences of these consumer groups.

6.4.2. Policy recommendations

Policy recommendations emanating from this research carry substantial implications for enhancing the Ethiopian rice market. Diversified marketing strategies that acknowledge the diverse preferences of urban and rural consumers are essential for capturing a larger market share. Efforts to enhance the quality of locally produced rice should be coupled with consumer awareness campaigns to shift perceptions and promote local pride in table rice consumption. In addition, innovative packaging and branding strategies can boost the visibility of local rice in the market and stimulate consumer interest.

Emphasizing sustainable agricultural practices, promoting diversified food sources, and investing in technological advancements to boost production could be crucial steps in mitigating the challenges posed by the increasing demand for rice in the country. Supporting rural producers' access to urban markets can bridge the gap between supply and demand, benefiting both producers and consumers. Encouraging the development of value-added rice products in line with changing consumer lifestyles can also open new avenues for market growth.

The study's findings underscore the need for collaboration among stakeholders, including producers, traders, researchers, and policymakers, to collectively address challenges and harness opportunities in the rice sector. Ultimately, continued research and collaboration among stockholders, and aligning production practices and marketing strategies with consumer preferences are paramount for fostering a resilient and thriving Ethiopian rice market that contributes to food security, economic development, and consumer satisfaction.

CHAPTER SEVEN

7. Summary of the Dissertation

Rice, one of the world's most vital staple crops in the world, plays an increasingly significant role in Ethiopia's agricultural landscape. While Ethiopia has traditionally been known for its diverse range of crops, rice has emerged as a strategic agricultural commodity in recent years. Rice production has gained much attention from policymakers, researchers, and agricultural stakeholders due to its potential to improve food security, reduce reliance on imports, and alleviate poverty. Rice holds immense significance in Ethiopia and its importance cannot be overstated. As the country strives to meet the food demands of its growing population, the cultivation and consumption of rice have witnessed a remarkable surge. This shift in dietary preferences and production patterns has prompted an exploration of improved rice technologies, commercialization strategies, and consumer behaviors, making it a subject of extensive research and analysis.

This dissertation presents seven chapters. The first chapter addresses the general introduction of the research, statement of the research problem, the research questions, objectives, scope, and limitations of the study. Chapter Two discusses the overview of rice in Ethiopia, concepts and definitions, and the nexus of improved rice technology adoption, commercialization, and consumption in Ethiopia's rice sector. Chapters Three to Six present four empirical studies on the analysis of the adoption of improved rice technologies and practices, the impact of adopting improved rice varieties, rice commercialization, and rice consumers preferences and behaviors in Ethiopia, individual papers with abstract, background, methodology, results, conclusions and policy recommendations. The final chapter summarizes the findings and implications of these chapters to the main discussion point, followed by a concise description of the main conclusions. Subsequently, it draws recommendations for policy and future research work.

Firstly, the adoption of improved rice technologies and practices among smallholder farmers in Ethiopia is examined. The study found that various factors influence adoption rates, with improved rice varieties, row planting, recommended rate of UREA fertilizer, recommended rate of DAP fertilizer, and weeding frequency being adopted at varying levels. Importantly, the research underscores that these technologies are complementary, and policies that promote one can have a positive effect on the adoption of others. This highlights the need for easier access to improved seeds, fertilizers, and labor-saving technologies to boost overall adoption and contribute to self-sufficiency.

Secondly, the impact of adopting improved rice varieties on yield, income, commercialization, and poverty reduction is evaluated. The study reveals that adopting improved rice varieties significantly increases yield, income, and commercialization, contributing to poverty reduction among smallholder farmers in Ethiopia. One of the most significant findings is the substantial increase in rice productivity among adopters, with yields approximately 0.564 tons per hectare higher than non-adopters. This surge in productivity underscores the tangible benefits of these improved varieties, which exhibit superior growth characteristics. Furthermore, improved rice variety adoption leads to increased engagement in rice commercialization, as evidenced by the Rice Commercialization Index (RCI) showing an increase of around 0.04 for adopters compared to non-adopters. This dual impact on production and income generation is pivotal for food security and economic well-being. The most striking outcome of the research is the remarkable poverty reduction associated with adopting improved rice varieties. Among adopters, the Multidimensional Poverty Index (MPI) decreases by about 1.7%, reflecting improvements across various dimensions of poverty. Subjective poverty among adopters also drops significantly by 12.4%, indicating an enhanced quality of life and improved economic status. These findings emphasize the importance of government collaboration with development partners to facilitate access to improved rice varieties, positioning adoption as a key strategy for enhancing productivity, reducing poverty, and achieving self-sufficiency.

Thirdly, the study examines rice commercialization among smallholder farmers in Ethiopia, focusing on the factors influencing it. The descriptive findings reveal that a significant portion of smallholder farmers engage in semi-commercial rice production, with 31% categorized as subsistence producers, 40% as semi-commercial, and 29% as commercially oriented. Rice has emerged as a pivotal market-oriented crop in Ethiopia, with 87% of households participating in rice marketing and dedicating approximately 57% of cultivated land to rice production. This suggests substantial potential for further commercialization in the rice sector, highlighting the need for the implementation of productivity-enhancing technologies and agricultural mechanization to enable smallholder farmers to produce a marketable surplus. Promoting rice commercialization not only benefits farmers but also has a multiplier effect throughout the rice value chain, stimulating job creation and income distribution among rural and urban communities.

Lastly, the study explores consumer preferences and behaviors rice market, shedding light on the evolving dynamics of rice consumption and demand. It reveals that per capita rice consumption has steadily risen in Ethiopia over the past 15 years. This growth underscores the influence of various factors on consumer choices, including socioeconomic factors, affordability, perceived quality, convenience, cultural compatibility, and more. The research identifies distinct patterns in rice preferences, consumption habits, and quality attribute perceptions among urban and rural consumers. Urban consumers tend to favor imported rice due to perceived quality and attractive packaging, while rural consumers opt for locally produced rice because of its affordability and compatibility with traditional dishes. Quality attributes such as color, price, impurity levels, and breakage play significant roles in shaping consumer preferences, with variations across regions.

The study's findings highlight the potential for promoting agricultural technology adoption among smallholder farmers by emphasizing the complementarity among various improved rice technologies. Policies affecting one technology are likely to influence others, suggesting that these technologies should be promoted as a comprehensive package. Additionally, institutional and economic factors, such as input prices and accessibility, play a crucial role in technology adoption. Therefore, governmental and developmental partners need to support the affordability and accessibility of improved rice technology packages.

In addition, interventions to enhance the adoption of rice varieties should target farmers' access to information, market, extension services, and other inputs, which enhances farmers' willingness to use improved rice varieties. It could also be necessary to develop appropriate linkages of research institutions with farmers, and extension service agents. In addition, demonstrating and scaling out of the improved rice technologies through field days and demonstration sites are also important avenues to show the effectiveness of improved rice varieties to farmers and enhance their adoption. Furthermore, the national rice research program should also work on the development of varieties that can meet the preferences of farmers. Furthermore, improving the rice seed system across regional states (availability, accessibility, and affordability of seeds) could enhance the uptake of improved rice variety and leads to higher welfare impacts. Therefore, governmental and developmental partners should devote more attention to the provision of an enabling environment for the adoption of improved varieties to ensure a positive change in the livelihood of rice farm households. Gains at the household level are expected to contribute to the wider economy in the form of tax and employment opportunities in the long run.

To further enhance rice commercialization in the study area, it is crucial to place a special focus on the adoption of productivity-enhancing technologies, the development of irrigation facilities, strengthening social institutions, and facilitating access to credit-providing institutions. Given the limitations of available agricultural land, intensified farming through promoting improved rice technologies and mechanized farming, should be actively pursued to boost rice productivity and maximize commercialization. Moreover, access to rice marketing demands road and marketing infrastructure to mobilize agricultural resources and products. The government, development organizations, and farmers' cooperatives have to invest resources to facilitate the equitable access of producers to market. This could increase the bargaining power of producers and reduce transaction costs, further incentivizing rice commercialization.

Based on the research findings, several policy recommendations can enhance the Ethiopian rice market. First, diversified marketing strategies should be developed to cater to the diverse preferences of urban and rural consumers, acknowledging their distinct choices. Second, efforts should be made to enhance the quality of locally produced rice while conducting consumer awareness campaigns to change perceptions and promote local rice consumption. Third, innovative packaging and branding strategies should be employed to increase the visibility of local rice in the market and stimulate consumer interest. Fourth, emphasis should be placed on sustainable agricultural practices and investment in technological advancements to boost rice production and address rising demand. Fifth, supporting rural producers in accessing urban markets can bridge the supply-demand gap, benefiting both producers and consumers. Sixth, the development of value-added rice products that align with changing consumer lifestyles and preferences should be encouraged. Lastly, fostering collaboration among various stakeholders, including producers, traders, researchers, and policymakers, is essential to collectively address challenges and seize opportunities in the rice sector.

In conclusion, collaboration among various stakeholders, including producers, traders, researchers, and policymakers, is essential to address challenges and leverage opportunities in the rice sector. Continued research and alignment of production practices and marketing strategies with consumer preferences are crucial for building a resilient and thriving Ethiopian rice production and market that contributes to food security, economic development, and consumer satisfaction.

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9. Appendices

9.1. Appendix 1. Conversion factors used to compute Tropical Livestock Units (TLU)

Appendix Table 50. Conversion factors used to compute Tropical Livestock Units (TLU)

Animal Category	TLU-equivalent
Calf	0.25
Heifer or Bull	0.75
Cows or Oxen	1.00
Donkey (young)	0.35
Donkey (adult)	0.70
Sheep or Goat (adult)	0.13
Sheep or Goat (young)	0.06
Horse or Mule	1.10
Chicken	0.013

Source: Storck *et al*. (1991)

9.2. Appendix 2. Multicollinearity test results of MVP model variables

Appendix Table 51. VIF and Conditional number index for MVP model variables

	Certified seed		**Row Planting**		**Recom URA**		**Recom DAP**		**Recom Weeding**	
	Eigen value	Cond Index	Eigen value	Cond Index	Eigen Value	Cond Index	Eigen value	Cond Index	Eigen value	Cond Index
1	12.666	1.000	12.660	1.000	12.775	1.000	12.809	1.000	12.891	1.000
2	0.843	3.876	0.831	3.903	0.831	3.922	0.858	3.863	0.831	3.940
3	0.823	3.922	0.800	3.977	0.771	4.071	0.761	4.103	0.767	4.100
4	0.752	4.105	0.747	4.118	0.758	4.105	0.739	4.164	0.734	4.192
5	0.700	4.255	0.718	4.200	0.683	4.325	0.601	4.616	0.622	4.555
6	0.563	4.743	0.566	4.729	0.561	4.772	0.567	4.753	0.565	4.776
7	0.504	5.016	0.528	4.895	0.493	5.089	0.509	5.016	0.494	5.107
8	0.405	5.595	0.404	5.599	0.388	5.737	0.412	5.577	0.363	5.957
9	0.309	6.404	0.311	6.385	0.311	6.407	0.311	6.417	0.308	6.469
10	0.278	6.751	0.279	6.736	0.275	6.822	0.277	6.801	0.272	6.884
11	0.259	6.997	0.259	6.993	0.259	7.029	0.259	7.034	0.259	7.058
12	0.193	8.093	0.193	8.100	0.193	8.142	0.193	8.140	0.192	8.192
13	0.177	8.462	0.176	8.475	0.175	8.545	0.176	8.540	0.176	8.561
14	0.153	9.106	0.152	9.123	0.153	9.142	0.151	9.208	0.153	9.189
15	0.121	10.230	0.120	10.266	0.121	10.279	0.122	10.254	0.120	10.353
16	0.106	10.922	0.106	10.914	0.105	11.043	0.105	11.027	0.104	11.130
17	0.071	13.396	0.071	13.368	0.071	13.433	0.071	13.442	0.071	13.488
18	0.064	14.034	0.064	14.035	0.064	14.105	0.064	14.102	0.064	14.154
19	0.015	28.921	0.015	28.632	0.014	29.752	0.015	28.813	0.014	29.875
Condition Number		28.921	28.6317		29.7523		28.8129		29.8752	
t(correlation matrix)		0.1887	0.1945		0.1887		0.1949		0.1930	

Mean VIF = 1.19

9.3. Appendix 3. Marginal effect on the adoption of improved rice technologies

Appendix Table 52. Marginal effects on the adoption of improved rice technologies (unconditional marginal effects, calculated at the mean)

Explanatory variables	Improved seed	Row Planting	Recom Urea	Recom DAP	Recom Weeding
Sex of HH	0.055	-0.004	0.184**	-0.092	0.098
	(0.074)	(0.078)	(0.075)	(0.097)	(0.091)
Age of HH	-0.002	0.003	-0.002	0.003	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Rice Experience	0.004	0.002	0.003	-0.004	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Household size	-0.015	-0.013	-0.007	-0.002	0.028*
	(0.012)	(0.011)	(0.014)	(0.013)	(0.014)
Education	0.031***	0.017	0.022	-0.003	0.026*
	(0.012)	(0.011)	(0.015)	(0.014)	(0.016)
Received Credit	-0.002	0.025	-0.094	-0.07	-0.055
	(0.046)	(0.048)	(0.057)	(0.055)	(0.06)
Irrigation Access	-0.022	-0.007	0	0.026	-0.115**
	(0.043)	(0.042)	(0.05)	(0.05)	(0.051)
Asset Comp	0.085	0.053	-0.056	0.049	-0.047
	(0.046)	(0.049)	(0.058)	(0.057)	(0.059)
Extension Contact	0.003*	0.002	-0.002	0.003	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Off farm	0.004	0.078	-0.019	-0.124**	0.032
	(0.044)	(0.052)	(0.055)	(0.052)	(0.061)
Rice Area	-0.186	-0.369***	-0.429***	-0.395***	-0.158
	(0.119)	(0.111)	(0.146)	(0.14)	(0.144)
Plot distance	-0.026**	0.008	-0.012	0.036***	0
	(0.013)	(0.012)	(0.014)	(0.014)	(0.014)
Soil fertility	0.004	-0.068**	-0.033	0.052	-0.056
	(0.036)	(0.034)	(0.042)	(0.04)	(0.044)
Last year Rice	-0.027	0.063	-0.118**	0.106*	0.047
	(0.045)	(0.052)	(0.06)	(0.057)	(0.062)
Livestock Ownership	0.051*	0.01	0.044	0.039	-0.029
	(0.031)	(0.028)	(0.04)	(0.035)	(0.036)
Cultivated land	-0.045	0.021	-0.190***	0.045	-0.223***
	(0.044)	(0.042)	(0.05)	(0.047)	(0.046)
Social Capital	0.126	0.229***	-0.139	0.288**	0.06
	(0.096)	(0.089)	(0.119)	(0.119)	(0.123)
Market distance	0	0	0	0	0
Cooperative Membership	0.022	-0.066	0.034	0.01	0.016
	(0.044)	(0.043)	(0.055)	(0.052)	(0.053)

Note: Figures in parenthesis are standard errors
*** Significant at 1%, ** Significant at 5%, * Significant at 10%

Appendix Table 53. Conditional marginal effects, calculated at the mean assuming that all other dependent variables are zero

Variables	Certified Seed	Row Planting	Urea Recommendation	DAP Recommendation	Weeding Recommendation
Gender (male)	0.015 (0.038)	-0.001 (0.04)	0.131*** (0.051)	-0.112 (0.088)	0.077 (0.084)
Age (years)	-0.001 (0.001)	0.001 (0.001)	-0.002 (0.002)	0.003 (0.002)	-0.004 (0.002)
Rice experience	0.002 (0.002)	0.001 (0.002)	0.002 (0.003)	-0.004 (0.003)	0 (0.004)
Family size (number)	-0.008 (0.006)	-0.006 (0.006)	-0.006 (0.011)	0 (0.011)	0.031** (0.014)
Education	0.012** (0.006)	0.006 (0.006)	0.012 (0.011)	-0.01 (0.011)	0.02 (0.015)
Credit Received	0.006 (0.024)	0.023 (0.026)	-0.061 (0.044)	-0.046 (0.042)	-0.04 (0.058)
Irrigation Access	-0.005 (0.022)	-0.002 (0.021)	0.011 (0.039)	0.03 (0.04)	-0.113** (0.049)
Asset Comp	0.045* (0.023)	0.018 (0.025)	-0.057 (0.047)	0.04 (0.044)	-0.055 (0.059)
Extension contact	0.002* (0.001)	0 (0.001)	-0.002 (0.002)	0.002 (0.002)	-0.001 (0.002)
Non-Off farm	-0.004 (0.022)	0.057* (0.034)	-0.006 (0.044)	-0.109*** (0.038)	0.04 (0.062)
Rice Area	-0.031 (0.062)	-0.136** (0.069)	-0.257** (0.122)	-0.194 (0.121)	-0.043 (0.147)
Plot distance	-0.014** (0.007)	0.003 (0.006)	-0.012 (0.011)	0.03*** (0.011)	0.001 (0.014)
Soil fertility	0.012 (0.018)	-0.039** (0.019)	-0.027 (0.033)	0.062* (0.032)	-0.054 (0.044)
Crop rotation	-0.015 (0.022)	0.025 (0.029)	-0.109** (0.045)	0.089* (0.05)	0.053 (0.062)
Livestock ownership	0.025 (0.016)	-0.002 (0.014)	0.028 (0.03)	0.026 (0.029)	-0.042 (0.034)
Cultivated land	-0.002 (0.024)	0.017 (0.022)	-0.132*** (0.044)	0.071* (0.039)	-0.2*** (0.048)
Social capital	0.05 (0.05)	0.084*(0.049)	-0.172* (0.096)	0.208** (0.097)	0.032 (0.122)
Rice ecosystem	-0.038 (0.031)	0.064*** (0.024)	-0.071 (0.045)	0.022 (0.04)	-0.082 (0.056)
Market distance	0(0)	0(0)	0(0)	0(0)	0(0)
Cooperative membership	0.014 (0.022)	-0.038 (0.024)	0.023 (0.043)	0.015 (0.042)	0.012 (0.052)

Note: Figures in parenthesis are standard errors
*** Significant at 1%, ** Significant at 5%, * Significant at 10%

Appendix Table 54. Conditional marginal effects, calculated at the mean assuming that all other dependent variables are one

Variables	Certified Seed	Row planting	Urea Recommendation	DAP Recommendation	Weeding Recommendation
Gender (male)	0.042	-0.014	0.2*	-0.108	0.053
	(0.144)	(0.13)	(0.115)	(0.069)	(0.077)
Age (years)	-0.004	0.005	-0.002	0.003	-0.003
	(0.004)	(0.003)	(0.002)	(0.002)	(0.002)
Rice experience	0.005	0.002	0.002	-0.005	0
	(0.005)	(0.006)	(0.004)	(0.004)	(0.003)
Family size	-0.02	-0.015	-0.004	0.003	0.026**
(number)	(0.019)	(0.018)	(0.013)	(0.013)	(0.011)
Education	0.034*	0.013	0.01	-0.014	0.012
	(0.018)	(0.017)	(0.014)	(0.014)	(0.013)
Credit Received	0.009	0.065	-0.079	-0.062	-0.032
	(0.073)	(0.07)	(0.063)	(0.055)	(0.048)
Irrigation	-0.018	-0.005	0.012	0.032	-0.088**
Access	(0.07)	(0.068)	(0.046)	(0.046)	(0.042)
Asset Comp	0.128*	0.034	-0.082	0.037	-0.052
	(0.077)	(0.08)	(0.054)	(0.053)	(0.045)
Extension	0.004*	0.001	-0.003	0.002	-0.001
contact	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Non/Off farm	-0.03	0.156**	-0.001	-0.161***	0.029
	(0.07)	(0.073)	(0.055)	(0.062)	(0.046)
Rice Area	-0.02	-0.399**	-0.283*	-0.153	-0.011
	(0.182)	(0.187)	(0.152)	(0.156)	(0.12)
Plot distance	-0.043**	0.016	-0.01	0.032**	0.003
	(0.02)	(0.02)	(0.013)	(0.013)	(0.011)
Soil fertility	0.054	-0.129**	-0.036	0.086**	-0.04
	(0.058)	(0.058)	(0.04)	(0.038)	(0.036)
Crop rotation	-0.054	0.081	-0.133**	0.088*	0.043
	(0.072)	(0.079)	(0.064)	(0.052)	(0.047)
Livestock	0.073	-0.019	0.024	0.028	-0.038
ownership	(0.046)	(0.045)	(0.036)	(0.035)	(0.027)
Cultivated land	-0.019	0.051	-0.16***	0.073	-0.152***
	(0.072)	(0.068)	(0.055)	(0.048)	(0.044)
Social capital	0.113	0.232	-0.222**	0.199*	0.008
	(0.151)	(0.145)	(0.113)	(0.12)	(0.098)
Rice ecosystem	-0.145	0.214***	-0.076	-0.002	-0.06
	(0.097)	(0.074)	(0.056)	(0.048)	(0.048)
Market distance	-0.001	-0.001	0	0	0
	(0.001)	(0.001)	(0)	(0)	(0)
Cooperative	0.059	-0.123**	0.024	0.032	0.009
membership	(0.069)	(0.069)	(0.053)	(0.05)	(0.041)

Note: Figures in parenthesis are standard errors
*** Significant at 1%, ** Significant at 5%, * Significant at 10%

9.4. Appendix 4. Bibliographic details of published articles

1. **Abebaw Assaye**, Endeshaw Habte, and Seiichi Sakurai. Adoption of improved rice technologies in major rice producing areas of Ethiopia: a multivariate probit approach. *Agriculture & Food Security*, volume 12(9), pp.1–19, April 2023. https://doi.org/10.1186/s40066-023-00412-w

2. **Abebaw Assaye**, Endeshaw Habte, Seiichi Sakurai, and Dawit Alemu. Impact assessment of adopting improved rice variety on farm household welfare in Ethiopia Federal Democratic Republic of Ethiopia. *Journal of Agriculture and Food Research*, Volum 10, pp 1-12, December 2022. https://doi.org/10.1016/j.jafr.2022.100428

3. **Abebaw Assaye**, Seiichi Sakurai, and Dawit Alemu. Commercialization of smallholder rice producers and its determinants in Ethiopia. The 6th International Rice Congress, Manila, Philippines. Oral presentation number 244 (IRC2023), October 2023

9.5. Appendix 5. Data collection sheet (questionnaire used)

Chiba University, Graduate School of Horticulture

Food and Resource Economics

Rice Consumers' Household Sample Survey Questionnaire

On

Rice production, marketing and food security in Major Rice Producing Areas of the Country

CONSENT STATEMENT

Introductory statement:

Hello, my name is ____________________. I have been assigned by Mr. Abebaw Assaye to collect research data for his PhD thesis research. He is a Ph.D. student at Chiba University, Japan. The aim of this research is to study the impact of rice marketing and technology adoption on the welfare and food security of the farmers in Ethiopia. I would like to ask you some questions related to general characteristics of your household, resource ownership, rice production, marketing, consumption, and your household food security situation. This interview will take approximately 15 minutes. Your response to these questions will remain anonymous. Taking part in this study is voluntary. If you choose not to take part, you have the right not to participate and there will be no consequences. All information provided by you will be kept confidential. Your privacy will be protected to the maximum extent allowable by law. We will not share information that identifies you with anyone. After entering the questionnaire into a database, we will destroy all information such as your name which will link these responses to you.

If you have any questions, you can contact:
Name: Abebaw Assaye, mobile: +251912383203/+819097944328. E-mail: abebawal@gmail.com
May I continue to ask you some questions? 1. Yes, 2. No
By continuing this interview, you indicate your willingness to voluntarily participate in the study
Thank you for your kind cooperation

PART A: HOUSEHOLD AND VILLAGE IDENTIFICATION

VILLAGE IDENTIFICATION	7. Kebele____________ village_______
1. Region	8. Date of interview (dd/mm/yyyy):
2. Zone	**9.** Time started (24 HR)
3. District (Woreda)	**GPS reading of homestead**
4. City	**10.** Latitude (North)
5. Sub city	**11.** Longitude (East)
6. Name of data Enumerator	12. Altitude (meter a.s.l)
HOUSEHOLD IDENTIFICATION	
1. Name of household head	

2. Sex of household head 1. Male 2. Female
3. Age of the household head
4. Education level of the household head in years of schooling 0. Illiterate, 1. Read and write, 2-21 year of formal education (put actual year of schooling
5. Marital status 1. Single 2. Married 3. Divorced 4. Widow 5. Separated
6. Primary occupation of household head 1. Farming 2. Civil service 3. Trading 4. Artisanship (hand craft) 5. Other specify
7. Annual average income in birr ________________
8. Household size
9. How long you lived as a household in years

PART B: CONSUMERS' CHARACTERISTICS

10. Do you consume rice? 1. Yes 2. No
11. Do you eat rice as part of your diet? 1. Yes 2. No
12. How often do you eat rice? 1. Every day, 2. 4-5 times a week (often), 3. 2-3 times a week, 4. Once in a week 5. 1-3 times a month, 6. Few days in a year 7. Never eat
13. At what part of the meal do you prefer to consume rice? 1. Breakfast 2. Lunch 3. Dinner 4. All (in the form of injera)
14. Where do you eat rice usually? 1. Home, 2. Restaurants, 3. Party (social events) 4. All 5. Others
15. For how many years do you consume rice? In years
16. What type of rice do you usually eat? 1. Local, 2. Imported, 3. All
17. How do you consume/cook rice? 1. In the form of injera, 2. As table rice, 3. Bread, 4. Porridge, 5. As table rice & in the form of injera, 6. Injera, table rice & bread 7. All
18. Which rice do you prefer to consume from local rice? 1. White rice (polished), 2. Brown rice (husk removed), 3. Parboiled rice (with bran), 4. Parboiled rice (without bran) 5. White rice for table rice and brown rice for injera
19. Which rice do you prefer to consume from imported rice? 1. Broken rice 2. Good quality rice 3. Basmati rice 4. NA
20. Have you ever cooked rice in your house to eat as table rice? 1. Yes, 2.No
21. Have you cooked rice in your house to eat as table rice at least once a week? 1. Yes, 2.No
22. If "you have never cooked table rice" Why is your reason? 1. I don't know how to cook 2. I don't have rice cooking material 3. Not easy to cook rice 4. I don't like to eat rice as table rice, 5. Others 6. NA
23. If you consume rice in the form of injera, what was the ratio of rice in the mix? (%)

______%Rice, _______%of Tef, ______% Maize, ______%Finger millet, ____%others
24. Who in the household prefers to eat rice most? 1. Head, 2. Spouse, kids, 4. Other 5. ALL
25. From whom you learned rice cooking and eating? 1. Family, 2. Friends, 3. Media, 4. extension, 5. Schools

PART C: RICE CONSUMPTION AND MARKETING PRACTICES

1. How often do you buy rice in a year?
2. How much rice do you buy per year?
3. How much do you pay for 1kg of rice?_________ Local, __________ Imported
4. Which rice is more expensive? 1 imported rice 2. Local rice 3. NA (DK)
5. Which rice do you prefer to buy most? 1. Imported 2. locally produced
6. If you prefer imported, why do you prefer imported? 1. Always available in the market 2. Affordable price 3. Good quality 4.others 5. NA
7. If you prefer local, why do you prefer local rice? 1. Always available in the market 2. Affordable price 3. Good quality 4.others 5. NA
8. From whom do you buy rice mostly? 1. Millers 2. Wholesalers 3. Processors 4. Farmers 5. Retailers 6 Supermarkets 6. NA
9. From whom do you buy imported rice mostly? 1. Millers 2. Wholesalers 3. Retailers 4. Supermarkets 5. Imported 6. NA
10. Do you have a particular customer/retailer you buy rice from? 1. Yes 2. No
11. Are locally branded rice available in shops near your residence? 1. Yes 2. No
12. Would you increase your consumption if your income increases? 1.Yes, 2. No.
13. Perception in trends of rice consumption in the last 5 years. 1. Increasing, 2.constant 3. Decreasing 4. NA
14. What was the reason for the change in consumption?

PART D: ACCEPTABILITY & PERCEPTION OF RICE.

To what extent do you consider the following as constraints to local rice consumption?

Note: 1. Not very important, 2. Not important, 3. Neutral, 4. Important, & 5. Very important

1. Packaging	
2. Texture	
3. Attractiveness	

4. Flavor	
5. Taste	
6. Availability	
7. Price	
8. Expansion	

PART E: RICE PREFERENCE

How would you rank these rice quality attributes in order of importance to you (1=Most important; 14=least

Physical Attributes	**Scale** (1= most important, 15= least)	**More preferred**
1. Color		White, brown
2. Grain shape		Long & slim, long & fat, average, short
3. Level of impurities		Very few, few, average
4. Rate of breakage		Very low, low, average
5. Price		Cheap, average, expensive
6. Grain cohesion (sticky nature)		Very sticky, sticky, average
7. Compatibility for making injera (Softness)		Very good, good, average
8. Grain size		Very long, long, average
9. Swelling capacity (Flour density (wuha yenesal))		High, medium, low
10. Compatibility for making local beverage		Very good, good, average
11. Taste		Very good, good, average, poor
12. Aroma		Very good, good, average, no aroma
13. Texture		Very tender, tender, average, hard
14. Perceived Freshness		
15. Origin of rice		Fogera, Chewaka, Pawe, Guraferda, Gambela, Imported

PART F: CONSUMER PERCEPTION ON LOCAL RICE

How do you perceive local rice base on the following statement?

Quality Attributes	**Responses** Strongly disagree=1, Disagree=2, Neutral=3, Agree=4, Strongly Agree=5
1. Rate of consuming local rice is more than production	
2. Local rice consumption is on decreasing rate	
3. Local rice processing is of low quality	
4. Government needs to pay more attention to local rice production.	
5. There is a lack of proper awareness in society about rice consumption	
6. Future of local rice consumption is really a matter of concern	
7. Rice importation should be banned for the growth of local rice	
8. Government's present policy will increase local rice consumption	
9. It is easy to get local rice in the market	
10. Local rice is cheaper than imported	
11. It tastes better than imported rice	
12. I prefer local rice due to compatibility for making injera	
13. locally produced rice are not as good as imported products	
14. Imported rice has always better quality	

The End