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Adoption of Common Bean Technologies and its Impacts on Productivity and Household Welfare in Ethiopia: Lessons from Tropical Legumes Project

Research Report No. 130



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Adoption of Common Bean Technologies and Its Impacts on Productivity and Household Welfare in Ethiopia: Lessons from Tropical Legumes Project

Research Report No. 130

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Preface

Following a decade long joint engagement between the Ethiopian Institute of Agricultural Research (EIAR) and the International Center for Tropical Agriculture (CIAT) through Tropical Legumes (TL) I and II project, this study was initiated to assess the contribution of the intervention in the areas where common bean is an important commodity. The project was primarily aimed at developing improved bean varieties and complementary management practices and avail to users through different mechanisms. It supported the seed system to ensure faster and wider diffusion of the new improved bean varieties to farmers. While the project was mainly implemented in Oromia and Southern Nations Nationalities and People Regional (SNNPR) States, the technology and knowledge spill-over is expected to reach all common bean production areas in the country. Accordingly, the study has a national scope and representative samples were drawn from all common bean production areas in Ethiopia.

This report presents adoption patterns of common bean varieties with associated technologies and the resultant effects on productivity and household well-being. In a bid to identify the key variables that govern the use of the technologies promoted by the project, on the one hand, and to examine the impact of the technologies adopted on the livelihood and productivity of bean farmers, on the other, appropriate statistical and econometric techniques were employed. The findings and the conclusions drawn thereof are assumed to represent features of common bean growers in the country. The recommendations are of paramount importance in informing the breeding program and seed system of common bean in the country.

The most important aspect of this study is the fact that we have augmented DNA analysis based estimate of adoption besides farmer recall based adoption estimates. The wedge between these two estimates and the implication for future adoption and impact studies are also elaborated.

We are hopeful that the report is of benefit to the national agricultural research system in general and the common bean research program in Ethiopia, in particular. Besides, the lessons drawn from the study would inform actors in the agricultural development domain including those operating in the seed system and policy makers to enhance their engagement in the promotion and use of new technologies in a more productive ways. Ultimately, the common bean farm households would reap the benefit of informed investment by concerned actors.

Authors

Foreword

The Ethiopian Institute of Agricultural Research (EIAR) is committed to making available technically efficient, economically feasible and environmentally safe improved agricultural technologies, which if appropriately disseminated, can transform the Ethiopian agriculture. It has been active in the sector as an important source of a range of technologies including crop, livestock and natural resources. As a strong partner to local and international organizations, EIAR is striving to deliver its mission while building the capacity required attaining its vision.

As one of the most important legume crops addressed by nationally coordinated research program, common bean has enjoyed a successful technology development, promotion as well as productive partnership with international partners like International Center for Tropical Agriculture (CIAT) and the Pan African Bean Research Alliance (PABRA). The crop is grown by more than 3 million smallholders on more than 290,000ha and accounts for about 3% of the land planted to grain crops.

Since 1970s the EIAR in collaboration with CIAT and PABRA has developed and released over 60 common bean varieties in Ethiopia. Joint projects like the Tropical Legume (TL I and II) have been instrumental both in the development as well as promotion of these varieties through interventions directed towards improving the common bean breeding and seed system. Generally, the national common bean subsector in Ethiopia has undergone continuous and spectacular growth since the economic liberalization took place in early 1990s. Bean yields grew at an average rate of 6% per year between 2006 and 2016. The volume of export has also grown by more than threefold over the same period.

This report examines the adoption and diffusion of common bean technologies across major production areas in the country. It has highlighted important issues that need to be addressed both by the research as well as the seed system actors. Low varietal turnover rate, estimated at 19 years, longer lag between varietal release and

awareness/adoption surfaced in the report as serious impediments for adoption. This calls for interventions to increase availability of new varieties within the informal seed systems- popularly used by farmers- if the return to investment on technology development and seed system has to be realized quickly. While the limitation of farmers to properly identify improved varieties (sometimes confusing it with local ones) remains a challenge, the use of DNA fingerprinting to rectify this constraint and accurately estimate adoption as well as impact of the technology is a step in the right direction. The institute, together with its partners, will do whatever is possible for the institutionalization of this approach.

The EIAR appreciates the joint efforts made with the counterparts in CIAT in planning, implementing and producing this research report. We will take the necessary steps to make sure that the recommendation from this study are well communicated and properly utilized.

Feto Esimo (PhD)
Director General

Executive Summary

Common bean improvement research in Ethiopia is aimed at increasing the productivity of smallholder farms for enhanced food security and higher household incomes. In 2007, the National Bean Research Program of the EIAR and the International Center for Tropical Agriculture (CIAT) intensified the efforts to improve bean productivity under the auspices of the Tropical legumes (TL II & III) project led by ICRISAT and financially supported by the Bill and Melinda Gates foundation. This study assessed the adoption and impact of improved common bean varieties and their associated management practices promoted under the Tropical Legumes Project. The study, along the traditional recall-based survey, applied DNA finger printing (FP) technique to reliably measure the adoption of varieties and its impact on bean productivity and subsequent impacts on household economic well-being measured by household food consumption score, daily dietary diversity score and per capita annual consumption expenditure.

Data used were collected using a survey of a nationally representative sample of 1122 bean growing households in 2016 by the Ethiopian Institute of Agricultural Research (EIAR) in collaboration with the CIAT currently in Alliance with Biodiversity International. The study findings demonstrate that improved common bean varieties are widely grown by farmers and a higher proportion of adopters accessed these varieties during the period of the project. Approximately 65% of the area allocated to beans is planted with improved varieties, grown by 57% of the farms while 42% of the households apply inorganic fertilizers in bean production.

The adoption of improved common bean technologies has contributed immensely to productivity growth with the highest gains occurring when varieties are adopted simultaneously with fertilizers suggesting a decision to bundle the varieties with good agricultural practices (fertilizer, in this case) has significant benefits to adopting farming families. Consequently, adopting households have increased their food consumption, dietary diversity and per capita consumption expenditure.

A shift of one hectare of land from landraces to improved bean varieties is found to increase per capita annual consumption expenditure by 23%, from the average of 6674 Ethiopian Birr (ETB) (about 318USD in 2016 exchange rate). Furthermore, if improved varieties are combined with fertilizers per capita annual consumption would be raised by 37% attesting to the complementary nature of the technology bundles. The study also revealed that households adopting common bean varieties have not only enjoyed higher consumption expenditure but also increased the proportion of their income allocated to non-food expenditures. About 54% of the households sell all their harvested beans and use the income from sales for purchasing nonfood household consumable items.

The findings from the study have important implications for future research and development efforts on common bean. The varietal turnover rate is still low, estimated at 19 years indicating improved varieties take long to get to the farming communities. It takes a respective 21 and 23 years for about 50% of the farmers to be aware and start to cultivate a new improved variety. This is one of the serious concerns that call for innovations to increase availability of new varieties within informal seed systems- popularly used by farmers- if the return to investment on common bean technology development and seed system has to be realized in a shorter period. The project promoted community-based seed multiplications but the marketing of such seed remained dependent on institutional (NGOs, GOs, community organizations) buyers who collect the seed and redistribute to other farmers. As seed production involve more cost than grain production, connectivity with larger market (common bean producers) will be an incentive for the seed producers. The two aspects highlight a disconnection between actors (i.e., those who multiply seed as a business (communities, in this case) and those who distribute seed to grain producers (institutional buyers) as a business) within informal seed system. If the connection between the actors is improved, it presents an opportunity to potentially accelerate varietal turn over. Thus, interventions within the informal seed systems should aim at establishing and maintaining the networks of actors including via digital solutions to enhance awareness of the varieties and existing demand on both ends. Besides, we found that farmers who access improved

varieties from informal sources are less likely to correctly identify the name of the variety they grow. This means that farmers who actively search for improved varieties from their informal sources may unintentionally choose old or landraces due to lack of proper labeling of such varieties in the local markets. This can be addressed by building the capacity of the actors in informal seed systems in such a way that they can easily identify varieties with proper names and market it as such. It also requires an effort on the part of the research and extension both in the naming (branding) and promoting of new varieties in ways simple-to-remember by the farming community.

1. Introduction

Common bean ¹(*Phaseolus vulgaris* L.) in Ethiopia is an important foreign exchange earner and constitutes one of the most important food legumes produced in the country. The crop contributes the highest share of export earnings from all pulses and close to ten per cent of total agricultural export value (FAOSTAT, 2010). It is also an important source of protein for small farmers in many lowland and mid-altitude areas of Ethiopia. The crop is also highly preferred by farmers mainly because it matures early enough to generate cash income needed to relax the liquidity constraints when most other crops are still in the field (Legesse et al. 2006).

Common beans are grown by close to 4 million smallholders on more than 290,000 ha and accounts for about 3% of all land planted to grain crops. It is mainly produced in Oromia and Southern Nations, Nationalities and People's Regional States (SNNP), which accounts for 41% and 33% of the national crop area respectively. Lately, the Amhara Regional State with a share of 23% has become an important producer of common bean (CSA, 2016). This growth in production is driven by the emergence of Farmer Cooperative Unions (FCU) in the regional state, which is actively engaged in common bean export. The production in Oromia Regional State is dominated by white pea canning bean types that are grown for export market while other bean types are grown in the rest of the regional states—used primarily for domestic consumption. In terms of growth habits, two common bean types are grown: bush type (determinate or semi-determinate) and climbing type (indeterminate). Bush bean types are concentrated in the central and southern parts of the country while climbers² are cultivated in the north-west (Metekel) and western parts of the country (Wollega).

¹ In this report common bean is interchangeably used with the term beans as well as haricot bean. They all refer to the same crop- common bean

² These are commonly planted along fences and on the borders of maize fields (Zelalem, 2002 in Kefyalew 1990)

The genesis of common bean production in Ethiopia is believed to have its roots in the coming of the Portuguese in 16th Century (IRMU, 1985 in Kefyalew, 1990). It started as a subsistence crop and received no formal coordinated research until early 1970s³ when the Melkassa Agricultural Research Center (MARC) (Demelash, 2018; Rubyogo et al., 2011) initiated systematic germplasm selection to replace low yielding, and pest and disease susceptible genotypes with better ones. A number of bean germplasms were evaluated for better adaptability and higher productivity. However, in the two decades that followed, the growth of research on common bean was constrained by state grain control and quota systems⁴ that eroded the farmers' interest in new technologies and good agronomic practices. Later in the early 1990s, after the introduction of several policy reforms⁵, the bean research portfolio was expanded to address the production challenges of pests, diseases; prolonged drought and low soil fertility stemming from soil degradation (Gebre-Madhin, 2001).

In 1996, the Ethiopian Institute of Agricultural Research (EIAR) joined other African National Agricultural Research Institutes (NARIs) and International Agriculture Research Organizations (IAROs) to form the Pan-Africa Bean Research Alliance (PABRA), coordinated by the International Center for Tropical Agriculture (CIAT). PABRA is a collaborative network of researchers, public and private-sector partners (Buruchara et al., 2011) supported by various donors, notably Government Agency of Canada (GAC), formerly the Canadian International Development Agency (CIDA), and the Swiss Agency for Development and Corporation (SDC). The goal of this collaborative

³ During this time, the revolutionary government took over from the imperial regime, adopted socialistic policies and introduced several policy reforms (Ayele Haile, 1990) that created an enabling environment for a coordinated research.

⁴These distorted the market-constraining the adoption of modern technologies that resulted in decline of yields for most crops including common bean.

⁵ In early 1990s, the Ethiopian government lifted the restrictions on official pricing and quotas (Gebre-Madhin, 2001) and implemented reforms of improving the licensing procedure, establishing and/or improving organizations linked to exports, such as the Ethiopian Export Promotion Agency and Ethiopian Standard and Quality Authority (Dawit and Demelash, 2003). These reforms paved way for private trade that raised farm gate prices and market incentives for farmers to invest in good management practices.

network is to strengthen the capacity of National Bean Research systems to address constraints that affect the bean subsector in sub-Saharan African countries.

The last two decades of PABRA have marked a historical revolution for breeding, release and dissemination of improved bean varieties in sub-Saharan Africa. To date, over 60 bean varieties have been released in Ethiopia. Of these, 36 varieties are lines from or crosses with the CIAT materials (PABRA database, 2014). These varieties differ in traits and geographical adaptability that reflects the dynamic evolution of bean breeding strategies in response to the changes in the production environment. Nine high-yielding varieties of common bean released in the first years of PABRA (i.e., 1990s - early 2000s) are generally resistant to a single constraint and were adapted to all bean growing areas in the country. Enhanced capacity for breeding within NARS and CIAT in terms of human resources and technology enabled a paradigm shift in the breeding strategy from a monolithic approach in 1990s to respond to multiple constraints and dynamic preferences of the market (<https://www.pabra-africa.org/breeding>). Such changes in capacity and approach culminated in the release of varieties that are resistant to multiple constraints, while maintaining market desired traits. These varieties constitute 66 percent of the varieties released since 1970s (Appendix A.1).

The national common bean subsector in Ethiopia has undergone continuous and spectacular growth since the last market reforms in early 1990s. FAO (2017) reported an average yield growth of 6% per annum between 2006 and 2016, surpassing the average growth rate for the East Africa region (4%) and the global average of 1.7% per year over the same period (Figure 1). The volume of export has also grown meaningfully increasing by more than threefold (from 53,810 metric tons to 192,990 metric tons) over the same period (CSA 2016).

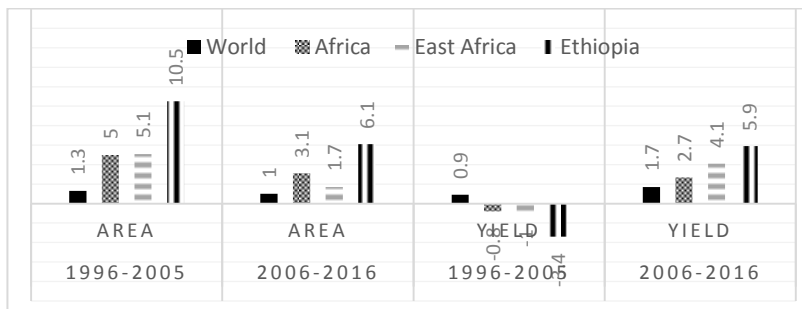


Figure 1.1 Average common bean annual growth rate between 1996 and 2017
(Computed from FAO data accessed in 2019).

The concerted intervention in bean research and development in the country led by the Melkassa Agricultural Research Center (MARC) of the EIAR, CIAT-PABRA and other partners have undoubtedly contributed to the subsector growth. In 2003, CIAT in collaboration with MARC, spearheaded research to develop functional informal decentralized seed systems and strengthen the linkage between the formal and informal seed systems (Teshale et al, 2006; Rubyogo et al, 2010). From this research, a framework for wider dissemination of improved common bean varieties was developed and scaled out between 2007 and 2016 under the Tropical Legumes (TL) II and III project (Kidane et al. 2015; Endeshaw et al. 2012)⁶. The goal of the TL project was to improve the productivity of legumes (common bean, cowpea, chickpea, groundnut and pigeon pea) in sub-Saharan Africa and South East Asia. The project was implemented by scientists from the National Agricultural Research Institutions of eight countries⁷ in

⁶ Partners, on-farm trials/demonstrations, cooperative, NGOs, community based seed producers, field days—have been employed to ensure wide dissemination of new varieties. Additional promotional tools used have included training and printed materials (posters, leaflets, production and post-harvest manual, mass media (radio and TV) (Rubyogo et al., 2011; Endeshaw et al. 2009a; Endeshaw et al. 2009b; Endeshaw et al. 2007; Teshale et al., 2006) and small packs. The introduction of small packs in common bean seed distribution was an innovative feature of the TL II beans project. Seed packs of 0.05 kg, 0.1 kg, 0.25kg, 0.5kg, 1kg, 2kg, and 5kg were used to create demand for new varieties popular (commercial) varieties, while pack size of 5kg, 12.5kg and 25kg were considered to provide access to improved bean seed by farmers with different purchasing power.

⁷ Countries were: Niger, Nigeria, BurkinaFaso, Ghana, Mali, Uganda, Ethiopia and Tanzania

collaboration with three CGIAR centers (International Crop Research in semi-Arid Tropics (ICRISAT), International Institute for Tropical Agriculture (IITA) and International Center for Tropical Agriculture (CIAT) with funding from the Bill and Melinda Gates Foundation (BMFG) via ICRISAT. A key feature of the interventions in the seed systems under the Tropical Legumes project was the aggressive partnerships that aimed at reaching all categories of users via multiple delivery channels (Figure 1.2).

Seed of improved variety was bundled with information on recommended management practices, notably fertilizer use and timely weeding, as a technological package (i.e., improved varieties, fertilizers and optimal weeding) had been aggressively promoted to farmers. Although, the crop management practices were not new, their use by farmers had significantly reduced during government controlled marketing regime. Immediately after market reforms, use of these management techniques/inputs remained low likely because time elapsed and farmers needed sometime to implement them and their profitability was perceived as uncertain. It was, therefore, critical to build the capacity of farmers through on-farm evaluation of fertilizer application rates, demonstrations and farmer field days. These efforts had been instrumental in unlocking the information and seed supply constraints to unleash wider access of improved varieties among small common bean farmers.

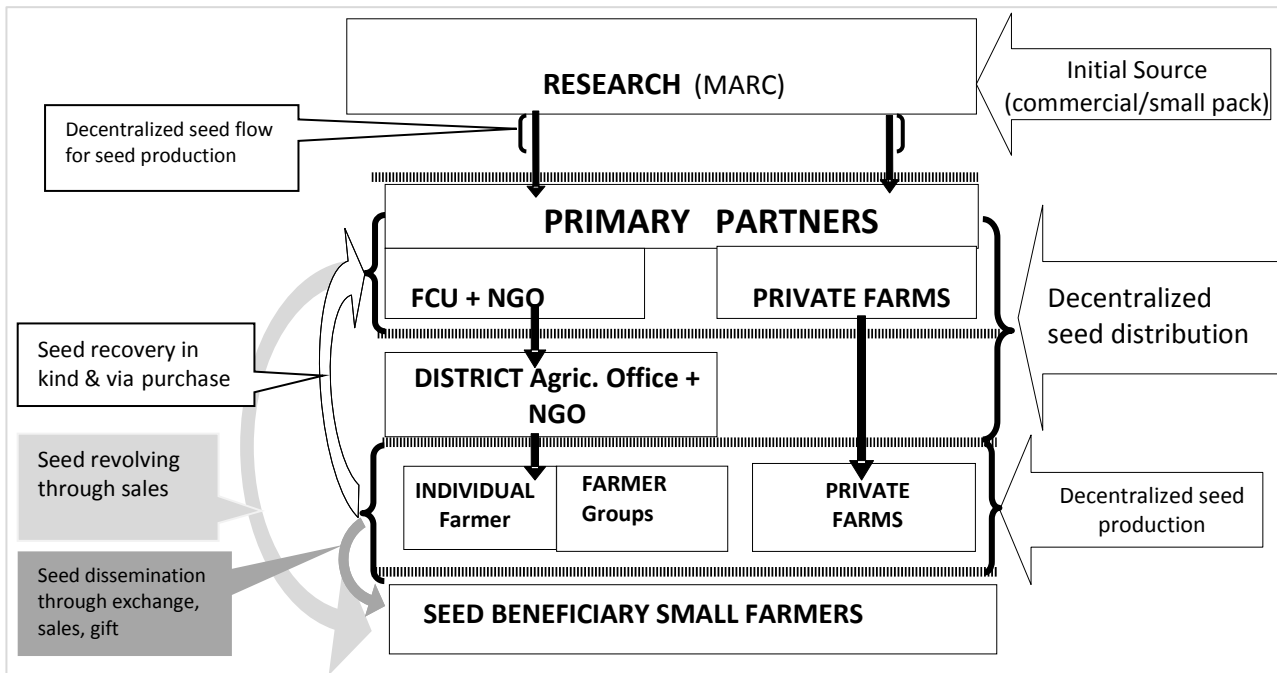


Figure 1.2 Seed delivery scheme
 (Source: Endeshaw *et al.*, 2012)

Development actors contend that the positive changes in production and productivity of the bean are partly attributed to the interventions in breeding, technology dissemination and farmer capacity development in key producing areas under the Tropical Legumes project. Nonetheless, this needs to be empirically supported, which this study attempts to do guided by the following objectives:

- 1) Examine varietal diffusion pathways and inclusivity,
- 2) Measure adoption of new varieties based on DNA fingerprinting methods and explain adoption and use of complementary management practices,
- 3) Estimate bean productivity gains resulting from adoption of improved technology and
- 4) Assess impacts on household economic well-being, measured by food security and aggregate per capita consumption expenditure.

The remaining part of report is structured into five sections. . The section that follows presents an overview of the survey design, implementation and challenges. Section three provides a comprehensive description of the survey results as an attempt to provide general understanding of the bean-growing households in Ethiopia and give insights into the immediate outcomes of the TL project interventions in the country. It also describes the main characteristics of bean growing households in terms of bean production systems, access and utilization of improved bean technologies promoted by the project.

Section four details the adoption of improved bean technologies at farm household and national levels. It also examines the adoption pathways, varietal diffusion, behavioral aspects associated with uptake of particular technology while paying attention to the gender dimensions. The impacts of improved technology adoption on bean productivity, which was the goal of the project and subsequent influence on household welfare is provided in section five. Section 6, provides a summary of the main findings and outlines the main take away from the study.

2. Study Design and Implementation

2.1 Sampling methodology

The study used primary data collected from a nationally representative sample of common bean growers. Considering the geographical administrative boundaries, convenience for survey administration and available data, three stages stratified probability proportional to size (PPS) sampling design was used to draw samples from each stratum. The strata included the four major common bean producing regions of the country, namely, Oromia, SNNPR, Amhara and Benishangul-Gumuz Region States (Table 2.1) which account for about 98 % of the national area under common bean in 2016 production season. The sampling procedure involved identifying major growing regions followed by a compilation of bean growing districts based on 2002/03 agricultural census report (which was the most recent agricultural census with bean production measured at districts (Weredas) level. Accordingly, a total of 275 common bean producing districts were identified and used as a sampling frame for the first stage sampling (Table 2.1).

Table 2.1 Number of common bean producing districts and area (ha) by region

Regional States	Area in hectare	Number of districts
Oromia	61,721	135
SNNPR	26,165	77
Amhara	17,607	44
Benishangul Gumuz (BNSG)	3,703	19
Total	109,196	275

In the second stage, the number of common bean producing households (sample size) required to get a nationally representative adoption estimates was determined using the following formula.

$$n = Dff * \left(\frac{(Z_{\alpha/2})^2 \sigma^2}{E^2} \right) + 0.1 * Dff * \left(\frac{(Z_{\alpha/2})^2 \sigma^2}{E^2} \right) \approx 1087 \dots\dots (1)$$

Where, Dff = Design effect = 1.5

E = Tolerable margin of error = 0.035

α = the maximum level of type-I error for the adoption estimate to be produced =0.05

σ^2 (Variability) = $p*(1-p)$ =0.21 (where p is common bean adoption rate=0.30)

$Z_{\alpha/2}$ =2, the Z – score corresponding to the desired level of significance (CI=95%)

The estimated sample size of 1087 was allocated proportionally to each of the four strata based on common bean area reported in the agricultural census for 2002/03 cropping year⁸ (Table 2.2).

Table 2.2 Stratum sample size, number of sample Kebeles and Weredas per stratum

Regional State	Common bean area (ha)	Stratum Household sample size (TSU)*	Number of sample kebeles (SSU)*	Number of sample districts (PSU)*
Oromia	61,721	599	50	17
SNNPR	26,165	253	21	7
Amhara	17,607	199	17	6
Benishangul Gumuz (BNSG)	3,703	36	3	1
Total	109,196	1087	91	31

*TSU=Tertiary Sampling Unit; SSU=Secondary Sampling Unit; PSU= Primary Sampling Unit

The next stage was to determine the number of households per kebele (n), which was computed using the following formula:

$$n = ((Z_{\alpha} + Z_{\beta}) / (0.5 + \ln(1 + ICC / (1 - ICC))))^2 \approx 12 \dots\dots (2)$$

Where, the standard normal deviate for $\alpha = Z_{\alpha} = 0.05$ and the standard normal deviate for $\beta = Z_{\beta} = 0.84$ and ICC is the inter correlation coefficient between kebeles estimated to be 0.254973 based on Equation 3.

⁸ This was the most recent bean area data disaggregated by district (wereda) used to constitute a sampling frame

$$ICC = \frac{MSB - MSW}{MSB + (\bar{n} - 1)MSW} = \frac{0.2098579 - 0.0344339}{0.2098579 + 14 * 0.0344339} = 0.254973 \dots\dots (3)$$

Where MSB and MSW are the between and within kebele mean squares of common bean area estimated using one way ANOVA model and \bar{n} is the average number of sample households per *kebele* estimated using the following formula:

$$\bar{n} = \frac{1}{n - 1} \left(\sum_{i=1}^n n_i - \frac{\sum_{i=1}^n n_i^2}{\sum_{i=1}^n n_i} \right) = \frac{1}{394} \left(722 - \frac{379481}{7855} \right) \approx 15 \dots (4)$$

The total number of kebeles to be sampled were determined by dividing the total sample size of households by the number of households sampled per kebele. The number of kebeles per stratum (n) is calculated by dividing the stratum sample size by 12 (number of households per

kebele). That is, $n = \frac{n_i}{12}$, where n_i is the number of total sample households

in stratum i . Based on convenience and logistical considerations, it was decided to limit the number of kebeles per district to three. Therefore, the number of sample districts in each stratum was determined by dividing the total number of sample kebeles by 3. However, we had more districts in the actual sample than indicated in the sampling plan for the mere reason that some districts had been restructured into two or more districts. In such districts, the number of kebeles per district was proportionally reallocated to fit the new administrative arrangement. Accordingly, the total number of sampled kebeles and households exceeded the initially determined size (91 and 1087, respectively) (see Annex 2.1). Nonetheless, we stuck to the 31 districts sampled when computing respective sampling weight. Any district, which was later divided into two or more is taken as one (the division is disregarded) and the same sampling weight is applied. Sampling weights attached to each one of the districts are indicated in Table A2.2 in the appendix.

2.2 Sample selection

Districts included in the survey were selected from a list of districts in each stratum obtained from the last national agricultural census report of 2002/2003. The second (*kebele*) and the third (household) stage sampling were conducted while in the field when the survey team visited the sampled districts and *kebeles* for the actual field work. Survey supervisors visited the district offices and acquired a list of all *kebeles*, from which a simple random sampling technique was used for selecting *kebeles* for the survey after excluding non-bean producing *kebeles*. Respondent households were then selected from a village list of households using a random start and then selecting the n^{th} household on the list systematically in the same order. The final sample distribution for the survey (after including few more households for contingency) is indicated in Figure 2.1.

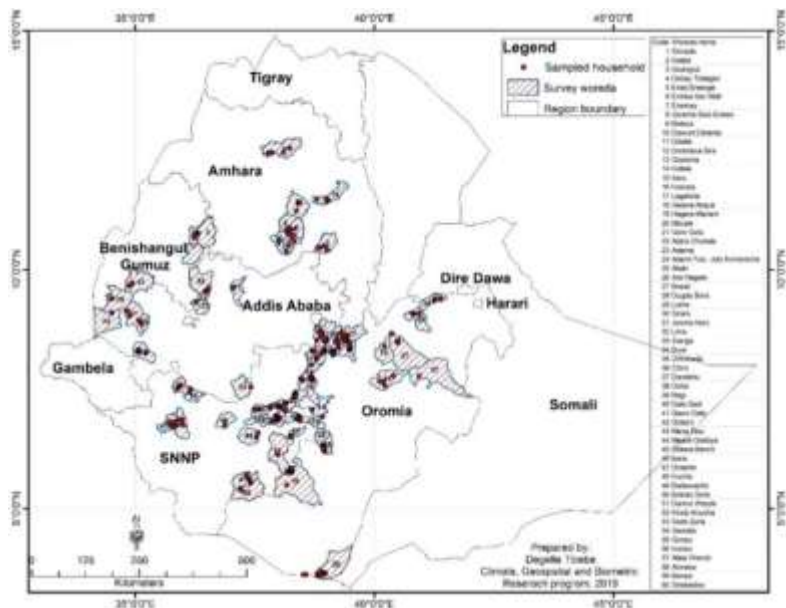


Figure 2.1 Geographical distribution of sample households selected for the national survey

2.3 Data collection and entry

In this study, data were collected at three levels: community (*kebele*), household and plot level. Community level data were collected using interviews with key informants involving *kebele* extension workers, model farmers and chairperson of the *kebele*. Interviews with the household heads provided data at household and plot level. In the event of missing household heads due mainly to extended absence for various personal and economic reasons, another senior member of the household knowledgeable about the household farming (production) activities was interviewed. In the extreme cases where it was difficult to get an appropriate household member to provide information, the household was replaced by another household living in the same *kebele* from the reserve list of sampled households.

At all levels, data were collected through direct interviews conducted by experienced enumerators and supervisors who attended a five-day training on survey instruments loaded on tablets with ODK application. CIAT provided technical support in setting up the questionnaire on the tablets and trained the survey team on the use of the ODK application and their operation. The instrument was uploaded to a remote server and the data collected using computer assisted personal interviewing method. The data were then subjected to rigorous inspection and cleaning (detecting and correcting for outliers, replacing or removing missing data) to ensure consistency and prepare it for analysis. The data thus collected was uploaded to a central place (drive) each day in real time. The process of data collection and data uploading was monitored by the principal investigator with support from CIAT technical personnel who had access to the central database.

The data collection took place from April to June 2017 immediately after the completion of the main cropping season (*Meher*) of 2016. Information from various sources indicates that the *Meher* season contributes about two-thirds of the national total bean production per year. The residences of all interviewed households and the community centers where the community key informant interview took place were geo-referenced. Every enumerator was expected to complete two household interviews a day. This was determined based on the

experience on average completion time during pre-testing of the data collection instrument. It was also determined in view of minimizing enumerators' fatigue which may lead to poor data quality.

Detailed household and plot level data were collected using a pretested questionnaire designed to elicit information relating to household and farm characteristics. At household level, data included socioeconomic; demographic characteristics; assets and social capital; consumption expenditure (last seven days food expenditure; 30 days as well as 12 months non-food expenditure); and other household welfare indicator variables for food and nutrition security; poverty scorecard and dietary diversity score. Farm characteristics included plot characteristics; sources of common bean seeds; common bean varieties cultivated; varietal attribute preferences; access to agricultural inputs and services; crops produced by the household and inputs use; total grain production from each plot; crop income among others. Sex disaggregated data were collected on the access and control of household resources, viz., plots, credits, income from bean outputs.

2.4. Variety identification and sample collection

Among others, identifying the bean varieties grown by sample farmers on each plot of the sampled farms and collecting seed samples of these varieties were important task of the data collection activity. Seed samples were the bases for identifying the varieties using the DNA fingerprinting technique. In an attempt to facilitate varietal identification, a list of all released/registered varieties was compiled from the PABRA database, later validated by the scientists in the National Lowland Pulses Research Program at Melkassa Agricultural Research Center (MARC) of Ethiopia and coded into the questionnaire. During the interviews, each household was asked to enlist all common bean varieties that he/she cultivated on each common bean plot during the study season (i.e., *meher* 2016 cropping season). Data on important phenotypical characteristics such as the colour and type of the variety were also collected to assist varietal identification and classification. As part of the data collection process, a handful of seed samples of various bean varieties grown on each plot were collected, labelled by a

unique identification number⁹ generated automatically from the household and plot identification numbers by the ODK application and then sealed for safe transportation. The same identification (ID) number served as matching ID between the DNA analysis (genotyping) results with farmer reports from the survey data. The seed samples collected from households were then transferred and stored at the National Lowland Pulse Research Program at Melkassa research center where a corresponding laboratory ID (label) for each variety was generated. Seed samples were shipped (by common bean breeders at Melkassa) to CIAT for DNA analysis following appropriate protocols. The reference library for all released varieties was established based on the breeder seed samples maintained by the national common bean research program in Ethiopia.

2.5 Definitions of endogenous variables

As a first step in the data analysis, key study parameters such as adoption of improved technologies, productivity and welfare indicators thereof that need to be explained in this work were identified by the investigators and presented in subsequent sections.

2.5.1 Measurement of varietal adoption and management practices

In this study, a household is defined as an adopter of improved common bean variety if he/she reported to have planted any improved common bean variety during the 2016 cropping season released on and after 1990. Similarly, adoption intensity is defined as the proportion of common bean area planted to improved common bean varieties during the study year. Defining adoption of management practices, however, is found to be challenging for the fact that farmers often modify the agronomic techniques upon application. For instance, researchers in the common bean program recommend twice weeding to keep the crop free of weeds up to flowering stage as an optimum weed management strategy. Also, row planting with a spacing of 40 cm x 10 cm involving a seed rate of 80-100 kg/ha, depending on the seed size is another

⁹ Enumerators recorded the seed sample identification number on a sticker, which they posted on the plastic seed sample bag.

management recommendation that farmers need to follow for optimum bean yield. In view of the aforementioned recommendations, a household was considered as an adopter of recommended management practice if he/she used either row planting, irrespective of the spacing size, or fertilizer or both. Therefore, in evaluating the impacts of the project, the study focused on technological package that consists of improved varieties and management inputs/practices and defined adoption as a multi-valued ordered variable that take on values from zero for none adoption and three for full adoption of the package. It is common for farmers to apply a new technology on part of their land allocated to common bean and manage the other part with traditional technology. To account for partial adoption, we collected data on adoption variables at a plot level and disaggregated seed planted by variety.

2.5.2. Measurement of productivity

Estimating productivity involves a careful measurement of output per unit area. In this study, for estimating productivity, we used both farmer reports of area cultivated and quantity of seed planted on each plot as a proxy for area. The total harvest per plot was calculated as sum of dry grain harvest and fresh green pod harvest (in dry equivalent) both estimated in kilograms. An additional question was also posed to further examine the robustness of productivity estimates by asking farmers to provide her/his rational estimate of total expected production from the bean variety if he/she grew it on a quarter of a hectare.

2.5.3 Welfare indicators

Various indicators are often used to measure economic well-being. In this study economic well-being is estimated by the food and nutrition security measured by food consumption score and, daily dietary diversity while poverty was represented by per capita consumption expenditure and poverty score index. Details of the welfare measurements are given below.

2.5.3.1 Food and nutrition security

As noted by Coates et al. (2003) food security is multidimensional in nature calling for complementary indicators for its understanding. In

this study, three indicators are used to measure food security including food consumption score (FCS), household dietary diversity score (HDDS) & minimum dietary diversity and food expenditure. Food consumption score is a composite score used as a proxy for caloric intake and captures diet diversity of food groups included within a diet. It was computed based on eight broad food groups consumed in 7 days prior to the interview: 1) starch (tubers and cereals), 2) vegetables (dark green, leafy and other vegetables), 3) fruits, 4) meat (eggs, fish, fresh and organ meat), 5) legumes, 6) dairy (milk and its products), 7) oil and 8) sugar. The number of days each food group is consumed is weighted by nutritional indices¹⁰ following the Food and Nutrition Technical Assistance (FANTA) approach (Kennedy, et al.2010) and aggregated into one index, with expected maximum score of 112 if a household consumed all these food groups daily in the last 7 days. The FCS indicates the status of a household's food consumption as poor food consumption if it is between 0 and 21, borderline food consumption if its FCS is between 21.5 and 35, and acceptable food consumption if FCS > 35.

Similarly, the HDDS was used as a measure of household's access to a variety of food types. It is also a proxy for nutrient adequacy of the diet taken. It was computed based on a 24-hour recall period (Swindale & Bilinsky, 2007) with 7-16 food groups examined. It is worthy to note that HDDS takes on different names depending on the target; individuals (IDDS), household (HDDS), or women (MDDS_W). We used the MDDS_W' (FAO and USAID, 2016)¹¹ calculated based on Guidelines by FANTA for measuring micronutrient adequacy.

2.5.3.2 Per capita consumption expenditure

Per capita consumption expenditure is commonly used for determining household wellbeing because in a developing country context, it reflects the actual consumption and hence a more reliable estimate of household

¹⁰ starches multiplied by 2, vegetables by 1, fruits by 1, meats by 4, legumes by 3, milk by 4, oils by 0.5 and sugar by 0.5.

¹¹ the Food and Agriculture Organization of the United Nations and USAID's Food and Nutrition Technical Assistance III Project (FANTA), managed by FHI 360, Rome, 2016

well-being than income, which is prone to measurement error and respondent bias (Deaton, 1997). Besides, empirical studies have repeatedly shown that a significant percentage of households, particularly those in low-income groups, actually spend more than they earn suggesting consumption expenditures may be financed from sources other than household income. In an attempt to capture this contention, we used a 7-day recall period for household food expenditure, and a 30-day recall period for frequently purchased consumable items or services/ non-durable goods while a 12-month recall period for durable items and transfer payments spent by the household. All the consumption expenditures were converted into total annual consumption levels and standardized by the adult equivalent of the household to get per capita consumption expenditure. The food expenditure data consisted; i) quantity of food bought (or expenditures) and costs associated with different foods consumed within and outside the house; ii) foods received by any household member as either a gift or as payment for work, goods or services; iii) foods produced by household members (Pérez-Escamilla and Segall-Corrêa, 2008)¹². In an attempt to account for spatial differences in prices, the expenditure is

divided by the Paasche index P_p^h computed as $P_p^h = \sum w_k^h \left(\frac{P_k^o}{P_k^h} \right)$

where P_k^h is the price for good k faced by household, while P_k^o is the price in reference community. All prices were obtained from a community questionnaire on selected food items.

2.5.3.3. Poverty score card

The poverty score index is an indirect measure of poverty used to estimate a household’s economic level with known accuracy based on verifiable data that is quick and inexpensive to collect. Following Schreiner and Chen (2009), we calculated poverty scores by

¹² This method estimates calories consumed on average per household member per day, making it essential to have access to culturally appropriate and valid food composition tables.

aggregating responses from a number of questions on household characteristics including household size, whether all children (6-12 years) go to school, dwelling rooms in the house, materials used for wall construction, type of toilets, source of cooking fuel, ownership of mattress or bed, ownership of radio, watches, cattle, sheep, goats or jewelry. Poverty score lies between 0 and 100, higher scores indicating a better off household.

2.6. Data analysis

Various statistical tools were used to describe and summarize the data. Besides descriptive techniques such as measures of central tendency and dispersion (mean, median, standard deviations) frequency tables, percentages, as well as graphs such as pie-charts and bar graphs are used to pictorially present data. Inferential statistical techniques such as t-test, one-way analysis of variance (ANOVA), Bonferroni tests, chi-square-test and others measures of association were also employed to analyze the data. In all instances, STATA 14 statistical packages was used for data analysis. Also, several econometric models aimed at explaining the adoption behavior of sample farm household and the impact of adoption on the selected welfare indicators are used to identify the drivers of adoption as well as the welfare gains from the use of modern common bean technologies. Details of the empirical models are provided in the sections where they are used.

3. Results and Discussion

3.1 Descriptive Results: Profile of bean-growing sample households

3.1.1 Socio-demographic characteristics

Descriptive statistics on household demographic characteristics, land tenure systems and household assets including agricultural equipment, crops and livestock are reported in Tables A3.1, A.3.2 and A.3.3 in appendix. Generally, common bean-growing households in Ethiopia have families headed by middle-aged individuals, with low levels of formal education and literacy (Table A.3.1). Majority of the household

heads are male (92%) living with spouses and children in a household of about six people. Bean-growing households in the Amhara Regional States are relatively smaller and headed by slightly older individuals with fewer years of formal education. And yet, the regional state has the highest percentage of household heads who could read and write compared to Oromia and SNNP regional states. While the mean and median years of household education level is about three, with significant difference between regional states, households from SNNP and Amhara had relatively highest and lowest years of education, respectively.

3.1.2 Social capital and access to credit

Households have connections to various types of social groups, including farmer research groups, saving and credit associations, farmers' union, women association and communal labor groups. In the order of descending importance, households are often connected to each other through burial groups, 1-to-5 farmer group (a group of five farmers), local administration, communal labor groups, input supply cooperatives, savings and credit groups (Table A3.1). Farmer research groups are the least prominent group in terms of household membership. Generally, burial groups are informal groups, common in all settings in Ethiopia which are tasked with providing funeral and other related services in the event of death to the member as well as his/her family members. It is a strong social group that connects many households. A 1-to-5 farmer group, on the other hand, is an arrangement facilitated and nurtured by the government. It involves a group of five farmers who allegedly discuss about farming and other local issues. Since 1-to-5 farmer group is a government initiated, membership may not be necessarily determined on voluntary basis.

Very few common bean-growing households demand for credit with 18%, 8% and 3% seeking credit for purchasing fertilizer, seed and agricultural equipment, respectively. Among those who sought credit, the majority obtained for fertilizer (80%), while less than 3% obtained it for agricultural equipment (Table A3.1).

3.1.3 Household sources of income

Households combine agricultural and non-agricultural income generating activities to sustain their livelihoods. Approximately 60% of the households earn income from non-agricultural activities. Non-agricultural salaried employment was the least important occupation, as it serves only 5% of the households while 11% of the households earn from providing non-agricultural casual labor. Other non-farm income sources used to augment farming income to cope with shocks such as climate change (Ford et al., 2006) are land rent, land sharing out, machine service provision, milling, housing rentals and sell of other non-agricultural assets. Income from non-agricultural assets was available to 28.2% of the households, earning on the average 5,664 Ethiopian Bir (ETB) per year (Table 3.1). Income transfers from other households are accessed in the form of cash (8%) and safety nets (14%).

Table 3.1 Non-agricultural incomes sources (endogenous and exogenous incomes)

Income source	Average income earned by those who used the source (in ETB)		Percentage of households earning from the income sources
	Mean	Std. Dev.	
Cash transfer	1,809.7	5,928.76	8.02
Non-food transfer	609.88	1884.031	2.23
Animal transport rental income	3,887.50	2,496.90	1.43
Land income	4,217.86	4,240.98	2.50
Pension	2,516	2,413.86	0.45
Non- Agricultural assets	9,467.14	18,187.51	4.99
Casual labour non-agricultural	4,359.88	4316.45	11.05
Salary	14,927.23	14,450.84	4.63
Machine service	6,500.00	6,128.62	0.36
Safety net	4,569.76	4,561.57	13.99
Shared out land	4, 975	769.25	4.55
Investments (e.g milling, house rent)	8,747.23	9,168.90	5.79
All non-agric. incomes	5,548.93	6,212.31	59.99

As in many parts of rural Ethiopia, agriculture is the main source of livelihood in the study area employing about 97% of common bean-growing households (Table A3.1). Nearly a quarter of the households earn income from sale of grain and/or livestock, earning on the average 12,422 ETB (~USD 564.9 based on the exchange rate in 2016), making these households the highest earners from agriculture. Food transfers from relatives and government is the second most popular income source (Table 3.2), but its contribution in terms of value was minimal, being ETB 255 (USD 11.6) per year per household among those who reported it. A few households supply casual labor to other people's farms while a few others earn from selling tree products and fruits.

Table 3.2 Agricultural annual incomes earned by households and sources

Income source	Average income earned by those who used the source		
	Mean (ETB)	Std. Dev.	% of households earning this income
Food transfer/ Gifts from Individuals/ Friends/Relatives /government	255.95	926.04	16.49
Agricultural tool income	142.50	300.70	0.27
Agricultural sale (Livestock & grain)	12,422	26,203.25	22.64
Charcoal	3,410.69	3,850.63	6.51
Casual labour agriculture	2,334.57	2,544.46	7.84
Tree sales	1,944.68	1,391.02	3.30
Fruit tree income	1,680.22	1,515.58	5.97
Pooled	4,313.38	4,006.93	2.00

Note: At the time of data collection, in 2016, 1US\$=21.99 ETB)

3.1.4 Crop and livestock production

Major agricultural crops cultivated in *meher* season of 2016/17 included cereals, notably, maize, wheat, tef and sorghum; and legumes mainly common beans (Table A3.2a). Maize is the major cereal crop cultivated in the study area accounting for 24%, followed by tef (17%) and beans 16%. Although cereals appear to be important across regional states, maize dominates in Oromia and SNNRP regional states while tef is more important in the Amhara regional state. Households in SNNRP and BNSG appear to grow more diverse crops compared to the other two regions with about 50% and 57% of the total cultivated area, respectively, covered by the major crops. However, disregarding the

area share and considering the number of plots cultivated, bean could be considered as the dominant crop occupying 26 percent of the total plots followed by maize and tef (Table A3.2a).

We tried to examine the crop choice within households and the result is summarized in Table A3.2b. From the total sample households 92% were male headed (Table A3.1) and almost all were married. For seventy-two percent of the male headed households crop cultivation decisions (pertaining to what crops to grow on a given household plot) are made jointly by heads with their spouses. From the remaining 28% male headed households, about 2% were unmarried suggesting that a quarter of married male-headed households make crop cultivation decisions without consulting spouses.

Female household heads make up only 8% of the bean-growing households and of this 77% do not have spouse and they make crop cultivation decision by themselves. There were 23% female heads living with spouses and about 17% reported that they consult their spouse when making crop cultivation decision. Unlike the male-headed households, the female-headed households have other members (6%) of the household who make crop choices for household plots- these other members could be their sons and daughters or relatives living in the house. The age of the female household head could also be one possible reason for the involvement of other member households in the plot management decisions. In terms of distribution across regional states, other family members making agricultural decisions are relatively more common in Oromia than any other Regional states. Generally, there is a tendency towards joint and consultative decision making on crop choices across all regional states. Compared to the general anecdotal evidence about male dominated common bean production, results in Table A3.2b suggests that there has been an improvement in the engagement of female farmers in important agricultural production decisions in recent years.

Common bean-growing households practice mixed crop-livestock farming system. Livestock is used as a safety net asset to guard farm household against shocks and agricultural related risks such as crop failure. Cattle are the dominant livestock kept in the study areas

followed by poultry and donkey. Camels, mainly kept in the pastoralist areas, were reported only in Oromia Regional state (Table A3.2a). Equipment used for farming includes hand hoes, plough, sickles and gunny bags (Table 3.3). The number of livestock units¹³ possessed by typical households is also small, averaging 3.4 TLU, with slightly higher numbers observed in BNSG and Oromia Regional states. A small proportion of farmers in Benishangul Gumz (BNSG) Regional state reported ownership of tractors (Table A3.3).

Table 3.3 Average number of agricultural equipment owned and livestock units

	Number of assets/equipment owned Mean (Std. Dev)				
	Pooled	Amhara	BNSG	Oromia	SNNP
Livestock Units (TLUs)	3.40 (5.00)	2.93 ** ^o (2.21)	4.27 (3.31)	4.04 (6.35)	2.15*** ^o (1.98)
Hoe	2.05 (2.12)	2.30 (1.33)	3.33 (1.80)	1.99 (2.48)	1.86 (1.66)
Ox-Plough	1.19 (0.86)	1.37 (0.65)	1.55 (0.67)	1.25 (0.97)	0.86 (0.63)
Sickle	2.02 (1.74)	3.02 (1.70)	2.61 (1.14)	1.86 (1.86)	1.52 (1.10)
Gunny bag (100 kg sack)	6.66 (6.56)	7.60 (5.87)	10.23 (7.25)	7.29 (7.34)	4.10 (3.89)

O=Oromia; ***=significance at 1%

3.1.5 Land tenure, size and utilization

A number of studies have revealed land tenure has got a significant impact on the adoption decision of behavior of smallholder farmers. In the study area, land tenure systems involve owned (owner operated, rented in, shared in, and leasehold). Of these types of ownership, household owned and operated is the most dominant followed by rented-in and leasehold. The average land holding by the sampled households is about 2 hectares. Of the study area, Benishangul Gumz had the largest land holding size of about 4.0ha and SNNP the smallest average landholdings (1.26ha) (Table 3.4). These results are consistent

¹³ For livestock unit we used a camel equivalent where cattle=0.7 of a camel, pig=0.2, goat=sheep=0.1, bull=0.6, Heifer=0.5, calf=0.2, donkey=0.5, Horse=0.8, Mule=0.7

with the regional state population density which show SNNP as having the highest population density of 141 people per square km and BNSG regional state as the least populated with 15.9 people per square km. About 82% of the plots cultivated in *meher* 2016 were established on land owned by the households while 10 % were on land rented in by the household.

Table 3.4. Average farmer estimated area and number of household plots/subplots planted in all crops and common beans

Parameters		Amhara	BNSG	Oromia	SNNPR	Total
Average area (ha) cultivated per HH	By all crops	2.19	4.14	2.41	1.51	2.23
	By common beans	0.51	0.97	0.53	0.51	0.54
	Share of area allocated to bean (%)	23.5	23.43	21.97	33.73	23.98
Average area (ha) owned per HH		2.29	2.79	2.26	1.27	2.05
Total number of plots		918	125	1850	492	3,385
Mean distance to the HH plot (Min.)		37	31	20	16	25
Number of plots/subplots (average per household)	#Total plot*	4.39	3.79	3.01	1.87	3.02
	#Total subplots*	5.35	5.15	4.49	3.02	4.33
	# Common Bean subplots*	1.29	1.3	1.2	1.03	1.18
	Share subplots allocated to beans (%)	24.15	25.29	26.6	34.17	27.22

* **Plots** are land area planted into one or more crop types; **Sub plots**: sub division of a plot which is planted in only one type of crop; HH=household

The number of subplots on a plot is equal to the number of distinct crops planted on the plot. When a plot is planted in two crops it will have two subplots, but if planted in one crop, it will have one subplot and can be considered as one subplot

On average, a bean-growing household cultivates about three plots¹⁴ (Table 3.4). In fact, the number of plots per household are highest in

¹⁴ A plot is like a parcel, which could be cultivated in one or more crops.

When the plot is cultivated in more than one crops which are planted neither as mixed nor as intercropped, is the area planted to each crop

Amhara and least in SNNP compared to the overall mean. On average, a farmer travels 25 minutes from residence to the plot (Table 3.4). Households with a greater number of plots tend to spend more time to reach to the plot location suggesting the higher the land fragmentation, the longer it takes a farmer to reach to a plot. . In some instance plots are divided into subplots for the cultivation of different crops. The average number of sub-plots allocated to crop production per household is five and about one of these is cultivated with common beans. The share of common bean sub-plots was the highest in SNNP (34%) and lowest in Amhara (24%) Regional states (Table 3.4).

Based on farmer estimate, the average area a household cultivated in meher season was about 2ha, 26 percent of which is allocated for common bean. With the exception of SNNP where the highest share of the total cultivated area is allocated to common bean, farmers in the remaining three regional states allocate comparable share to common bean. Except in Amhara regional state, common bean farmers cultivated higher proportion of the land they own (Table 3.4) acquired either through renting or shared in tenure arrangement (see Table A3.2). Farmers in Benishangul Gumuz (BNSG) region seem to have comparatively better access to land through renting or other forms of tenure apart from ownership (also see Table A3.2a).

The lion share (84%) of the plots cultivated on land owned by the households were jointly owned by the household head and the spouse (Table A3.2a). Generally, spouses (mainly wives) and other household members do not have sole ownership right in almost all the regional states. Nonetheless, the prevalence of joint ownership of land between husbands and spouses is an important development that can offer access as well as participation in the crop allocation decision for women (esp. spouses) in the household. This, in turn, may potentially contribute to

considered as sub plots. So, a plot can have a number of sub-plots. A plot cultivated only in one crop or more (in a mixed/intercropping pattern) the plot will be the same as the sub-plot.

reduced gender differences in productivity as well as access to important household resources.

3.2 Common bean production

Almost all of the sampled farmers grow common beans, while 87% of the common bean-growing households cultivated common bean in *meher* season of 2016. The remaining 13% of the households who did not plant beans in *meher* cited climate change (associated with rainfall) and lack of enough land (Table 3.5) as main constraints for not cultivating common beans. More than half (54%) of the farmers who did not grow common beans in Oromia reported climate change, mainly drought, as the main reason whereas lack of land is reported as the main impediment in the three regional states. The land constraint appears to be more severe in SNNRP and Amhara regional states as reported by 64% and 42% of the households who did not grow common bean, respectively.

Table 3.5 Main reasons (based on % of household reported) for not cultivating bean in *meher* 2016

	Regional States				
	Amhara [6%] (n=12)	BNSG [-] (-)	Oromia [16%] (n=98)	SNNP [14%] (n=37)	Pooled [13%] (n=147)
Reason for not growing beans					
Climate change	-	-	54.08	24.32	42.18
Lack of land	41.67	-	31.63	64.86	40.82
Poor market prices last season	41.67	-	19.39	5.41	17.69
Seed not available	25.00	-	15.31	2.7	12.93
Diseases	8.33	-	7.14	-	5.44

Note 1: numbers in []- are percentage of respondent from the total in the respective regional states who did not cultivate common bean at the study time.

Note 2: The percentages don't add up to 100 because some respondent gave more than one reason.

Other constraint faced by farmers who failed to grow common bean during the survey season were poor price signals and failure to access seed as reported by 18% and 13% of the farmers, respectively. Lack of seed, in general, and quality seed, in particular is also reported as a major constraint by a previous nearly a decade ago (Ferris and Kaganzi, 2008). The problem of low producer prices offered in the local market

in the season before the survey was important constraint in Amhara and Oromia regional states. It was more so in the Central Rift Valley (CRV) of Oromia regional state where largest share of the export volume comes from. All sample farmers from Benishangul Gumz regional state grew beans in the 2016 *meher* season and the study did not register any constraints.

3.2.1 Types of common bean grown in *meher*

Common bean types grown by farmers are classified based on grain-processing feature as well as plant growth habit. The result showed that the cooking bean type is most popular bean type grown by 68% of the households while 32% of the households grew canning types. Canning beans are popular in the Central Rift Valley grown by about 75% of sample household in Oromia (Table 3.6).

Table 3.6 Percentage of households growing different types of Common Bean, by regional state and sex of household head

Bean types	Regional States					Sex of HH headship		
	National	Amhara	BNSG	Oromia	SNNP	M	F	
By processing type								
Canning	32.2	57.09	11.63	33.21	9.68	31.88	35.9	
Cooking	67.8	42.91	88.37	66.79	90.32	68.12	64.1	
Total	100	100	100	100	100	100	100	
By growth habit								
Bush	64.73	54.09	46.94	61.45	87.41	36.07	33	
Climbing	35.27	45.91	53.06	38.55	12.59	63.93	67	
Total	100	100	100	100	100	100	100	

Pearson chi2 (1) = 0.7954, Pr = 0.372 Pearson chi2 (3) = 160.79 Pr = 0.00

In terms of growth habits, majority of the households (65%) grew bush beans while 35% grew climbing cultivars (Table 3.6). Climbing bean is more popular in Benishangul Gumz regional state, cultivated by 55% of the households, in the *meher* 2016 cropping season and lowest in SNNP, grown by 13 % of the households. The gender disaggregated data across the growth habit as well as grain processing type indicate that the distribution is fairly comparable between male and female headed households (Table 3.6).

3.2.2. Bean cultivation and management practices

Common bean cultivation in Ethiopia depends on the amount and distribution of rainfall, with only a few households (3%) practicing irrigation. Accordingly, planting coincides with the on-set of rains. In *meher* season, planting begins in the first week of June and goes on to the second week of July. That is, about three-fourth (75%) of the farmers finish their planting activity within a range of 6 weeks starting from the first week of June and extends to July.

Although the planting period for common bean mainly falls within the six weeks' time mentioned, there is the scope for planting to extend by four weeks giving it a wide range of planting window depending on the rainfall pattern. In extreme case, few farmers plant at the end of the fourth week of August (Table A3.3).

As in other crops, common bean could either be broadcasted or planted in rows. Traditionally, farmers in Ethiopia broadcast bean seeds during planting while row planting is a new practice that has been promoted with the introduction of improved varieties. The underlying assumption behind promotion of row planting practice is that it facilitates crop management such as weeding; thereby contribute to improved yields. About, 37% of the bean plots plant in rows while the remaining 63% of the plots are planted using traditional broadcasting method (Table 3.7).

As depicted on Table 3.7, planting methods did not differ significantly between male and female-headed household. However, planting methods differ significantly across regions. While broadcasting is the dominant method across most of the regional states, SNNP regional state stands out distinctly with 68% of the plots planted in rows (Table 3.7).

Table 3.7 Common Bean cultivation (management) practices across regional states (% subplots)

Management practices		Regional State						Sex of household		
		Pooled	Amhara	BNSG	Oromia	SNNP	Test stat*	Female	Male	Test stat* (p stat)
Method of planting	Row planting	37.37	23.70	27.91	31.57	68.27	144.32	45.54	36.69	3.12
	Broad-casting	62.63	76.30	72.09	68.43	31.73	(0.00)	54.46	63.31	(0.08)
Method of weed control	Manual	98.52	100	100	97.79	99.55		97.59	98.59	5.05
	Herbicide	0.19	0.00	0.00	0.29	0.00	6.76	1.20	0.10	(0.80)
	Both herbicide & manual	1.30	0.00	0.00	1.91	0.45	(0.344)	1.20	1.31	
Irrigated plot (%)		2.95	1.48	0.00	4.20	1.48	9.43 (0.024)			
Number of times for manual weeding		1.69	1.40 (AO, AS)	1.57	1.74 (OA)	1.74 (SO)	7.47 (0.00)	1.76	1.68	0.23
Chemical Input use (% sub plots)	Chemical fertilizer	42.16	36.95	30.59	44.86	49.79	43.43 (0.00)	43.31	43.79	0.08 (0.77)
	Organic fertilizer	10.71	13.56	4.71	10.52	8.44	19.45 (0.00)	10.86	9.74	1.14 (0.29)
	Pesticides	2.50	1.11	0.59	3.83	0.56	39.39 (0.00)	2.69	2.23	0.70 (0.40)
	Herbicides	19.08	2.99	19.41	29.31	8.72	392.05 (0.00)	20.58	17.46	5.26 (0.02)

*Chi-Squared/ t-stat/F-stat (p value)

Weed control is considered an important common bean management practice that influences productivity. Irrespective of household types, most farmers weed twice manually to control weeds over the production season. Nonetheless, weeding frequency differed across regional states- farmers in Amhara regional states practice less frequently compared to farmers in Oromia and SNNP regional states where weeding is done nearly twice over the season (Table 3.7).

3.3.3 Inputs used in bean production

Although there is slight growth in inorganic fertilizer consumption in Ethiopia, it is more often applied in cereal crops than in common beans. According to CSA (2018), about 57% of the total crop area in Ethiopia receive some amount of inorganic fertilizers. The average quantity of inorganic fertilizers use is estimated at 84kg/ha, much of it applied in cereal crops (101kg/ha) compared to pulses (33kg/ha) (CSA, 2018). Even worse, the average quantity of inorganic fertilizer applied in bean is the lowest estimated at about a kilogram per hectare. Survey data revealed that about 43% of the bean plots were treated with inorganic fertilizer (Table A3.3) while 19% received some type of herbicides to control weeds (Table A3.3). There is no significant difference in the use of fertilizer between the female and male-headed households suggesting either inorganic fertilizers are not perceived to have a significant effect on the yield of common bean or are equally less accessible by both male and female farmers.

The average fertilizer use in common bean production ranges from 25kg/ha for DAP to 14kg/ha for NPS, and UREA (20kg/ha) falls in between (Table 3.8). There is significant difference in the use of DAP and NPS fertilizer across regional states. The use of DAP in Amhara regional state is way below the pooled average but the corresponding figure for NPS in this region is the highest next to Oromia. Generally, the standard deviations in almost all of the cases are above the mean indicating that there were many households using little or no fertilizer in their plots. A household apply an average of 183kg/ha of organic fertilizer (manure) and the difference is significant across regions. Amhara and Oromia regional states stand out in terms of using organic fertilizer above the pooled average (Table 3.8).

Compared to the three types of fertilizer, DAP is applied to beans (18kg/ha) in larger quantities but still is less than the average used for all plots planted in different crops (25kg/ha). The average quantities of UREA and NPS used for bean are comparable (Table 3.8). Except for UREA there is significant difference across regional states in the average quantities of fertilizer used for beans. Farm household in the SNNP regions apply, on average, the largest quantity of DAP (35kg/ha) well above the pooled average (18kg/ha).

Table 3.8 Average quantity of and expenditure on inorganic and organic fertilizers applied by households on all as well as bean plots in meher 2016

Regional State	Para-meter	Quantity (kg/ha)			Expenditure (Bir/ha)			
		DAP	UREA	NPS	Organic fertilizer	DAP	UREA	NPS
For all plots								
Amhara (a)	MEAN	12.11* ^{bos}	20.32	15.74	230.28	165.49	236.45	219.57
	SD	23.30	22.64	23.42	497.27	314.42	261.84	332.31
BNSG (b)	MEAN	36.74	12.76	1.47	56.95	521.78	162.75	20.34
	SD	114.10	11.85	8.12	116.89	1597.18	149.80	116.83
Oromia (o)	MEAN	24.33* ^s	21.44	16.24* ^b	220.94	325.82	224.56	219.54
	SD	55.16	44.69	34.45	691.21	551.31	365.03	446.30
SNNP (s)	MEAN	33.63	16.55	7.49* ^{ao}	74.58* ^{ao}	452.15	180.62	97.34
	SD	42.74	27.60	25.53	317.67	584.66	296.87	338.52
Total	MEAN	24.59	19.83	13.66	183.51	331.24	214.65	184.99
	SD	51.21	37.13	30.42	580.11	589.80	328.02	400.61
F-test stat (p val)			1.48	7.28				
		7.62 (0.00)	(0.22)	(0.00)	4.96 (0.00)			
For bean plots								
Amhara (a)	Mean	8.60	8.69	4.46	174.80	35.72	54.79	61.21
	SD	86.37	60.70	22.16	691.87	171.62	256.84	327.22
BNSG (b)	Mean	5.60	5.05	0.61	0.00	75.27	60.81	9.70
	SD	17.30	16.40	3.48	0.00	232.18	195.44	55.70
Oromia (o)	Mean	14.21	12.86	13.66* ^a	275.43	207.69	142.59	191.41
	SD	36.97	34.82	38.25	953.99	585.82	388.26	503.63
SNNP (s)	Mean	35.35* ^{abo}	10.33	10.27	42.01* ^o	481.21	108.69	114.82

Regional State	Para-meter	Quantity (kg/ha)				Expenditure (Bir/ha)		
		DAP	UREA	NPS	Organic fertilizer	DAP	UREA	NPS
	SD	48.36	31.59	43.18	211.54	683.81	333.24	453.02
Total	Mean	17.66	11.15	10.55	191.35	231.30	113.99	140.81
	SD	53.78	40.44	36.35	774.37	566.33	348.36	454.84
F-test stat (p value)		11.48 (0.00)	0.83 (0.48)	3.94 (0.01)	5.53 (0.00)			

SD=standard deviation; * significant at 1% or 5% level of significance; letters **a,b,o**, and **s** refers to the comparison regional states

The average quantity of UREA and NPS fertilizer used in Oromia and SNNP regions are comparable and almost similar to the pooled average while the other regions use below the overall mean. Like the quantity used for plots planted in different crops, the use of organic fertilizer for bean plot is still large for Oromia followed by Amhara regional state.

Table 3.9 presents intensity of inorganic fertilizer use disaggregated by gender. On the aggregate, irrespective of crop type, the average quantity of inorganic fertilizer used by the sample household did not significantly differ between male and female headed household. The large standard deviation in almost all cases is indicative of the fact that there were many sample farmers who did not use fertilizer of any type at all.

Labor and seed are perhaps the primary inputs used in bean production in Ethiopia. We aggregated the labor input for each of the field operations based on the adult man equivalents. Bean management practices that require substantial labor inputs include but not limited to land preparation, planting, weeding, fertilizer or manure application, spraying in case of disease outbreaks or pest attacks and harvesting. As depicted in Table A3.3, majority of the households used draught animal power to cultivate their land and transport produce both from farm to home and to markets thereafter. This is evidenced by the high percentages of farmers owning oxen and donkeys.

Table 3.9 Average quantity of and expenditure on inorganic and organic fertilizers applied by households on all as well as beans bean plots in meher 2016 (disaggregated by Gender)

Gender	Parameter	Quantity (kg/ha)				Expenditure (Bir/ha)		
		DAP	UREA	NPS	Organic fertilizer	DAP	UREA	NPS
		For all plots						
Female	MEAN	36.07	21.96	9.24	125.71	500.15	262.97	141.50
	SD	79.23	37.82	22.31	530.07	1104.88	411.95	335.66
Male	MEAN	23.56	19.64	14.06	188.70	316.08	210.31	188.90
	SD	47.83	37.08	31.02	584.35	517.53	319.31	405.84
Total	MEAN	24.59	19.83	13.66	183.51	331.24	214.65	184.99
	SD	51.21	37.13	30.42	580.11	589.80	328.02	400.61
t-test (p value)		2.25* (0.03)	0.57 (0.57)	-1.46 (0.15)	-1.00 (0.32)			
		For bean plots						
Female	MEAN	17.22	7.79	5.76	131.70	230.44	85.82	85.51
	SD	38.30	27.27	19.17	686.33	507.35	260.54	278.63
Male	MEAN	17.70	11.44	10.96	196.48	231.38	116.41	145.58
	SD	54.92	41.37	37.44	781.62	571.38	354.92	466.71
Total	MEAN	17.66	11.15	10.55	191.35	231.30	113.99	140.81
	SD	53.78	40.44	36.35	774.37	566.33	348.36	454.84
t-test (p value)		-0.076 (0.94)	-0.755 (0.45)	-1.20 (0.23)	-0.70 (0.48)			

SD=standard deviation, * significant at 1% or 5% level of significance

The result in Table 3.10 indicates that weeding has the highest labor requirement compared to the other operations. Comparatively, the amount of labor used for each operation is relatively lower for Amhara regional state with 91 man-days per ha for all the operations and the highest for Oromia with 136 man days per ha. The difference may arise from the efficiency of labor use, which could be associated

Table 3.10 Aggregated family and hired labor (in adult man equivalent) used for different field operation on plots cultivated in different crops, by region & sex of HH

	Land preparation and planting	Weeding (cultivation)	Harvesting	Threshing	For all operations
Regional State					
Amhara (a)	16.40 (19.66) ab ¹ , ao ¹	34.17 (49.01) ao ¹	26.66 (33.46) ao ¹	13.46 (18.02) ab ¹ , ao ¹	90.70 (110.15) ab ³ , ao ¹
Benishangul Gumz (b)	30.82 (42.81)	37.77 (54.70)	38.37 (64.22)	27.05 (51.55) bs ¹	134.01 (180.07)
Oromia (o)	29.29 (56.08) os ¹	45.78 (94.40) os ²	38.85 (77.75)	21.71 (35.97) os ²	135.63 (224.76)
SNNP (s)	22.19 (45.59)	36.43 (66.85)	34.31 (66.16)	17.64 (29.11)	110.57 (168.01) os ²
National	25.22 (48.11)	41.01 (81.01)	35.37 (67.86)	19.42 (32.88)	121.02 (193.17)
F test stat (p value)	13.95 (0.00)	4.61 (0.00)	5.58 (0.00)	14.42 (0.00)	10.18 (0.00)
Sex of Household head					
Female	29.52 (46.25)	40.88 (56.57)	31.1 (53.74)	19.41 (36.81)	120.91 (159.87)
Male	24.98 (48.21)	41.02 (82.14)	35.6 (68.55)	19.43 (32.66)	121.02 (194.85)
t test stat (p value)	1.22 (0.22)	0.03 (0.97)	1.07 (0.29)	0 (0.99)	0.01 (0.99)

Note: 1manday=8hrs of work for adult man; for child lab (<15yrs) =0.5 man-day of adult man; for adult woman=0.8mandays of adult man; Significance at: ¹= 1%, ²= 5%, and ³=10% level of significance

with the type of farm implements used as well as the weather condition under which the labor operates. For example, farmers in Amhara weed their plot less frequently compared to other regional states (see Table 3.7). Consequently, farmers in Amhara and SNNP regional states generally use lower amount of labor compared to the overall mean. The corresponding figure for the BNSG and Oromia regional states is bigger than the aggregate mean, and the difference across the regions is statistically significant.

Table 3.10 also shows sex disaggregated labor inputs for different farming operations. The result suggests no significant difference in quantity of labor used between these two groups contrasting with studies which commonly report that gender linked technology adoption and productivity gap is mainly associated with female farmers being more constrained by labor and other productive inputs (Fisher and Car 2015; Fisher and Kandiwa, 2014; Peterman et al., 2014; Doss and Morris, 2001).

Family is the main source of labor. Hired labor contributes only about 8% of the total labor required for all operations. Oromia and BNSG region engage significantly higher proportion of hired labor than Amhara and SNNP. The latter two regions are known as main source of hired labor (Table A3.4). Households hire labor mainly for harvesting and weeding, likely because of competition for family labor from other enterprises. Female-headed households were found to be using significantly larger share of hired labor than male headed households (12% vs 8%) (Table A3.4). This is likely because of additional hired labor used by female heads for land preparation and planting unlike the male heads who seem to be less labor constrained for such operation.

3.3.4 Major contributors of family labor

The study attempted to understand who among household members spends more time working on common bean plots. Accordingly, the result showed that most (58%) of the common bean plots were managed by sole household heads while 35% of the bean plots are managed by both the head and spouse (Table 3.11). There is significant difference in the share of plots

managed by different members of the farm households across the regions. Joint bean plot management involving the head and spouse is relatively more important in the SNNP region. Sole management of the bean plots by the head is the most common practice across the regions.

Table 3.11 Who spends more time working on the bean plot

Household gender	Percentage of common bean plots					χ^2 (p value)
	Pooled Sample	Amhara	BNSG	Oromia	SNNP	
Household head, solely	58.02	60.00	72.09	61.79	43.54	38.94 (0.00)
Spouse, solely	1.74	2.22	0.00	2.03	0.74	
Both Head and Spouse	34.57	32.59	27.91	30.89	47.60	
Other House hold member	5.67	5.19	0.00	5.28	8.12	

3.4 Descriptive statistics on outcome variables

This section presents the descriptive analysis of the outcomes on common bean production and economic well-being of bean growing households. According to the theory of household behavior, economic well-being of a household depends on the flow of consumption of goods and services available to it. We separate outcomes into intermediate (represented by technology adoption and associated productivity) and those on economic well-being (such as food security and wellbeing represented by dietary diversity, per capita consumption expenditure and poverty score card). In this section, data on economic well-being are compared across regional states and by sex of household headship while comparisons by adoption status appear in Section 5.

In terms of dietary quality, results show that bean-growing households generally consume unbalanced diets dominated by cereals and legumes. Based on 7-days recall, the study found that some households across the

country do not consume Iron and Vitamin A rich foods¹⁵ weekly, consistent with the literature that intake of these nutrients in developing countries was limited (Hawkes and Ruel, 2011). Only 4% of the households across the study area consume Iron and Vitamin A rich foods daily while another 20% of households consumed iron rich foods 1 to 6 days per week (Figure A3.5a). Surprisingly, access to iron rich food does not seem to vary much across locations nor the economic status of the household. Comparisons of top wealth quintile with poorest quintile, shows slightly small differences in consumption of the three key nutrient food groups. For example, 3% of the poorest households and only 5% of wealthiest quintile households consume iron rich foods on a daily basis (Figure A3.5b). To shed more light on the quality of diets, the commonly used dietary diversity score ‘the household dietary diversity score (HDDS)’¹⁶ (FAO and USAID, 2016)¹⁷ was calculated. The HDDS was computed based on 24 hours recall of food items consumed following guidelines provided by FANTA for measuring micronutrient adequacy. The 24 hours HDDS ranges from 2 to 11 out of maximum score (Table A3.5). Our data showed that people living in a typical common bean-growing household consume food from 6 food groups daily, but dietary diversity is slightly lower among households in Amhara and SNNP regional states (Table A3.5). The low dietary diversity in the two regional states could be due to high likelihood of food shortage incidence in a given year (CSA and WB, 2013). About 18 percent of the households had a 24 hours HDDS below the minimum threshold of five, which implies that the diets of common bean-growing households lack micronutrient adequacy (Table A3.5). Compared to other regions, Amhara had the worst micronutrient

¹⁵ Protein foods included; fresh meat, eggs, milk and legumes. Vitamin A foods (Vitamin A rich vegetables, & Vitamin A rich Fruits), Iron rich foods (Organ meats).

¹⁶ According to Mekuria et al. (2017) Household dietary diversity refers to the number of food groups consumed by household members in a specified period of time usually 7 days or over a 24-hour period. Household dietary diversity score is regarded as low when that particular household consumed less than or equal to three food groups within 24 hours before the survey Kennedy et al (2011). Medium dietary diversity score signifies that members of a particular household consumed four to six food groups within 24 hours before the survey. A high household dietary diversity score is awarded when households consumed seven or more food groups within 24 hours before the survey (Kennedy et al., 2011).

¹⁷ the Food and Agriculture Organization of the United Nations and USAID’s Food and Nutrition Technical Assistance III Project (FANTA), managed by FHI 360, Rome, 2016

adequacy with 30% households falling below the HDDS minimum threshold of 5 followed by SNNP with 28% of the households below a minimum threshold of 5 food groups (Table A3.5).

The average, household food consumption score was 57, which is above the threshold of 35 for acceptable food consumption. However, about 2% of the households had poor food consumption while 8% were at the borderline between good and poor. Most of the common bean-growing households falling in the borderline comes from the SNNP regional states. While 90% of the households, in general, fall in the acceptable food consumption score, the corresponding figure for common farmer in the SNNP regional state was about 75%, some 15% below the overall average. (Table A3.5). Unlike the poor, households at the borderline consume legumes once a week. Those with poorer consumption barely consume legumes (Figure A3.5c) and their diets is composed of a staple, vegetable and condiments (Figure A3.5c).

Using the total consumption expenditure on food and non-food items, results also show an average household expenditure of about 24733.65 ETB per year, with food budget accounting for 71% of the budget¹⁸ (Table A3.5). The average per capita bean consumption is about 18 kg per person per year, higher than 1-16 kg per person per year for Ethiopia reported by Ferris and Kaganzi (2008) (Table A3.5). Bean consumption is significantly higher in SNNP region than in Benishangul Gumuz and Oromia regional states.

¹⁸ Expenses on education and health care as well as those that went into assets were excluded from the computations of total nonfood expenditure

4. Improved Common Bean Variety Adoption, Diffusion, Varietal Replacement in Ethiopia

4.1 Introduction

Common bean breeding and improvement efforts in Ethiopia seek to increase bean productivity and resilience to biotic and abiotic stresses through targeted breeding strategy. Since the 1970s, more than 50 bean varieties have been released for different traits and for different agro ecological zones, representing high common bean varietal diversity. Many of these varieties were released using conventional breeding. Recently, advanced breeding techniques such as gene pyramiding against common bean diseases like angular leaf spot, common bean blight and anthracnose are being used in addition to MAS (Marker Assisted Selection) (Demelash, 2018). The released varieties are high yielding than landraces, with an immense potential to increase farming outcomes thereby contribute to the overall welfare of adopting families (Alwang et al., 2019). It is with this objective in mind that the Tropical Legumes project, implemented between 2007 and 2018 with funds from the BMGF via ICRISAT, had been working to enhance the adoption and diffusion of improved bean varieties by developing appropriate varieties and strengthening the bean seed system.

Over the project period, seeds of over 30 bean varieties well adapted to the production environment had been multiplied and distributed. The seed multiplication and distribution effort focused on varieties released on or after 1990 as these varieties contain resistance to multiple constraints (see Appendix A1.0) compared to those released before the 1990's. Of these varieties, seven were released during the project period, while 23 varieties were in existence at the time of the project inception, though not widely disseminated to the farming communities.

Besides, availing seeds of improved varieties for distribution, stakeholder engagement at various levels was considered key to the project success. To this effect, MARC, in collaboration with CIAT

engaged a wide range of stakeholders along the bean value chain through innovation platforms established in different parts of the country (starting from the Central Rift Valley- home to the major production and marketing area) to leverage fast diffusion of the targeted varieties. Strategies to create demand and improve access to varieties involved diversification of seed production models, packaging seed in a commercial and small seed pack to meet farmer demands. This was expected to bring changes in the varietal portfolios in the farmers' hand. Despite the concerted effort to develop well performing varieties and promote them to farmers, empirical evidence on varietal adoption, diffusion among the growing households and impact on well-being is hardly available. Therefore, a component of the study focused on assessing the contribution of the tropical legumes project with due emphasis on improved research derived bean variety adoption, varietal turnover and diffusion.

A slow varietal turnover (replacement rate) has been a concern and generated immense debate among breeders, seed systems specialist and policy makers. Given the growing interest to accelerate varietal replacement, there is a need to empirically understand the underlying factors governing the rate of varietal turnover. Thus, this study contributes to these discussions by analyzing factors that explain time lag between variety release and adoption. As adoption of new varieties begins with creation of awareness, investments to popularize the new varieties are a crucial component for accelerating varietal turnover. However, for the case of common bean varieties in Ethiopia, varieties developed before the project commenced were largely not in use as evidenced by the low adoption rate at that time. Interventions in the TL project aimed to shorten the lag between the release and awareness/adoption of improved bean varieties. The analysis of the time when farmers became aware and/or started planting a variety after release might provide insights on the return to the investment in the TL project.

The study applied DNA fingerprinting to reliably measure the extent to which, varieties promoted under the tropical legumes project have been adopted by farmers. We first examine the adoption of all improved varieties and then that of a subset of improved varieties developed

and/or disseminated under the project. The study also sought to contribute to the growing literature on understanding how correctly farmers are able to identify varieties on their farms when recall method is used. In Ethiopia, similar studies have been done for wheat and maize (Jaleta et al., 2020) and this study adds perspectives from the case of legumes.

In the subsection that follows, we provide an overview of the methods used to identify varieties in farmers' plots. A description of the bean varieties identified from the survey follows while comparing the results of farmer reports with those of DNA analysis to understand the extent of error when using traditional farmer recall in measuring adoption of improved bean varieties in Ethiopia. While analyzing the correctness of variety identification by farmers, we explore any correlation with the source of seed planted, paying special attention to seed dissemination channels promoted under the project. The descriptive results are disaggregated by region and socioeconomic groups to discern if there was any correlation with variety identification. Subsection two of this chapter uses DNA varietal identification results alone and examines the extent to which varieties promoted under the Tropical legumes project have been accessed by target users, their adoption and diffusion across geographical region. In addition to improving smallholder access to improved varieties, TL projects intended to accelerate diffusion of varieties by cutting down on the time lag between release and actual access by the target farmers. We estimate a varietal turnover based on area weighted average variety age both at national and at region regional level in subsection three while subsection four analyzes the time lag between variety release and awareness to identify the factors that explain it. The chapter concludes with a quick summary on the implications for research and seed systems and policy recommendations.

4.2 The data and variety identification strategy

Two approaches are often used to identify improved varieties grown by farmers. As is the case in most adoption studies, in this study, farmers were asked to report the varieties planted on each plot they cultivated during the *meher* 2016 cropping season. As an aid to varietal

identification, a list of all varieties considered as improved was compiled from the PABRA database, validated by the scientists in the national bean research program in Ethiopia before coding and inclusion into the questionnaire. The questionnaire also contained follow up questions on a few phenotypical characteristics such as color and type of the variety to assist in classification of the variety. In the second method, we used DNA fingerprinting to identify varieties. For every variety name reported by farmers as grown during the study season, each respondent provided a handful of seed samples of various bean varieties grown on each plot. Each seed sample was placed in a plastic bag labelled by a unique identification number¹⁹ that was generated automatically from the household and plot identification numbers by the ODK application. The same identification (ID) number served as matching ID between the DNA analysis (genotyping) results with that of the survey data²⁰. A total of 1046 bean seed samples were collected from the sample farmers during the survey²¹. Finally, 970 of the seed samples collected from the farmers were given lab identifiers and immediately planted in the lab at MARC to secure pure seed samples for genotyping before shipping to CIAT-Uganda laboratories at Kawanda, where the seed samples were germinated and DNA samples extracted for DNA analysis²². Breeders at CIAT also characterized the samples based on phenotypical traits, (i.e., seed size and color).

¹⁹ Enumerators recorded the seed sample identification number on a sticker, which they posted on the plastic seed sample bag.

²⁰ The seed samples collected from households were then transferred and temporarily stored at the national bean research program laboratory at Melkassa research center where a corresponding laboratory ID (label) for each variety is generated.

²¹ It was not possible to collect seed samples for some of the bean plots as some farmers had no left over seed at the time of the survey. Yet still, about 216 of the recorded samples in survey were not delivered from the field as bags were empty which suspect that these got lost during movement in the field. The survey took place 6-7 months (depending on location) after harvest. As the study locations were far from MARC where the bean national research program was based, the seed had to stay with the survey team until handed over to the program lab where it was temporarily stored. Some of the seed samples had insect pests and others had rotten due to exposure to moisture.

²² The reference library for all released varieties was established based on the released common bean varieties which were sent to the CIAT laboratory for DNA analysis through the national common bean research program in Ethiopia

4.3 Common Bean varieties identified using recall and DNA results

From the 1046 seed samples, only 829 seed samples (sample plots) were subjected to DNA analysis while for 521 plots reported by farmers, seed was either missing at the time of interviews or got lost in transit from the field to the research station. Thus, DNA analysis for these plots was not done. Out of the 829 samples, 276 were identified as land races and 553 identified as improved. To compare the extent to which farmers' varietal identification matches with that of DNA fingerprinting analysis, we used the farmers' responses to the questions related to the type of varieties grown in *meher* 2016. In the first question, farmers were asked on whether the variety grown was improved or landrace. In the second question, respondents identified the variety cultivated in each plot by name²³. Figure 4.1 indicates the extent to which farmers self-reported and DNA varietal identification match or fail to match. Here, we matched farmers' self-reported with DNA varietal identification into improved or landrace (from DNA result). The matching is done for those varieties identified by the DNA results including improved and landrace as one set, and later considering the improved varieties alone as another set.

²³ List of all improved varieties

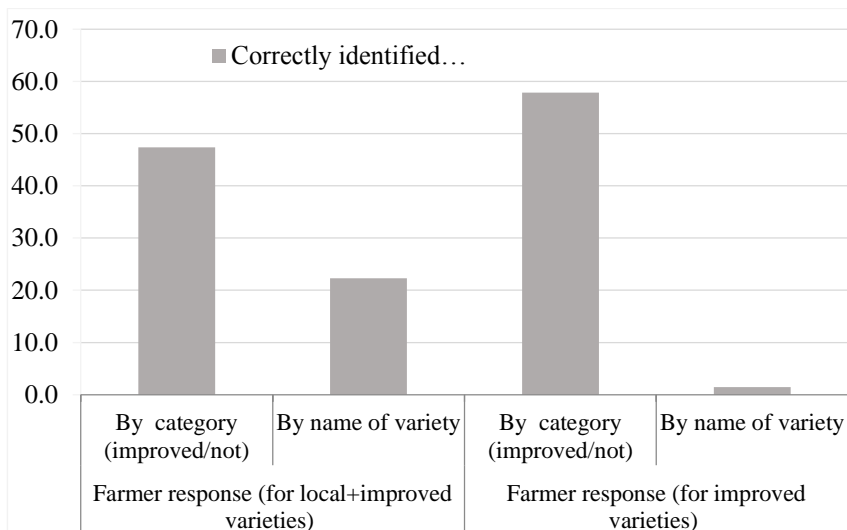


Figure 4.1. Extent of farmers' correct identification of bean varieties (by category and by name) (Percent)

In 47% of the samples, there was a correct match between farmer self-report and DNA varietal identification into improved or local category. This means that for the 53% of the samples, there was a mismatch between farmer self-reported and DNA varietal identification into improved or local. The correct matches were higher for landraces compared with improved varieties, meaning that farmers are more likely to correctly identify landraces than improved varieties. For example, out of the varieties correctly identified by farmers, 74% were landraces. While farmers were able to correctly identify 58% of the seed samples by category as improved, only less than 2 percent of the improved seed samples were correctly identified by their names (Figure 4.1). There were also seed samples (about 9%) which farmers identified neither by category (as improved/local) nor by any name, were most of these varieties identified as Mexican 142 (46%), landraces (18%) and Awash-1 (12%) in the DNA result. This indicates that farmers' ability to identify improved varieties is generally inadequate, and yet much less reliable when asked to identify varieties by their names. This mismatch also poses a challenge to impact assessment studies as well as the seed supply system as it does not help much in estimating the demand by

varieties. The mismatch is more evident when we examine how the top popular bean varieties identified as improved (based on the DNA analysis) were identified by farmer self-reports (based on recall method). For example, Mexican 142, a variety cultivated by majority of farmers according to the DNA result, was not identified (reported) by any single farmer. The farmers' self-report, on the other hand indicated that Awash-1 and Nasir (in that order) are the dominant bean varieties cultivated by the sample farmers.

Figure 4.2 shows that farmers identified most of the widely cultivated old improved bean varieties (like Mexican 142) mainly as landraces. This could be because, when a variety stays longer on farmers' hand, they may tend to perceive it as local. For instance, Mexican-142, an old small-sized white bean variety, is mainly reported as local. It is also partly confused with another relatively recent white bean variety known as Awash 1- farmers misreported about 11 percent of the plots planted to Mexican-142 as Awash 1.

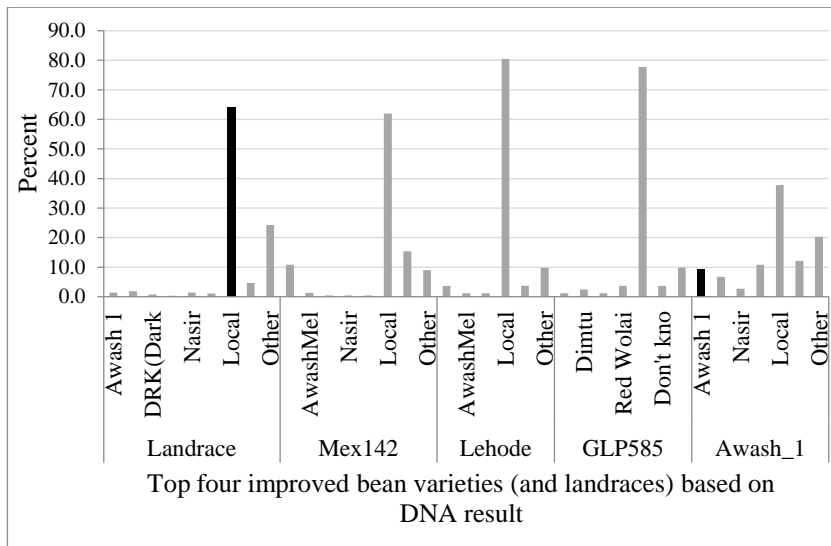


Figure 4.2 How did farmers identify the top four dominant improved bean varieties (and the landraces) from the DNA results?

From the DNA analysis, a total of 15 varieties improved were identified from the seed samples (Table 4.1). Four of these improved bean varieties (GLP585, KWP9, Lyamungu_85, ADP40_KATWELA) were not in the registry book of varieties released in Ethiopia. They might have come from neighboring countries. This means that the sample farmers grew eleven out of nearly 60 improved varieties released by the national bean research program between 1980 and 2014. Those eleven varieties grown by farmers were: Awash 1, Awash Melka, Roba1, Hawasa-Dume, Nasir, Nazareth, Chore, Dimtu, DRK, Goberasha, and Red Wolaita (Table 4.1).

Table 4.1 Common bean varieties grown and the share of area/plots planted to varieties, comparison between DNA result and farmer reporting

Names of Common Bean Varieties	Year of release	Share of plots (%)		Share (%) of plots reported correctly by farmers ^{NB}
		Subsample (DNA result) (n=829)	Full sample (Farmer report) (n=1350)	
KWP9	2014	0.4	-	-
Lehode	2010	9.9	-	-
Hawasa_Dume	2008	2.2	0.7	-
Cranscope	2007	1	-	-
Anger	2005	3.4	-	-
Argene	2005	0.1	-	-
Nazareth	2005	0.4	1.3	-
Nasir	2003	0.8	3.5	57.1
Awash Melka	1999	0.2	1.3	-
Awash_1	1990	8.9	3.9	9.5
Roba_1	1990	2.1	0.3	5.9
Lyamungu_85	1985	0.7	-	-
GLP585	1982	9.8	-	-
Mexican142	1973	26.7	-	-
ADP40_KATWELA	-	0.2	-	-
Landrace Local	-	33.3	56.1	64.1
Chore	2006	-	1.0	-
Dimtu	2003	-	0.6	-
DRK (Dark red Kidney)	2007	-	0.4	-
Gobe Rasha	1998	-	0.0	-
Red Wolaita	1974	-	1.4	-
Don't know	-	-	8.4	-
Other	-	-	21.0	-
TOTAL		100.0	100.0	

^{NB}. This is based on only the % of farmer reported plots (varieties) that were correctly matched with the DNA. Estimates in this column do not add up to 100 as they are specific to each variety. For example, for Nasir: out of plots cultivated to Nasir (based on DNA), farmers correctly reported 57% of the plots as cultivated in Nasir. The remaining plots of Nasir were reported as cultivated in other variety.

Among improved varieties, Mexican 142 dominates, and it is particularly so in Amhara and Oromia regional states where canning bean type is important (Table 4.2a). The result in Table 4.2 also indicated that Mexican 142- an old variety- is the most dominant variety planted in about 27 percent of the bean plots distantly followed by Lehodie (9.9%), GLP585 (9.8%), and Awash 1(8.9%). The popularity of Mexican 142 which was also corroborated by Beshir and Nishikawa (2012), in their study in the Central Rift Valley, stands in contrast with the expectation of bean breeders. The fact that this variety is not supplied through the formal seed system might have created an impression that it is out of production. However, the result suggested otherwise. In fact, the variety was under production (by farmers (for grain) and by Ethiopian Seed Enterprise (ESE) (for seed) up to 2010) and well established long before other varieties come in to the system. This, generally, poses important questions that need to be answered. That is, whether this behavior is out of farmers' interest in the variety, or is it because they have confused it with other varieties, which they prefer but ended up with a wrong one from the seed supply chains. Nonetheless, the wider presence of older variety (even in the two larger regional states) suggests that the speed of varietal diffusion is quite low. We look at varietal diffusion in section 4.6

Overall, these four varieties (Mexican 142, Lehode, GLP585, and Awash 1) occupied nearly 46% of the bean plots established in *meher* 2016. There were only three bean varieties (Nasir, Awash 1, Roba1), in that order, which farmers (in few number of cases) correctly identified by their names. Five improved bean varieties (Chore, Dimtu, DRK, Goberasha, and Red Wolaita) reported as cultivated by farmers, had no corresponding result from the DNA analysis to validate their identity.

Table 4.2a Distribution of bean varieties across regions (DNA result)

Bean Varieties	Type	Number of cases reported by each region				Total
		Amhara	BNSG	Oromia	SNNP	
Anger	Cooking	4	4	9	11	28
Argene	Canning	-	-	1	-	1
Awash_1	Canning	6	2	53	13	74
Awashmelka	Canning	2	-	-	-	2
Cranscope	Canning	-	-	7	1	8
Hawasa Dume	Cooking	2	-	5	11	18
Mexican142	Canning	113	2	105	1	221
Nasir	Cooking	-	2	1	4	7
Nazareth	Canning	-	-	3	-	3
Roba 1	Cooking	-	6	8	3	17
Lehode	Canning	25	-	56	1	82
GLP585	NA*	46	6	13	16	81
KWP9	NA	-	-	2	1	3
Lyamungu_85	NA	-	-	5	1	6
ADP40_KATWELA	NA	-	-	1	1	2
Landrace		24	4	185	63	276
Unknown(no sample)		54	17	303	147	521
Total plots (Full sample)		276	43	757	274	1,350
# varieties (Full sample)		9	8	16	14	17
Total plots (Sub sample)		222	26	454	127	829
# Varieties (Sub sample)		8	7	15	13	16

*NA: Not available because varieties are not released within Ethiopia

4.3.1 Relationship between farmer socioeconomic characteristics and correct identification of varieties

We checked for any correlation between the farmers' socioeconomic characteristics and their ability to correctly identify the variety grown. The result in Table 4.2b indicated that gender of the household head doesn't have a significant association with varietal identification. Similarly, farmers' correct identification of bean improved varieties had no correlation with their socioeconomic status²⁴, which means that

²⁴ The socioeconomic status is expressed based on quantiles of the farm household's poverty score.

poorer and richer farmers are equally likely to identify the improved varieties with significant errors. The relationship becomes slightly visible among these groups only when we consider the match for both the local and improved varieties. However, the farmers' ability to correctly identify a variety had meaningful correlation with the regional states they belong to. Farmers in Oromia and SNNP are likely to correctly identify a variety. About 26-29% of the seed samples (local/improved) were correctly identified by the farmers. However, if we consider the match only for improved varieties, except in Oromia, none of the farmers from the other regional states correctly identified a single improved variety (Table 4.2b).

Table 4.2b Relationship between farmers' varietal identification and Region/Gender as well as farmers' socioeconomic status

	For both Improved and landrace		For improved varieties only	
	# matches	% match	# matches	% match
Regional States				
Amhara	19	8.56	0	0
BNSG	1	3.85	0	0
Oromia	132	29.07	8	3
SNNPR	33	25.98	0	0
Total	185	22.32	8	1.4
<i>Pearson chi2(3)</i>	42.3026, <i>p</i> =0.000		8.5701 <i>p</i> =0.036	
Sex of household head				
Female	17	25	1	2.1
Male	168	22.1	7	1.4
<i>Pearson chi2(1)</i>	0.3078, <i>p</i> =0.579		0.1494, <i>p</i> =0.699	
Quantiles of socioeconomic status (based on Poverty score)				
Quantile 1	28	17.4	1	0.8
Quantile 2	38	25	3	3
Quantile 3	52	28.7	0	0
Quantile 4	26	16.3	1	0.9
Quantile 5	41	23.4	3	2.7
Total	185	22.3	8	1.4
<i>Pearson chi2(4)</i>	10.6993, <i>p</i> =0.030		5.1124, <i>p</i> =0.276	

4.3.2 Relationship between seed source and correctness of varietal identification

Result in Table 4.3 is from a bivariate analysis of correctness of farmer varietal identification. These results suggest that source of information for bean farmers is an important factor that influences the farmers'

ability to correctly identify improved varieties. Farmers receiving information from 'other farmers' and 'family members' are better in correctly identifying the landraces they grow. On the other hand, farmers receiving information from the government extension do well in identifying the improved varieties better than those using the other sources.

Table 4.3 Correlating varietal identification with source of seed and information,

Source of seed	For both Improved and landrace (*N=829)			For improved varieties only (*N=553)		
	# matches	# mismatch	% match for each source	# matches	# mismatch	% match for each source
Own saved	138	392	26.0	6	330	1.8
Gov't extension	1	32	3.0	1	25	3.8
Private trader/shop	0	14	0.0	0	11	0.0
Local market/open air	38	121	23.9	1	102	1.0
Farmer-to-farmer seed	5	13	27.8	0	13	0.0
Gift from neighbor	3	10	23.1	0	8	0.0
Other sources**	62	0	0.0	56	0	0.0
Total	185	644	22.3	8	545	1.4
<i>Pearson chi2(12)</i>	33.691, <i>p</i> =0.001			2.7762, <i>p</i> =0.997		
Source of information						
Extension (Gov't, Research)	16	113	12.4	7	89	7.3
NGO	0	18	0.0	0	16	0.0
Seed trader/agro dealers	1	12	7.7	0	12	0.0
Agric. coop/farmer groups	0	4	0.0	0	4	0.0
Other farmers	145	432	25.1	1	366	0.3
Family members	23	65	26.1	0	58	0.0
Total	185	644	22.3	8	545	1.4
<i>Pearson chi2(4)</i>	18.612, <i>p</i> = 0.002			27.8741, <i>p</i> =0.000		

* N refers to total seed sample

**Other sources include relatives, NGO, farmer trade, farmer groups, research centers, on farm trial, food aid

4.4 Adoption and diffusion of improved varieties: DNA results only

The result based on the DNA analysis showed that more than 65% of the plots/area planted to common beans is covered with improved varieties (cf. 38% under farmer reporting) (Figure 4.3). The result from farmer report is consistent whether we consider all the plots (38%) or sub sample of plots (38.7%) -for which there was seed sample. Thus, farmer recall method underestimates adoption rate for improved bean varieties.

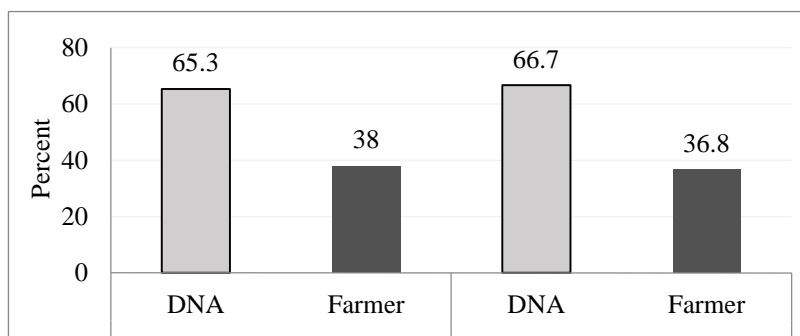


Figure 4.3 Adoption rate²⁵ of improved bean varieties based on DNA results and farmer report

According to DNA variety identification, nine TL2/3 project varieties, namely, Anger, Argeniem Awash1, Awash Melka, Cranscope, Lehodie, Hawassa Dume, Nasir, and Nazareth-2, were cultivated in *meher* 2016: Figure 4.4 presents the share of bean plots that were cultivated with improved (old and TL separately) varieties. These varieties which were promoted under the tropical legumes project occupied 29% while those released earlier and thus excluded from the TL3 project occupied 38% of bean plots established in *meher* 2016 (Figure 4.4). The landraces covered about 33 % of the plots.

²⁵ *For the DNA result adoption rate is calculated out of the total seed samples (sub sample of the total plots) collected from farmers. For farmers, it is calculated based on farmers' response on whether the variety is improved or not for all plots

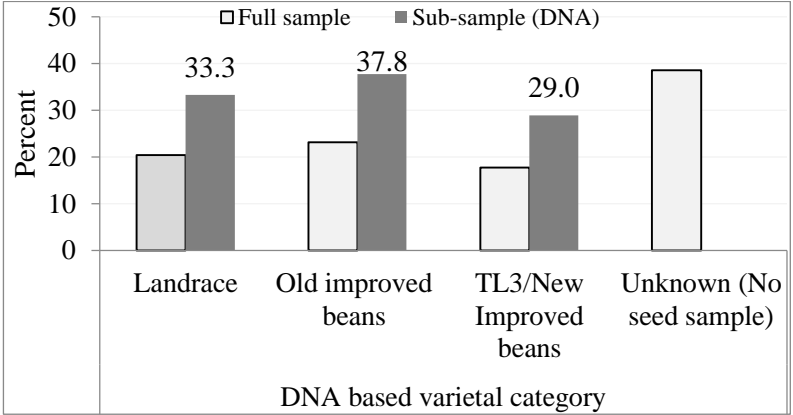


Figure 4.4 Adoption based on DNA result (Full sample includes plots with no seed sample)

There was a significant association ($p=0.00$) between location (regional state) and type of varieties (adoption category) grown (Table 4.4). While most (54%) of the seed samples (plots) in BNSG are of the TL/New improved varieties, the corresponding figure for Amhara (18%) is the least. Oromia and SNNP had comparable proportion of their plots cultivated to these new varieties. None the less, it is important to note that the regional states are not equally important in terms of their contribution to the national bean production. BNSG contributes the least (only one per cent) of the national bean production compared to SNNP (33%) and Oromia (41%) where the primary project intervention districts were found. Amhara region, where bean cultivation was introduced relatively late, contributes about 23 per cent of the total production, and seems to have a late-comer advantage of growing both the new and old improved bean varieties.

Table 4.4 Proportion of cases (seed samples) and area occupied by different category of bean varieties (by region)

Adoption category	Subsample (DNA analysis) (%)					Full sample (%)				
	Proportion of cases					(seed sample) (%)				
	Amhara (n=222)	BNSG (n=26)	Oromia (n=454)	SNNP (n=127)	Total (N=829)	Amhara (n=276)	BNSG (n=43)	Oromia (n=757)	SNNP (n=274)	Total (N=1350)
Landrace	10.8	15.4	40.7	49.6	33.3	8.7	9.3	24.4	23.0	20.4
Old improved	71.6	30.8	27.8	15.7	37.8	57.6	18.6	16.6	7.3	23.2
TL3/New Improved	17.6	53.8	31.5	34.6	29.0	14.1	32.6	18.9	16.1	17.8
Unknown (No seed sample)	-	-	-	-	-	19.6	39.5	40.0	53.6	38.6
Pearson chi2(6) 167.9762 Pr = 0.000					Pearson chi2(9) = 263.9982 Pr = 0.000					
Adoption category	Proportion of area from the sample (%)					Proportion of area from the sample (%)				
	Amhara (72.3ha)*	BNSG (13.1ha)	Oromia (134.5ha)	SNNP (46.3ha)	Total (266 ha)	Amhara (89.7ha)	BNSG (24ha)	Oromia (233ha)	SNNP (103ha)	Total (449ha)
	[63,967. 24]	[5,382.]	[116,696.9 1]	[98,324. 41]	[290,202. 43]	[63,967. 24]	[5,382.]	[116,696. 91]	[98,324. 41]	[290,202. 43]
Landrace	10.7	10.5	43.1	54.7	34.7	8.6	5.8	24.8	24.7	20.6
Old improved bean	71.1	27.4	27.9	14.2	37.2	57.3	15.1	16.1	6.4	22.0
TL3/New Improved	18.2	62.1	29.1	31.1	28.1	14.6	34.4	16.8	14.1	16.6
Unknown (No seed sample)	-	-	-	-	-	19.4	44.7	42.4	54.8	40.7

* Refers to the total area in ha for the respective region. *Figures in () are total area in hectare under bean computed from the study sample. ** Figures in [] are total (national) bean area in hectare for the 2016 cropping season from CSA.

The old improved varieties are less popular in the SNNP, but dominant in Amhara region. The landraces, on the other hand, still have relatively sizeable presence in SNNP (49.6%) and Oromia (40.7%) compared to Amhara (10.8%) and BNSG (15.4%). A slower diffusion trend in the intervention regions might need an in-depth examination although a number of propositions can be stated. Issues associated with poor varietal identification can possibly play a role as farmers are inclined to grow what they think is improved even if it is not according to the DNA result. Results also revealed that farmers who grow Mexican 142, an old variety, identified it as local, which implies that they intentionally chose it as their preference perhaps due to lack of an alternative. The regions are apparently too large and it may take some time before the diffusion reaches a larger proportion of farmers. Specifically, Amhara region relatively located far away from Melkassa Agricultural Research Center might lack early access to seed of new varieties.

4.5 Adoption of improved varieties across socioeconomic groups

We have tried to examine the relationship between the socioeconomic variables and the adoption categories based on DNA result (sub sample that excludes the unknown varieties) as well as using the full sample, which includes the unknown varieties, for comparison purpose. The result in Table 4.5 indicates that there is strong association between adoption of the different sets of bean varieties and the socioeconomic status ($p=0.004$) of the household. The use of old improved varieties is popular across all the wealth quantiles. Yet, in relative terms, well-off farmers (quantile 4 and 5) use a relatively more TL/new varieties in their portfolio than the other three quantiles (the poor). This might suggest that the well-off had better access to the new variety seed than the poor. Nonetheless, in absolute terms the proportions of the new varieties constituted in each quantile looks comparable with the range (26% to 31%) being small (Table 4.5). Despite, the small difference, all groups seem to have had access to the seed one way or another. This is probably due to the farmers-to-farmer social networks as most of the farmers (nearly 70%) depend on other farmers as information source.

Table 4.5 Relationship between adoption and socioeconomic characteristics of the household head

Socioeconomic variables	Sub sample (DNA analysis) (%)			Pearson Chi2 (p value)
	Land-race	Old improved bean variety	TL3/ New Improved variety	
Wealth Quantile of sample farmers				
Quantile 1	24.8	46.6	28.6	0.182
Quantile 2	34.9	36.2	28.9	
Quantile 3	38.7	35.4	26	
Quantile 4	31.3	38.1	30.6	
Quantile 5	36	33.1	30.9	
Gender				
Female	29.4	38.2	32.4	0.728
Male	33.6	37.7	28.6	

4.6 Diffusion pathways for improved varieties

Important bean technology diffusion pathways involve horizontal (peer-to-peer through face-to-face interactions, word of mouth, farmer meetings) as well as vertical channels. Nearly 80 percent of the farmers get information from other farmers and family members while only 16 per cent got from the extension service (Figure 4.5 and Table 4.6). Research as a direct source of agricultural related information was less likely to be reported in all the four regions.

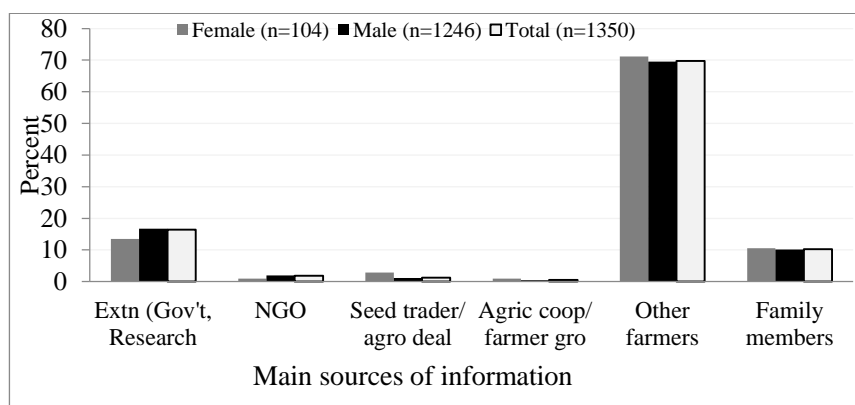


Figure 4.5 Relationship between source of information and gender of the household head (plot manager)

There are regional differences in accessibility to extension service by bean farmers. It was relatively more accessible to farmers in the SNNP as well as to farmers who were relatively well-off (those in the wealth quantile 3, 4 and 5). Although, most of the farmers who used the government extension as source of information grew improved varieties (new or old), there were also farmers who use this source but still grow landraces. In majority of the cases, (for 68% of the old and 63% of the new improved varieties), other farmers were main source of information. Irrespective of the region and farmers' socioeconomic status, other farmers remain an important source of information. Farmers who served as information source might have been reached either through the government extension or other networks of relationship. The aggressive seed dissemination program of the TL project is likely to have contributed to this farmer-to-farmer information exchange. The project did a lot in seed dissemination using small pack to enhance faster diffusion of newly released improved varieties (Endeshaw et al., 2018). The long period (ten years) of the project also enabled diffusion through social network to take effect.

Table 4.6 Relationship between main source of information and (a) socioeconomic status, (b) region

Major source of information	Wealth Quantiles (%)					Total (n=1,350)
	Q1 (n=301)	Q2 (n=262)	Q3 (n=294)	Q4 (n=236)	Q5 (n=257)	
Extension Research (Gov't)	14.62	12.98	16.67	20.76	17.9	16.44
NGO	3.65	1.91	0.34	1.69	1.56	1.85
Seed trader/agro deal	1.99	1.15	0.68	1.27	1.17	1.26
Agric. coop/farmer groups	0	0	0.34	1.69	0.78	0.52
Other farmers	68.44	70.61	73.47	65.25	70.04	69.7
Family members	11.3	13.36	8.5	9.32	8.56	10.22
<i>Pearson chi2(20) = 32.4213 Pr = 0.039</i>						
Major source of information	Regional States (%)				Total (n=1,350)	
	Amhara (n=276)	BNSG (n=43)	Oromia (n=757)	SNNPR (n=274)		
Extension Research (Gov't)	11.23	16.28	12.68	32.12	16.44	
NGO	0.36	4.65	2.91	0	1.85	
Seed trader/agro deal	1.09	2.33	1.72	0	1.26	
Agric. coop/farmer groups	1.45	0	0.26	0.36	0.52	
Other farmers	71.01	62.79	74.24	56.93	69.7	
Family members	14.86	13.95	8.19	10.58	10.22	
<i>Pearson chi2(15) = 96.2987 Pr = 0.000</i>						

Results in Table 4.7 indicated that information through Government extension, NGOs and research is delivered through trainings while information from other farmers, cooperatives, traders, radio and mobile print media is through advice. Field days, visits and demonstrations, except in case of research station, are very rare means of accessing information for farmers.

Table 4.7: Frequency and ways through which the farmers access information from the listed sources

Information access ways	Information sources and farmer information access percentage								
	Government extension	Research	Coop Union	Other farmer	Traders/dealers	NGO	TV/Radio	Mobile print media	Mobile phone
Demonstration	3.22	13.04	0	0.33	0	0	6.45	18.52	5
Training	43.24	34.78	12.36	2.76	0.91	58.97	4.44	14.81	0
Advice	51.48	43.48	86.52	89.42	98.78	41.03	87.9	59.26	95
Field day	0.39	4.35	0.56	3.2	0.3	0	1.21	7.41	0
Field visit	1.67	4.35	0.56	4.3	0	0	0	0	0
How often the farmer accesses information (%)									
Every month	19.18	0	10.11	61.19	15.5	10.26	48.4	48.15	35
Every season	53.67	8.7	36.52	30.43	46.81	20.51	38.7	37.04	45
Once a year)	27.16	91.3	53.37	8.38	37.69	69.23	12.9	14.81	20

Farmers, followed by government extension, play a significant role in diffusing information. When it comes to seed, most of the new varieties tend to reach farmers via formal sources including the government extension and NGOs. The same sources are used to get old improved varieties, yet, in the case of old varieties, the informal sources (farmer groups, traders and other farmers) tend to dominate (Table 4.8). Clearly, the sources of improved varieties (old or new) are well spread across formal and informal seed channels as important dissemination pathways that explain differences in the adoption of improved bean varieties in Ethiopia. Some of the varieties identified as landraces by the DNA analysis are observed to be supplied by both formal as well as informal sources although the data showed that they are mainly coming from the informal sources. This is likely associated with farmers' identification

of some of these varieties as improved, when they are not according to the DNA analysis.

Table 4.8 Formal and informal source of improved varieties grown on meher 2016

<i>Source of seed</i>	Sub sample (DNA analysis) (%)			Pearson Chi2 (p value)
	Land-race	Old improved bean variety	TL3/ Improved variety	
Extension (Gov't)	25.6	34.1	40.3	0.010
NGO	11.1	44.4	44.4	
Seed trader/ agro deal	7.7	53.8	38.5	
Agric. coop/ farmer group	0.0	75.0	25.0	
Other farmers	36.4	37.3	26.3	
Family members	34.1	40.9	25.0	

4.7 Important traits and the performance of the existing varieties as perceived by farmers

A bean variety has a bundle of attributes related to production and consumption that provide value to the consumer. Each variety supplies a combination of attribute levels that attracts the farmer when deciding which variety to grow. The demand for the attribute combination is specific to the farmer and varies with farmer characteristics and production context. Each respondent was asked to rate each attribute on scale of 1-5 based on the importance attached; whereby one represents ‘not important at all’, five, extremely important. In follow up questions, respondents identified their most preferred currently grown variety and another variety recently stopped growing. Then a question was included to rate the variety performance in terms of each trait (consumption/ production/ marketing) on a scale of 1-5 where one is very poor and five excellent. If a trait receives a low performance rating and highly important rating, this indicates that breeders need to improve levels of that trait. The overall rating of a producer’s satisfaction (or a “satisfaction value”) with a variety is calculated by multiplying the performance rating by the importance value (rating) attached to the trait. The specific traits under each bundle (consumption/ production/ marketing) is indicated in Table A3.6b

The results, in general, indicate that yield and earliness under the production trait, as well as all the marketing and processing traits (except storability) are important as these are highly preferred traits across the regions with average score ranging from 3.6 for grain price in Amhara up to 4.4 for ease of shelling in BNSG (Table A3.6b). Overall, the consumption traits seem to be more important in BNSG and SNNP region where bean consumption is relatively higher. Yield among the production, and market demand from the marketing traits are the attributes having the highest average score (3.9 out of 5.0) compared to all the other attributes (Table A3.6b). Bean varieties currently grown by the respondents are primarily valued for yield (16.6 out of 25.0) followed by maturity period and market demand both of which have similar score of 15.9 out of 25 (Table A3.6b). The following most important attributes attached to these varieties were grain price (15 out of 25), color of the beans (14.7/25), ease of shelling and nutrition values (14.6/25 each) and taste of the beans (14.4/25) .

Table 4.9 presents the weighted average satisfaction level given to the two categories of varieties (i.e currently grown vs recently abandoned varieties) for the three bundles of traits: production, marketing and consumption traits. Based on the percentage of the mean overall score, traits associated with marketing and processing stand out as the most valued bundles of attributes (accounting for about 57% (14.3/25) of the highest possible average score) in the varieties currently grown by the bean farmers (Table 4.9). The corresponding value for the production traits (about 51% (12.7/25)) and consumption traits (about 51% (12.8/25)) are comparable. The results are also consistent across regions. While farmers from the SNNP value all the three bundles of traits in the varieties they grow almost in a comparable manner, farmers in Amhara regional state seem to perceive lower performance of their varieties in terms of production and consumption traits. In BNSG, consumption trait is the next most important bundle after marketing. The performances of varieties on consumption and production traits in Oromia are quite comparable.

Table 4.9 Farmers' satisfaction level^{NB} for different traits of varieties currently grown and those recently abandoned (Weighted score)

Regional State	Parameter	Traits for variety currently grown (Score range 1-25)			Traits for variety recently abandoned (Score range 1-25)		
		Production	Marketing & Processing	Consumption	Production	Marketing & Processing	Consumption
Amhara	Mean	11.5	14.1	10.5	10.3	10.9	10.9
	SD	3.5	4.5	2.6	3.4	3.2	2.7
	Max	21.4	25	20.3	18.9	19.3	17.7
	Min	5.7	6	3.4	4.4	6	4.1
	Percent*	46.0	56.4	42.0	41.2	43.6	43.6
BNSG	Mean	10.8	14.2	13.2	9.2	11.2	11.7
	SD	3.7	3.9	2.6	2.4	3.3	3.4
	Max	18.3	18.8	19.6	14.1	19	19.1
	Min	6.7	8	9.6	5.9	7	5.6
	Percent*	43.2	56.8	52.8	36.8	44.8	46.8
Oromia	Mean	12.9	14.3	13.2	10.6	11	10.9
	SD	5.3	5.1	4.6	5.3	5.1	4.4
	Max	25	25	25	25	25	24.3
	Min	3	3	3	2.7	2.8	1.9
	Percent*	51.6	57.2	52.8	42.4	44.0	43.6
SNNP	Mean	13.7	14.7	13.8	10.1	10.2	11
	SD	4	4	4.8	5.3	5.4	5.9
	Max	22.3	23.8	24.3	21.1	21.3	23.6
	Min	5.9	6	5.7	2.7	2.3	2.3
	Percent*	54.8	58.8	55.2	40.4	40.8	44.0
Total	Mean	12.7	14.3	12.8	10.4	10.9	11
	SD	4.8	4.8	4.4	4.9	4.8	4.4
	Max	25	25	25	25	25	24.3
	Min	3	3	3	2.7	2.3	1.9
	Percent*	50.8	57.2	51.2	41.6	43.6	44.0

^{NB}The original score given for the traits (1-5) are weighted by the value attached to the trait itself as in Table A3.6a. The weighted score ranges from 1-25, 1 least important, 25 most important

*Percent=(Weighted mean score/ The highest possible weighted score)*100; the denominator, 25, is the highest possible weighted score.

Varieties currently grown seem to outperform the ones that farmers have recently dropped in all traits but more so for market and processing traits (14.3 vs. 10.9) and production traits (12.7 vs. 10.4) (Table 18). This result highlights the importance of variety properties in variety choice by farmers and reflects the fact that breeding has generally improved the levels of traits that is contributing to positive gains in farmers levels of satisfaction with varieties. However, there is very limited scope for trait trade-offs as shown in the correlation matrix indicated in Table 4.10. There is high positive correlation between the bundles of production, and marketing traits- this implies that farmers

who value one category (e.g. production) of traits highly is likely to attach high value on the other category (marketing). This is because higher yielding capacity of the variety contributes to profitability of bean production (Katungi et al., 2011) and thus, a preference for market oriented producers.

Table 4.10 Correlation matrix between the three bundles of traits

Bundles of traits	Consumption traits	Marketing & processing	Production traits
Consumption traits	1.00		
Marketing & processing	0.62 (0.00)	1.00	
Production traits	0.67 (0.00)	0.95 (0.00)	1.00

Note: numbers in parenthesis are *p values*; the matrix is generated using the overall (sum of) weighted scores of each parameters under the three bundles of traits

4.8 Analytical framework and Estimation strategy

4.8.1 Varietal age and varietal replacement

The rate at which farmers replace their varieties can provide an important piece of information on the newness of the variety grown and the speed with which new varieties are diffused, or how soon they replace the old ones. The rate at which varieties are replaced (turnover rate) is also important in understanding the longevity of disease resistance in varieties and the vulnerability of a crop to disease epidemics. The varietal replacement rate can also affect productivity and contribute to yield variability. There is also an emphasis by economists on the importance of varietal turnover as a means of demonstrating the high returns to public investment in crop improvement (Alston et al. 2000; Day-Rubenstein et al. 2005; Walker and Alwang 2015). Information on varietal turnover is also important in understanding the performance of seed system in supplying seeds of the quality required by farmers and the dominance (or not) of varieties developed by plant-breeding in a given cropping system (Spielman and Smale, 2017).

The characterization of a given variety as “new” or “old” can be arbitrary (Brennan 1984). For this reason, researchers have proposed several precise definitions that measure rates of varietal turnover. A measure proposed by Gustafson (1963), tries to construct an index of varietal newness by comparing the proportion of area planted to presently grown varieties with the proportion planted to the same varieties in earlier period. The limitation with this method is that it is sensitive to the choice of target period for turnover of varieties; and requires long time series data to construct the index for any given year. The WAVA proposed by Brennan and Byerlee (1991) is commonly used as a relatively better measure of the varietal turnover/ replacement mainly because it accounts not only for the time (between release and first use) but also the areas share (extent of adoption) assumed by the variety. For a given year, the WAVA is computed as

$$WAVA_t = \sum_i p_{it} R_{it}$$

Where p_{it} is the proportion of the crop’s area cultivated in variety i in year t , and R is the number of years at time t since the release of variety i . To calculate the WAVA, the first step is to choose an appropriate geographical unit of observation (farm, village, state, province, nation, region, and world) and year (or time series) for analysis. Then, record all varieties grown by the household and the number of years since variety release for each. Finally, we calculate the sum over all varieties of the product of the number of years since variety release and the area share planted to the variety, for each observation of year and geographical unit.

In this study, we used (area)-weighted average variety age (WA or WAVA) to compute varietal turnover. WAVA considers time (from release to survey year) and space (area covered) dimension of a given variety. The method makes it possible to estimate the turnover at different units of analysis such as at household level, or at a given geographical domain like national, region, district, and so on. Accordingly, we have tried to look at the rate at which farmers change the improved varieties they grow following the indicator known as (WAVA). The computation is done only for the sub sample of plots from which seed samples were collected and subjected to the DNA analysis.

4.8.2 Time lag between variety release and adoption

Studies by Griliches (1957) and Mansfield (1961) showed that the rate of adoption of a technology is a function of the extent of economic merits (profitability) of the technology, the amount of investment required to adopt the technology and the degree of uncertainty associated with it and availability of the technology. The rate and speed of improved technology adoption depends on the availability of improved technologies, which involve the generation and dissemination of these technologies to users (e.g., farmers).

We apply duration analysis to identify the factors that affects the time until a farmer replaces one variety by another. Duration analysis is sometimes referred to as survival analysis or event history analysis. Duration data can be thought of as being generated by what is called a ‘failure time process. A failure time process consists of units—individuals, governments, countries, and so on— that are observed at some starting point in time. These units are in some state – for example, the individual is non-adopter, the government is in power, a country is at peace, and so on – and the same units are then observed over time. At any given point in time, these units are ‘at risk’ of experiencing some event, where an ‘event’ essentially represents a change or transition to another state – the individual become adopter, the government falls from power, a country is at war, and so on. After the event is experienced, the unit is either no longer observed or it is at risk of experiencing another kind of event. In some circumstances, units are not observed experiencing an event; that is, no transition is made from one state to another while the unit is being observed – the individual remains non-adopter, the government remains in power, the country remains at peace, and so on. As we will see, we call these cases ‘censored’ since we do not observe the subsequent history of the unit after the last observation point. This process is called a ‘failure time process’ because (a) units are observed at an initial point in time, (b) the unit survives for some length of time (or spell), and (c) then the unit ‘fails’ or is ‘censored’.

Hazard-based duration models that are flexible for many real-world situations are ideally suited to modeling duration data (Yannoutsos, 2009²⁶). Such models focus on an end-of-duration occurrence (such as time to technology adoption) given that the duration has lasted to some specified time (Kiefer, 1988²⁷; Hensher and Mannering, 1994²⁸).

Probability theory plays a fundamental role in duration analysis. Rather than focusing explicitly on the length of duration, duration analysis provides estimates of the probability that the state occupied by an individual will end in the next short time interval given that it has lasted to that period. Thus, if T is a non-negative continuous random variable representing the duration of stay in a given state - in the case of adoption, the time a farmer waits before adopting - the probability of an individual not adopting until or beyond time t is given by the survival function, $S(t)=Pr(T\geq t)=1-F(t)$ while the hazard function is defined as the limiting value of the probability that T lies between t and $t+\Delta t$, conditional on T being greater or equal to t , divided by the interval Δt , as Δt tends to zero, $h(t) = \lim_{\Delta t \rightarrow 0} \left(\frac{Pr(t \leq T < t + \Delta t | T \geq t)}{\Delta t} \right) = \frac{f(t)}{S(t)}$ where $F(t)$ and $f(t) = dF(t)/dt$ are the corresponding cumulative distribution and probability density functions. In technology adoption studies, the hazard function therefore represents the probability that a farmer adopts the new technology at time t , given that he or she has not adopted before t .

Parametric, semi-parametric and non-parametric duration models have been used to study the duration for occurrence of an event and the associated factors (Aryasepehr et al., 2002²⁹). All of them will be used in this study and explained as follow.

²⁶ Yannoutsos CF (2009). Modeling AIDS survival after initiation of antiretroviral treatment by Weibull models with change-points. New York. Springer. (springer.com/article/10.1186/1758-2652-12-9/fulltext.html).

²⁷ Kiefer NM (1988). Economic duration data and hazard functions. *J. Econ. Lit.*, pp. 646-679

²⁸ Hensher DA, Mannering FL (1994). Hazard-based duration models and their application to transport analysis. *Transport Rev.*, 14(1): 63-82

²⁹ Aryasepehr S, Ahmadzadeasl M, Akhavanfard S, Jafarian S, Saberidesfidvajani M, Saberifard M (2002). Design and analysis of survival studies. In: Ahmadzadeasl M, editor. Noor-e-Danesh Institute. Tehran.

Parametric Models

Parametric models are more efficient in their use of data because they do not reject what happens to covariates where adoptions occur. Functional forms that have been used for parametric duration models include the Exponential, Weibull, Gompertz, logistic, lognormal and log logistic probability distribution (Cleves et al., 2010)³⁰. Among all of them, the two most commonly used are the Exponential and Weibull distributions. However, some studies in marketing have used Gompertz distributions (Jain and Vilcassim, 1991³¹; Vilcassim and Jain, 1991)³² (See Table 4.10a).

The Weibull distribution is characterized by the hazard function:

$$h(t) = \lambda P t^{p-1}; t > 0, \lambda > 0 \text{ and } p > 0$$
$$\lambda = e^{x\beta}$$

where λ is the location parameter and p is the shape parameter because it determines whether the hazard is increasing, decreasing, or constant over time; x refers to covariates included in the duration model, and β represents coefficients to be estimated. Thus, the Weibull model exhibits a hazard rate that is monotonically increasing with time when $p > 1$, and monotonically decreasing with time if $p < 1$. When $p=1$, it exhibits a constant hazard rate and collapses to the exponential distribution model. The exponential is nested in the Weibull distribution. The hazard function of exponential distribution assumes a constant hazard rate: $h(t) = \lambda$, where $\lambda > 0$ implying that the hazard function is duration independent. A constant hazard rate ($h(t)$), in our context, means that the probability of being aware of or adopting a technology in a given time interval is the same regardless of how long the individuals remain unaware/non-adopter. The constant hazard

³⁰ Cleves, M. A., W. W. Gould, R. G. Gutierrez, and Y. V. Marchenko. 2010. An Introduction to Survival Analysis Using Stata. 3rd ed. College Station, TX: Stata Press.

³¹ Jain DC, Vilcassim NJ (1991). Investigating household purchase timing decisions: a conditional hazard function approach. *Marketing Sci.*, 10(1): 1-23.

³² Vilcassim NJ, Jain DC (1991). Modeling purchase-timing and brand switching behavior incorporating explanatory variables and unobserved heterogeneity. *J. Marketing Res.*, 28: 29-41.

assumption defines a family of probability distribution indexed by one parameter (λ).

The survivor function for the Weibull model can be defined as: $S(t) = e^{(-\lambda t^p)}$

The hazard rate of Gompertz model can be defined as: $h(t) = \lambda e^{\gamma t}$, where $\lambda = e^{x\beta}$ and γ is a shape parameter; x and β are as defined earlier. The survivor function is: $S(t) = e^{-\lambda \gamma^{-1} (e^{\gamma t} - 1)}$; the Gompertz model exhibits a hazard rate that is monotonically increasing with time when $\gamma > 1$, and monotonically decreasing with time if $\gamma < 1$. When $\gamma = 1$, the hazard is flat and we have the exponential model.

Table 4.10a Parametric duration models for explaining the adoption lags

	Exponential	Weibull	Gompertz
Cumulative density, $F(t)$	$1 - e^{(-\lambda t)}$	$1 - e^{(-\lambda t^p)}$	$1 - e^{-\lambda \gamma^{-1} (e^{\gamma t} - 1)}$
Survival function, $S(t)$	$e^{(-\lambda t)}$	$e^{(-\lambda t^p)}$	$e^{-\lambda \gamma^{-1} (e^{\gamma t} - 1)}$
Hazard function, $h(t)$	λ	$\lambda p t^{p-1}$	$\lambda e^{\gamma t}$

Semi parametric model

One potential problem with parametric models is that we are still having to make an assumption about the distribution of the disturbances and, hence, the distribution of the survival times. As a result, we might want to look for a modeling strategy that does not require any assumption about the distribution of the survival times. The key reason to removing the distributional assumption is that, because events occur at given points in time, they can be ordered. We can then conduct our analysis using the ordering of the survival times exclusively. Obviously, this would be an extremely inefficient use of the data. The advantage of this approach, though, is that there is no need to make an assumption about the distribution of survival (failure) times. Such an approach leads to semi parametric duration analysis and, specifically, to the Cox model if a conditional logit model is fit. It important to note that time plays no role in this analysis other than indicating the ordering of the observations. The approach to duration analysis goes under the name of semi parametric analysis. The reason is that this approach is non-parametric when it comes to time, but it is still parametric in the sense

that we are still parameterizing the effect of x . In other words, there is still a parametric component (logit, probit, etc.) to the analysis.

In Cox proportional hazard model (Cox, 1972³³), the hazard is assumed to be

$$h(t) = h_0(t)e^{\beta x}$$

The Cox model provides estimates of β but provides no direct estimate of $h_0(t)$ – the baseline hazard. Formally, the function $h_0(t)$ is not directly estimated, but it is possible to recover an estimate of the cumulative hazard $H_o(t)$ and, from that, an estimate of the baseline survivor function $S_o(t)$.

Semi-parametric analysis is nothing more than a combination of separate binary-outcome analyses, one per failure time, while parametric analysis is a combination of several analyses at all possible failure times.⁷ Parametric analyses will be more efficient (standard errors will be smaller) so long as the distributional assumptions that are made are appropriate. When no covariates are present, semi parameric methods such as the Cox model will produce estimates of relevant quantities such as the probability of survival past a certain point in time that are identical to the nonparametric estimates. If the covariates are qualitative in nature, parametric and semi-parametric models should yield more efficient tests and comparisons of the groups than nonparametric methods, and these tests should agree. Should the tests disagree, then this is a signal that some of the assumptions made by the parametric and semi-parametric models are incorrect.

Nonparametric Models

The non-parametric estimates provide the unconditional probability of surviving- remaining without experiencing an event (survival function), or likelihood of experiencing the event (hazard function) at time t .

An entirely non-parametric approach does away with assumptions about how each unit's observed value determines the probability of failure.

³³ Cox, D. R. 1972. Regression models and life-tables (with discussion). Journal of the Royal Statistical Society, Series B 34: 187–220.

Nonparametric methods often have difficulty with duration data because they cannot deal adequately with censoring and other issues. That said, when there are no independent variables, or the independent variables are qualitative in nature, then we can use certain nonparametric methods to estimate things like the probability of survival past a certain point in time. Nonparametric models do not make assumptions about (a) the distribution of failure times or (b) how independent variables change survival experiences.

Empirical estimation

In a survival analysis, after a subject is exposed to an event, it can face three possible outcomes at the time of the study. The first is experiencing the event, the second, not experiencing the event up to the study time (censored), and the third is when the subject is not tracked (lost) at the survey time. In this study, respondents were not asked whether they were aware /adopters of each and every one of the improved bean varieties or not. Rather we relied on whichever improved variety the respondents reported as aware and/or started using it. It is important to note here that the improved varieties considered are those whose true identity is identified based on DNA analysis. Since we are considering only those respondents who, based on their reporting, were aware on the one hand and started to cultivate the improved variety, on the other, all of them experienced the event (awareness/adoption). Those farmers, who did not report the awareness/adoption of the improved varieties (identified based on the DNA result), were not considered in the analysis. As the improved varieties were released at different point in time, it is difficult to associate any defined time lag (between release and awareness/adoption) for those who did not report any one of the improved varieties. Therefore, they are dropped from the analysis.

Therefore, the event (x) is either to be aware of an improved bean variety or start cultivating (adopt) it. The time is measured starting from the year the improved variety was released. Respondents were asked about the first time they came to learn (know) about the variety and start cultivating it. The year reported as the first time of awareness/adoption of a particular variety is deducted from the year of release to get the

awareness/adoption lag. Accordingly, results in Table A3.6 shows that there were negative lags to awareness (about 11% of the total observation) and to adoption (8% of the total observation) due to farmers reporting a year of awareness/adoption much earlier than the year a variety was released. Thus, we present the result in three scenarios to deal with the possibility of measurement error in the data.

In the first scenario we used the original data as it is (with negative lags). This likely happens when the farmer considers an improved variety as local. In the second scenario, we dropped all the negative lag years from the data. Finally, in the third scenario, the negative lags from 1 to 10 were replaced by their absolute (positive) values and for those below negative ten (i.e., -11, -12, ...) they were replaced by the absolute value of the mean for those observation. There were 7% and 5% of the total observations for awareness lag and adoption lag respectively with negative values extending from 1 to 10. For negative values extending from 11 to 36 (for awareness) and 11-27 (for adoption) there were 4% (awareness lag) and 3% (adoption lag) of the total observations (Table A3.6).

4.8.3 Results and Discussion

4.8.3.1 Varietal replacement

Figure 4.6 presents the area weighted average varietal replacement (turnover) rate disaggregated by region. The average area weighted variety age is 19 years—meaning that it takes on average close to two decades before a given improved variety is replaced from a farming community by a new one. At regional level, the area weighted average age of improved variety ranges from 8.8 years in SNNP to 31 years in Amhara (Figure 4.7). The fact that most of the bean area in Amhara region was covered with the older bean varieties (see Table 4.4) could be one possible indication of slower (longer) replacement rate in the regions. The comparatively shorter varietal replacement rate in the two regional states (SNNP and Oromia) could possibly be attributed to, among other, the interventions by the TL project for over a decade together with the growing market demand for different market classes of common bean. There has also been aggressive promotion activities

by the EIAR since 2004 through technology scaling up initiative (not specific to common beans, though) which exposed farmers in these important common bean production areas to the new varieties.

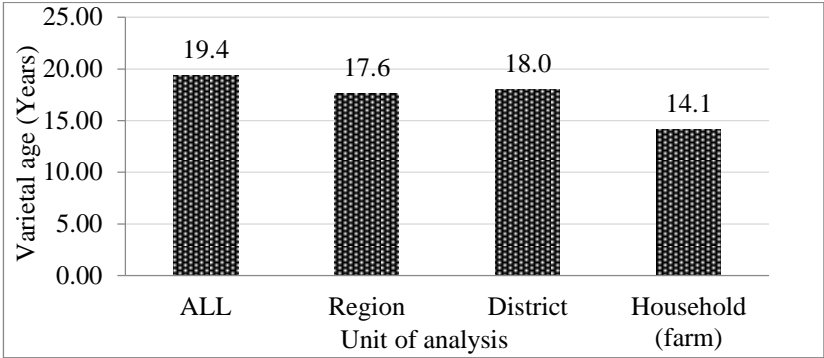


Figure 4.6 Average varietal age (turnover) of bean varieties based on different units of analysis

We also tried to see the speed of varietal replacement at districts and farm (household) level. Accordingly, the estimate based on farmer report showed that the average number of years a bean variety is cultivated by the farmers is about 8 years ($SD\pm 7.0$). The maximum number of years was more than 30 years, which was mainly for varieties that the farmers identified as local (Table A3.7). Farmers in the SNNP region had relatively shorter (about 9 years) varietal replacement rate while in Amhara regional state farmers tend to keep a variety for long up to 31 years before they change into a new ones (Figure 4.7 and Table A3.7). However, for a few of the improved varieties, such as Nazareth³⁴, farmers reported longer years than the age the variety has been in existence when identified as landraces/ local. When farmers confuse an improved variety for local, the number of years they report will likely be misleading. This will be evident only when the variety is precisely identified by techniques such as the DNA genotyping.

³⁴ Farmers reported 17 years, which was in fact 12 years old at the time of the survey.

Obviously, farm level rate of varietal replacement is relatively shorter (14 years) compared to the larger geographical domain. Otherwise, the turnover rate at region and district level is nearly the same.

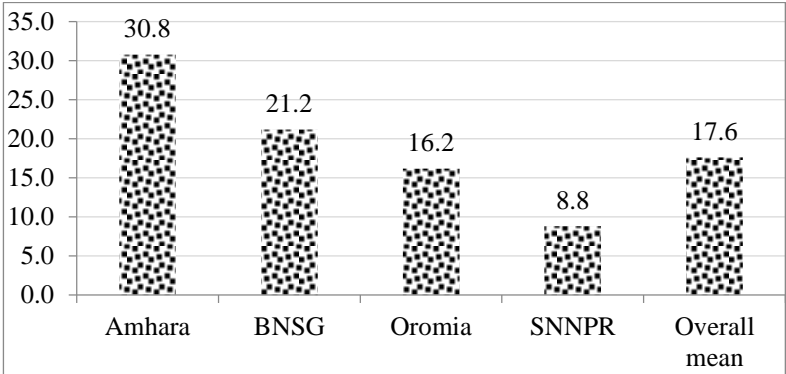


Figure 4.7 Average varietal age (turnovers) of common beans (in years at regional level)

4.8.3.2 Time lag between release and adoption of bean varieties

Figure 4.8 indicates that awareness about an improved variety and its adoption was intensive after 2006. The pick of awareness and use of both the new improved varieties (released and/or promoted during the TL project period) and the old ones (released earlier than 1990) was observed during the period when the Tropical Legumes project (TL) was implemented, that is, between 2006 and 2016.

The number of households who adopted the improved bean varieties for the first time increased during the period 2006 and 2016. It is also important to note that the landraces followed similar trend. This could be likely a spill over where most farmers got better opportunity to learn about bean varieties during the TL period. Nonetheless, farmers’ decision to grow the local varieties might have come from inability to make distinction between the local and improved variety. This is implied from the result indicated earlier (in Figure 4.2) where farmers misidentified the local varieties they grew by the name of improved ones.

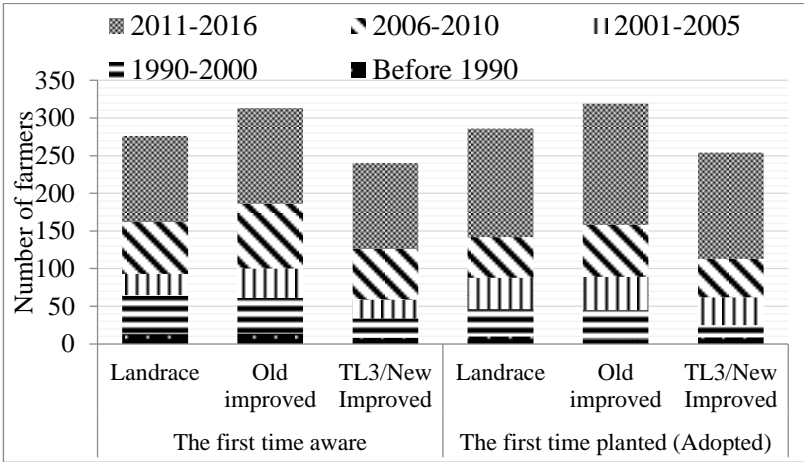


Figure 4.8 The first year farmer heard about and planted a bean variety they grew (Based on DNA result)

On average, it takes more than 20 years from the time of release until a typical bean farmer becomes aware and start to cultivate improved bean varieties (Table A3.7). The significance of the TL intervention in facilitating the knowledge and access to the newly released bean varieties is apparent from the result in Table A3.7 (for each variety) and Figure 4.9 (for improved varieties categorized as old and new). If we simply observe the range of time to awareness for the varieties released before 2000, that is 14 to 34 years, and 2 to 7 years in the case of those released after 2000, this is clear indication that the intervention of the TL project had meaningfully reduced the lag. Common bean varieties released between 2003 and 2016 when the study was conducted generally had short time lag up to awareness as well as adoption. Comparatively, varieties released before 2000, which were relatively older, had longer lag time to awareness as well as adoption. A similar trend is observed with regard to the lag between release and adoption of the improved bean varieties.

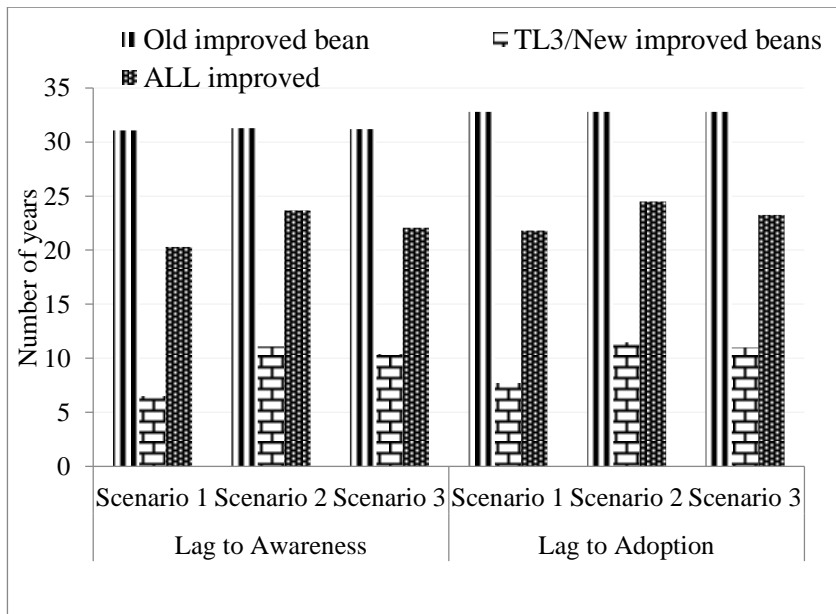


Figure 4.9 Average lag in years from release to awareness| adoption of old and new improved bean varieties

The result also indicates that the lag from awareness to adoption is small, which suggests that awareness is likely to translate to adoption in a short period. This is probably because of less externality that would otherwise influence people to wait to learn from others. The divisibility of the technology favors farmers to try out the variety and thus do not have to wait to learn from others. So, a lot needs to be done in reducing the lag to awareness. The short time span between awareness of a variety and use of it indicates that the older varieties, which have been shelved for long were well introduced into the production system due to the intervention. It can be argued that both the new and the old varieties would have remained longer on the shelf in the absence of an intervention such as the TL project. In fact, the unique feature of the project was that it engaged a number of actors involved in the bean production and marketing chain. Seed production, distribution, extension service (mainly through training and promotion activities),

and marketing of the grain were among the most important components embedded in the project.

4.8.3.3 Econometric results

The non-parametric estimates provide the unconditional probability of surviving- remaining without experiencing an event (survival function), or likelihood of experiencing the event (hazard function) at time t . The result from the hazard function (Figure 4.10) indicates that the probability of being aware of the improved varieties in around five years after release is about 2.5%. This likelihood of awareness did not pick up fast until the 20th year. It takes about five to seven years before the early adopters become aware of new improved bean varieties. The hazard rate shows the probability of the event (likelihood of being aware of the variety) grew from about 3% (at about the 5th year) to around 19% (close to the 40th year) in a time of more than 20 years. This is a huge delay given the R&D time (at least 7 years) taken to develop an improved variety. Likewise, the probability of adoption also followed similar trend over time. As expected, at any time t , adoption has a lower likelihood (probability) than that of awareness. The pattern suggested a shorter lag that those who are aware are more likely to decide, in a short while, to grow the varieties (Figure 4.10). Moreover, the steep growth in the likelihood of awareness and adoption after the 20th year onwards suggest the presence of a particular intervention, which drove such a shift.

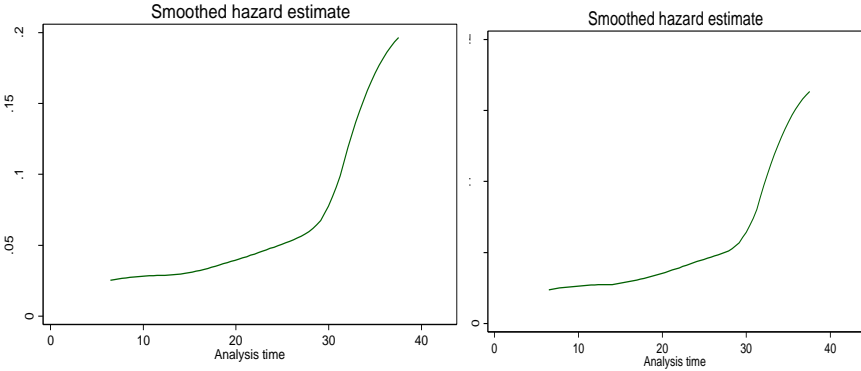


Figure 4.10 Likelihood of awareness (left), and adoption (right) of improved bean varieties at a given time t

The survival function (Kaplan-Meier estimate) in Figure 4.11 shows the proportion of the samples who remained unaware (non-adopter) of the improved varieties at a given time t . Like the hazard estimate, the survival function shows a similar pattern for awareness and adoption with the proportion of non-adopters being larger than those unaware at a given time t . This simply shows an obvious delay between awareness and adoption, which, in this case is relatively short. For example, by the tenth year, a little more than 65% of the sample remains unaware of the improved varieties; the corresponding proportion for non-adopters at this time was about 75%. For about 50% of the sample to be aware and start to cultivate the improved variety, it took about 21 and 23 years respectively.

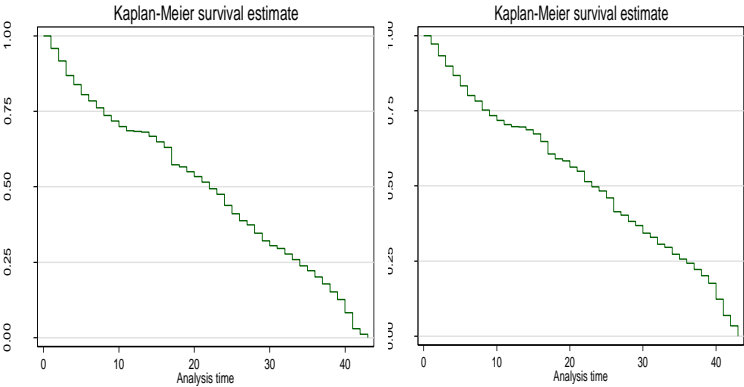


Figure 4.11. Time taken from time of release ($t=0$) to maximum awareness (left), and adoption (right) of improved bean varieties
(Note: the vertical axis refers to proportion of households not aware/ adopted the improved bean varieties)

The result in Figure 4.12 shows that households from Amhara had the longest time (longer survival time) to awareness and adoption of the improved bean varieties. It took close to 30 years for 50% of the samples to be aware of the improved bean varieties. The corresponding figure for Benishangul Gumz (BNSG) was nearly twenty years; and that of Oromia and SNNP was around 15 years. A similar pattern is observed in the case of adoption of the improved technology.

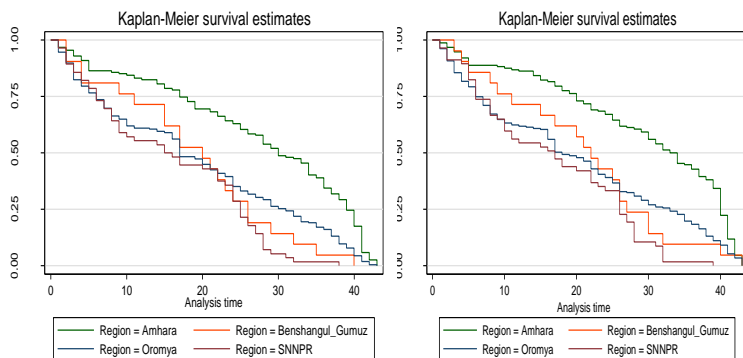


Figure 4.12 Regions and the delay to awareness (left) and adoption (right) of new improved bean varieties, a comparison

4.8.3.4 Determinants of time lag between variety release and adoption

In an attempt to explain the lag between release and adoption of improved bean varieties, we have run both parametric and semi-parametric regression models in the framework of survival analysis. The regressions involve three parametric models with different distributional assumption (viz., Exponential, Weibull and Gompertz) and one semi-parametric model (Cox proportional). Model diagnostic results reported in Table 4.11b show that all the regression models fit the data well based on the p value for each of them. The Akaike and Bayesian information criterion (AIC and BIC), however, suggest that the Gompertz model with the smallest value of the information criterion is considered as the best fit to the data. Our result discussion is, therefore, based on Gompertz model. Accordingly, the result is presented using the hazard ratio from Gompertz distribution.

The location variables are consistently and highly significant across the models. Farmers in SNNP are nearly two times (193%) more likely to be aware of improved bean varieties earlier than those in Amhara. The corresponding likelihood for BNSG and Oromia was 99% and 90% earlier than Amhara. The use of other farmers and family members as

main source of information offers at least 32% and 47% more chances of being quickly aware of improved bean varieties than those who mainly rely on government extension. Result follows similar pattern with the explanation for awareness lag. This may have to do with the marginal role of the formal seed sector in supplying seeds of improved bean varieties and the intentional effort under the PABRA to encourage farmer-to-farmer dissemination.

Of the individual household characteristics included in the analysis, only education seems to influence the likelihood of accessing information about a new variety and its subsequent adoption. For example, an additional year of schooling marginally increases chance of early awareness and adoption by about 3% (Table 4.11a).

Table 4.11a Parametric and semi-parametric regression model explaining the awareness lag

Variables	Exponential		Weibull		Gompertz.		Cox Proportional	
	Haz. Ratio	Std. Err	Haz. Ratio	Std. Err.	Haz. Ratio	Std. Err.	Haz. Ratio	Std. Err.
<i>Household characteristics</i>								
Farm size	1.02	0.03	1.03	0.03	1.04	0.03	1.03	0.03
Household size	0.98	0.02	0.97	0.02	0.97	0.02	0.99	0.02
Age of the HHH	1	0	1.01	0	1.01	0	1	0
Educational level of HHH	1.02	0.02	1.03	0.02	1.03*	0.02	1.03*	0.02
Gender (Male=1)	1.14	0.22	1.19	0.23	1.24	0.24	1.28	0.26
<i>Source of information (Base category =Gov. Extension)</i>								
NGO	0.81	0.24	0.76	0.23	0.73	0.22	0.71	0.21
Seed trader/agro deal	1.08	0.37	1.14	0.4	1.17	0.41	1.08	0.38
Farmer groups (coops+)	0.78	0.4	0.77	0.4	0.78	0.41	0.64	0.34
Other farmers	1.18	0.16	1.25	0.17	1.32*	0.18	1.45*	0.2
Family members	1.26	0.25	1.36	0.27	1.47*	0.29	1.56*	0.31
<i>Region (Admins. Location; base category=Amhara)</i>								
BNSG	1.4	0.3	1.7*	0.39	1.99 [^]	0.48	2.24 [^]	0.54
Oromia	1.5 [^]	0.2	1.7 [^]	0.21	1.90 [^]	0.23	1.97 [^]	0.24
SNNPR	1.8 [^]	0.3	2.3 [^]	0.4	2.93 [^]	0.53	3.06 [^]	0.56
Constant	0.02 [^]	0.01	0.00 [^]	0.00	0.01 [^]	0.00		
/ln_p			0.41 [^]	0.04				
p			1.51	0.06				
1/p			0.66	0.03				
/gamma					0.06 [^]	0		
No. obs	436		436		436		436	
Time at risk	9354		9354		9354		9354	
LR chi2 (13)	25.65		43.79		64.9		75.6	
Prob> chi2	0.02		0		0		0	

Table 4.11b Model diagnostic

	Exponential	Weibull	Gompertz	Cox proportional
For Awareness lag				
AIC value	1189.9	1103.5	997.1	4444.4
BIC Value	1242.9	1156.6	1050.1	4497.4
Prob> chi2	0.02	0	0	0
For Adoption lag				
AIC value	1165.4	1055.8	948.1	4480.4
BIC Value	1218.4	1108.8	1001.1	4533.5
Prob> chi2	0.01	0	0	0

Significance level *=at 10%; +=at 5%; ^=at 1%

5. Productivity and Welfare Impacts of Improved Common Bean Technologies among Smallholders in Ethiopia

5.1. Conceptual framework

The Tropical legumes project interventions were expected to improve bean production and household consumption outcomes of the beneficiaries given a range of activities implemented. Accordingly, the project implementers were equipped with knowledge and other resources to develop better varieties and select a package of good agricultural practice notably weed control, fertilizer and row planting, bundle them with varieties and disseminate the technological package to farmers. Technology dissemination from researchers to farming community followed multiple pathways involving both the public and private sector, actors who received training from researchers to support technology delivery. Access to technology in the form of better varieties and good management practices may help farmers raise productivity to produce more beans for consumption and surplus for sale. Income from bean sale can also be used to finance consumption of welfare enhancing items such as nutritious foods, clothing or any other consumable items. As farmers obtain higher yields, they may also decide to reallocate some land from beans to other crops. These pathways contribute to growth in household food for consumption and/or surplus for sell.

Results in Chapter 4 demonstrate high adoption of varieties promoted under the tropical legumes project as well as those the project worked to replace from farmers' plots. In this chapter, we test for evidence of the project impacts on the intermediate outcomes (i.e., bean yield) and household welfare, which is the ultimate outcome. As indicators of household welfare, we use the following proxies: food consumption score, daily household dietary diversity score for food & nutrition security and consumption expenditure for poverty reduction. Between 2007 and 2018, the TL2/TL3 project promoted a subset of improved varieties and use of fertilizers, row planting and weeds control. The study investigates whether use of these technologies promoted by the

project generated impacts on production and household economic well-being.

5.2 Estimation strategy

Tropical legumes interventions evaluated in this study did not follow experimental approaches, which is the gold standard for impact assessment. This is because the project implementation targeted to leverage different initiatives in the country and scale out best technologies widely. One key challenge of evaluating impact of such interventions is lack of non-randomness in the assignment of the households into adoption and non-adoption groups. In such a case, adopters self-select themselves into receiving the technological package or its components. For example, if there are differences in input requirements, managerial skills and capital intensiveness between local and improved technology, adopters may systematically differ from non-adopters. Improved technologies are also likely to be targeted to high productive areas or adopted on farms with unique observable and unobservable characteristics such as expected returns to the new technology that may also be correlated with expected outcomes such as yield and food security. Therefore, merely comparing means of adopters and non-adopters could easily be misleading if the estimation does not address the potential selection bias.

In the absence of controlled randomization, a quasi-experimental approach has been used to estimate the impacts of improved technology adoption on productivity and household economic wellbeing (e.g Smale et al., 2018, Manda, 2016; Khonje et al., 2018). This, however, requires careful modeling of adoption, the treatment variable, to control for its potential endogeneity in the outcome functions. The choice of treatment variables used for the impact evaluation was guided by two research questions. The first question sought to examine the impacts of TL improved varieties on production and welfare. In this setting, there is one treatment (i.e., improved TL varieties) and two control groups (i.e., growers of landraces and growers of old improved varieties). In this particular analysis, we do not control for agronomic inputs and management practices used by each households. Our second analysis investigates the impact of technological package (considering mainly,

improved varieties and fertilizers), supported under the tropical legumes project, on production and household welfare. Approximately 19% of the households do not weed their bean plots while 34% weed once. The remaining 47% of the households weed twice. In order to ensure sufficient number of observations in each adoption category, we combined old and new varieties as one subcomponent and focus on a technological package consisting of improved varieties and fertilizer.

We follow a multivalued treatment effects approach to estimate the impact of improved TL varieties as well as the technological package on production and household welfare. This approach enables pairwise comparisons among the outcomes of each treatment (i.e., adoption category on our case) and those of the control group. We combined Inverse-probability-weighted regression adjustment (IPWRA) with a multinomial endogenous treatment effects model (METE) to check and ensure for robustness of our estimates. The IPWRA is a matching technique to reduce heterogeneity and construct a counterfactual group that is similar to the treated group in time invariant variables. The assumption underlying this method is that when the treated and control groups are similar in time invariant characteristics such as demographic (i.e., age, education, experience, family composition etc), farm characteristics, climatic conditions and market factors, then the bean production inputs would be similar for treated and control groups but their yield might differ due to differences in the technology. However, the matching techniques control for observable factors, but differences between adopters and non-adopters that also affect their bean production model and yield can remain unobservable.

We attempt to address the challenge of unobservable heterogeneity between adopter and non-adopter groups by using a multinomial endogenous treatment effects model. The METE model, proposed by Deb and Trivedi (2006b), employs a joint framework to analyze a technology choice and its impact on outcome such as yield, income and consumption expenditure (Manda 2016; Varma, 2017; Khonje et al., 2018). This approach has the advantage of evaluating the effect of an individual practice and combination of practices, while accounting for interdependency between adoption of alternative practices and possible selection bias (Wu and Babcock, 1998; Mansur et al., 2008;

Manda,2016; Khonje et al., 2018). The METE model employs a selection correction method by computing and adding a latent factor structure, to correct for this bias (Bourguignon et al., 2007).

5.2.1 Matching techniques: IPWRA approach

The inverse probability adjustment regression (IPWRA) method was developed by Robins and Rotnitzky (1995) and van der Laan & Robins (2003) and has been used to address the problem posed by lack of randomness in observational data (Smale et al., 2018). The IPWRA estimates two separate models to predict treatment status and then outcomes; implemented as a three steps estimation procedure. In the first step, the probability that the individual is treated (i.e., belong to adoption group) is estimated and the propensity scores predicted. The inverse of the probability that each observation is in the treatment or control group is used to re-weight the sample in the second step. This creates a sample in which the distribution of covariates is independent of the treatment—thereby ensuring that the requirement of weak confoundedness is satisfied. In the third step, the expected outcome is estimated for each observation using a weighted outcome model that includes some of the observable characteristics used to estimate the treatment model and additional information. By doing this, the IPWRA renders the balancing of the covariates in the first stage model unnecessary. The important feature of the IPWRA estimator is double robustness, which means that it provides consistent estimates of the effects if either the treatment model or the outcome model is correctly specified (Woodridge 2010).

Now denote T_j the indicator for the choice of option j from the technological package (i.e., the treatment). Unlike the case of experimental approach, the observational data is from the subjects that choose whether to get the treatment or not. A bean-growing household was defined an adopter, i.e., obtained treatment, if the household was observed growing improved varieties only, fertilizer only or a combination of improved varieties and fertilizers at the time of the survey. In the data used in the study, we observed that 120 (10.7%) bean plots received fertilizers only, 518 (46.2%) plots received improved variety only and only 98 (8.7%) bean plots were managed

with a combination of improved varieties and fertilizers. This means that, 386 (34.4%) bean plots were cultivated with landraces without fertilizers and thus defined as non-adopters.

Based on this data, farmers can be classified into 4 mutually exclusive adoption groups as: 0) neither improved variety nor fertilizer (only landraces is planted) 1) fertilizer only, 2) improved variety (i.e., old and new combined) only, 3) a combination of improved variety and fertilizer.

If we let Y_{ijk} be the potential outcome k of a household i that belong to an adopter category j . Then, following Smale et al (2018), the generalized models for the outcome and adoption functions in the IPWRA estimation are:

$$\text{Outcome model: } Y_{ijk} = f(\beta_i, X_i) + \varepsilon_i \quad (\text{i})$$

$$\text{Adoption model: } \text{pr}(T = 1, 2, \dots, j) = h(\alpha Z_i) + \omega_i \quad (\text{ii})$$

Vector X contains covariates that are hypothesized to influence the outcome, Y_{ijk} whereas Z is a vector of covariates that explain the choice of the adoption option T_j . It is important to note that vectors X and Z may overlap whereas vectors ε, ω that consist of random variables in the respective equations are assumed to be correlated.

For empirical estimation, we included as predictors of the technology choice the household socio-demographic (such as education, age, sex of decision maker), economic and farm characteristics (household assets, agricultural equipment, landholding size, soil fertility status of the farm, distance from residence to agricultural plots). These factors are also expected to influence the farm productivity and subsequent outcomes such as food security and poverty status. Similarly, market access proxied by distance from village center to tarmac road as well as the attributes of the agro ecological conditions (rainfall distribution, soil PH, dummies for regions and incidences of climatic shocks) are hypothesized to influence adoption decision making and have a bearing on the agricultural outcomes and household welfare. As instrumental

variables, we included village level access to information and inputs proxied by Herfindal index on the diversity of sources of information on agriculture used by the household and Herfindal index on diversity of farmer groups in a *kebele*. Access to information and inputs can also influence welfare outcomes such as food security via other avenues other than technology adoption. For example, managers who receive information may improve their managerial ability and obtain higher productivity even when they do not change the technology. Because of this, these variables are also included in the outcome model. Finally, we test for the common support in our data by plotting the propensity scores for treated and control observations on graphs to examine the overlap of the distributions. Figure 5.1 and Figure 5.2 show that these distributions do, in fact, overlap.

In the final step, the regression adjustment (RA) estimator is used to predict the outcome. The RA model accounts for the nonrandom treatment assignment by assigning the inverse of probability of treatment for treated individuals and the inverse probability of not being treated for control individuals. Factors that would influence the outcome in a normal regression and the predicted treatment were included as covariates in the productivity outcome in addition to some of the explanatory factors that affect both the probability of adoption and the respective outcome. Then, the average treatment effects on the treated (ATET) is computed as

$$ATET_{ipwra} = N_j^{-1} \sum_{i=1}^{N_j} (\hat{Y}_{ijk} - Y_{i0k}) \quad (iii)$$

In the calculation, Y_{i0k} is the potential outcome of a household i that chose to remain with the traditional technology and thus did not adopt, while Y_{ijk} is, as earlier defined, the potential outcome k of a household i that receives treatment level j , i.e., adopter category j .

5.2.2 Multinomial endogenous treatment effects model

The METE is a two-stage estimation procedure whereby in the first stage, the mixed adoption is modeled as a multinomial selection model while accounting for unobserved variables. In the second stage, the impact of adoption on the respective outcome variables: yield, food

consumption and consumption expenditure is estimated using different estimators with selectivity correction.

We presume that a farmer makes a choice that maximizes his/her expected utility given the available production resources. Thus, he or she compares the utility expected from each option and selects the one that optimizes utility. Following the random utility approach, adoption of improved varieties and fertilizers in Ethiopia as technology package is a multivariate decision modeled as:

$$T_{ij}^* = Z'_{ij} \beta_{ij} + \mu_{ij} \quad \text{with} \quad (iv)$$

$$\left[\begin{array}{l} \tau_{1j} < 0 \\ 1 \text{ if } T_{ij} > \max_{m \neq 1} (T_{ij}^*) \\ J \text{ if } T_{ij} > \max_{m \neq j} (T_{ij}^*) \end{array} \right]$$

Where T_{ij} represents technological option $j = 0, 1, 2, 3$ faced by (available to) household i while vector Z_{ij} is a vector of observable exogenous variables hypothesized to influence the choice j made by the household. These include the household demographic and socio-economic characteristics, attributes of the natural environment such as rainfall, factors related to market access and those that capture technological access, i.e., access to extension, social learning, as well as technological attributes that may influence the decision to use the technology. Vectors β_{ij} and μ_{ij} are coefficient parameters to be estimated and random terms respectively. We presume that a farmer makes a decision to maximize his/her expected utility and thus his/her problem is to choose a combination of practices that provides the greatest expected benefit. Then, the probability that farmer i will choose technology combination j is expressed as:

$$P_{ij} = \text{Prob} \left(\tau_{ij} < 0 \mid Z_{ij} = \frac{\exp(\beta_{ij} Z_{ij})}{\sum_{m \neq 1}^J \exp(\beta_{ij} Z_{ij})} \right) \quad (v)$$

In the second stage of METE, the expected outcome equation is given by

$$E(Y_i|T_j X_i l_i) = \delta_i X_i + \sum_{j=1}^J \gamma_{ij} T_{ij} + \sum_{j=1}^J \omega_{ij} l_{ij} \quad (\text{vi})$$

Where Y is the outcome variable: yield and consumption expenditure for household i , X is a vector of exogenous variables that influence the outcome variables. The vector γ_{ij} consists of the coefficients denoting the effect of different subcomponents in the technological package relative to the control group, the non-adopters. The outcome variable is also a function of each of the latent factors, l_{ij} , which is the unobserved factors that also influence the selection into the treatment. Thus, it is important to account for possible unobservable heterogeneity that could potentially bias the estimates.

5.3. Results and Discussion

5.3.1 Descriptive results

Summary statistics of the explanatory variables hypothesized to influence adoption and household welfare—thereby included in econometric estimation are presented in Tables 5.1, Table A.5.1, and Table A5.2 of the appendix.

In terms of outcome variables, Table 5.1 indicates that the average per capita aggregate expenditure per year is 6694 Birr, with the adopters of improved varieties only reporting significantly higher consumption expenditure than non-adopters (i.e. growers of landrace and unidentified varieties without fertilizers). However, results show no significant difference when the outcomes of variety adopters is compared with those possessed by other adoption categories (i.e. varieties vs fertilizer; varieties vs a combination (varieties & fertilizer) category). The descriptive statistics also show that the quality of diets as measured by 24hour HDDS does not vary significantly across adoption categories. However, the mere bivariate comparisons could be misleading if the households in various categories differ systematically in other aspects. Hence, the need for an econometric analysis to control for confounding factors.

Table 5.1 Descriptive statistics of outcome variables in impact analysis

Adoption category	Number of observation	Yield in (kg/ha)	24-hour HH dietary diversity score	Food consumption score	Per capita aggregate consumption
Landraces only	131	977.96 (652.40)	6.16**a (1.48)	59.59 (18.66)	6673.66 (6170.56)
Adopters of old improved varieties	482	909.5*b (698.88)	5.73**b (1.60)	54.81 (16.87)	6930.01 (9053.47)
Adopters of TL improved varieties	157	1116.6*a (909.59)	6.15*a (1.59)	57.75 (19.51)	8255.37 (8043.75)
Landraces + unidentified varieties (i.e. non-adopters)	386	903.7 (675.6)	5.84 (1.62)	54.56 (19.57)	6043.2 ^b (5214.82)
Fertilizer only	120	1291.5 (1018.1)	6.13 (1.62)	56.03 (19.66)	7084.75 (5710.31)
Varieties (new and Old combined) only	519	901.3 (692.2)	5.76 (1.60)	55.97 (17.56)	7144.4*a (6525.0)
Full package (variety+fertilizer combination)	98	1343.0 (1046.4)	6.10 (1.61)	56.51 (18.95)	6872.147 (5297.39)
All categories combined	1122	997.88 (795.7)	5.90 (1.62)	55.47 (18.77)	6693.94 (5849.51)

Note: Number in parenthesis are standard deviations.

5.3.2 Econometric results

Diagnostics test results on the suitability of the IPWRA for the data are summarized in Figures 5.1a-c, 5.2a-c and Table 5.2. The first stage of IPWRA aims to generate propensity score, which serves to achieve the balance between covariates across adopters and non-adopter groups without meaningful interpretation (Takahashi and Barrett, 2013). As a first step to estimating impacts of TL project, we constructed the conditional probability model to estimate the likelihood that each household would be in each adoption category (landraces, old improved varieties only, TL varieties). For purposes of controlling for cases whose varieties were unidentified from DNA analysis, a category “unidentified varieties” was included among adoption categories, but results are not meaningful. Figures 5.1a-d report the distribution of conditional probabilities of each household assigning itself to an

adoption category, i.e., old improved varieties, TL varieties and “unidentified varieties”. Results in Figures 5.1a-d show that there is no much high-density mass close to zero nor at one--, thus confirms that the groups in adoption categories are comparable with those in the control group (i.e., landraces) based on the observable variables included in the analysis.

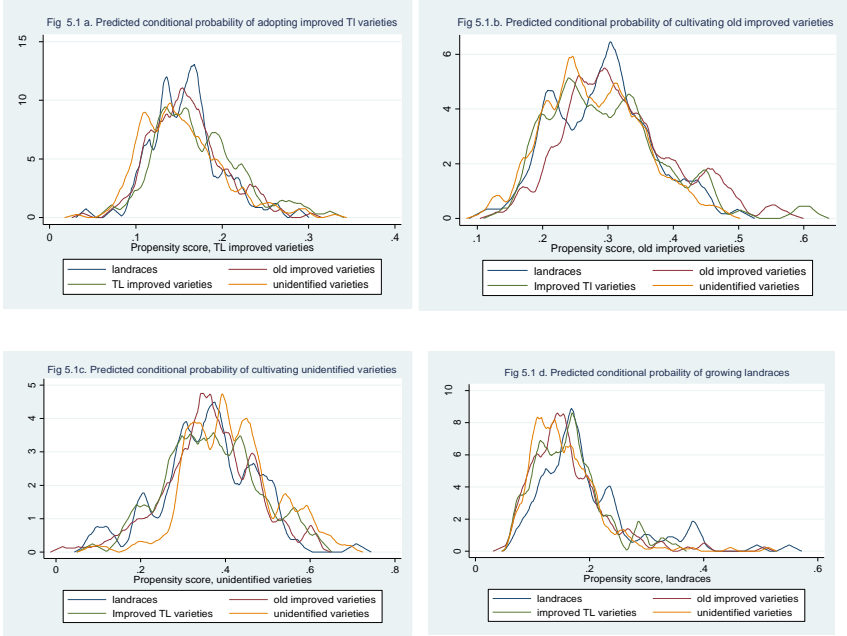


Figure 5.1a-d. Test for common support after IPWRA with treatment being type of improved varieties grown

According to Schminke and Biesebroeck, (2013), it is important for IPWRA to fulfill the assumption of overlap and non-cofoundedness for results to have a causal interpretation. The overlap assumption ensures that predicted inverse-probability weights do not get too large. To check robustness of the matching quality, we also estimated normalized differences computed as

$$= \left(\frac{\bar{h}_{1Z} - \bar{h}_{0Z}}{\sqrt{S^2_{1Z} + S^2_{0Z}}} \right)$$

Where h_z and h_0 are the means of covariate z for adopters and non-adopters while s_{1z}^2 and s_{0z}^2 are the respect standard deviations for covariate z . In most of the cases, adopters and non-adopters exhibit similar pattern under the two adoption measurements. For example, variables are not statistically different by adoption status. Household heads from both groups had comparable age, family size and educational status. When compared with the threshold of value of 0.25 (Imbens and Rubin, 2010), the results are consistent with graphical representation of overlap. Only two variables had estimates above 0.25 (Table 5.2).

Table 5.2. Assessing the overlap assumption based on normalized differences

Variable	Landra						
	ces	Old varieties		TL varieties		Unidentified	
	Mean	Mean	Normalized difference	Mean	Normalized difference	Mean	Normalized difference
Irrigation dummy	0.67	0.6	-0.13	0.6	-0.09	0.6	-0.11
Log age	3.72	3.7	0.09	3.7	-0.06	3.7	-0.01
Gender	0.95	0.9	-0.14	0.9	-0.08	0.9	0.00
Household size in adult equivalent	4.12	3.94	-0.03	3.8	-0.21	4.20	0.04
Herfindal index for farmer organizations	0.59	0.56	-0.07	0.6	-0.01	0.56	-0.04
Herfindal index for sources of information	0.56	0.61	0.16	0.6	0.07	0.58	0.02
Share of plots with moderate erosion	0.18	0.32	0.42	0.2	0.07	0.25	0.08
Share of plots with severe erosion	2.53	2.61	0.03	2.4	-0.11	2.30	-0.15
Dummy presence of market in Kebele	0.50	0.38	-0.25	0.4	-0.12	0.48	-0.02
Index for household assets	0.45	-0.1	-0.24	0.1	-0.16	-0.2	-0.28
Agricultural index	-1.64	-2.1	-0.15	-1.6	0.02	-0.9	0.03
Distance to tarmac road (km)	5.59	6.25	0.06	5.0	-0.06	4.85	-0.08
Distance (km) to nearest urban town	21.49	20.0	-0.07	18.4	-0.13	16.8	-0.23

The same procedure was repeated with the second adoption variable “technological package of fertilizer and varieties” for several treatments and one control-thus a multivalued treatment. Results in figure 5.2 a-d show that the assumption of common support was satisfied.

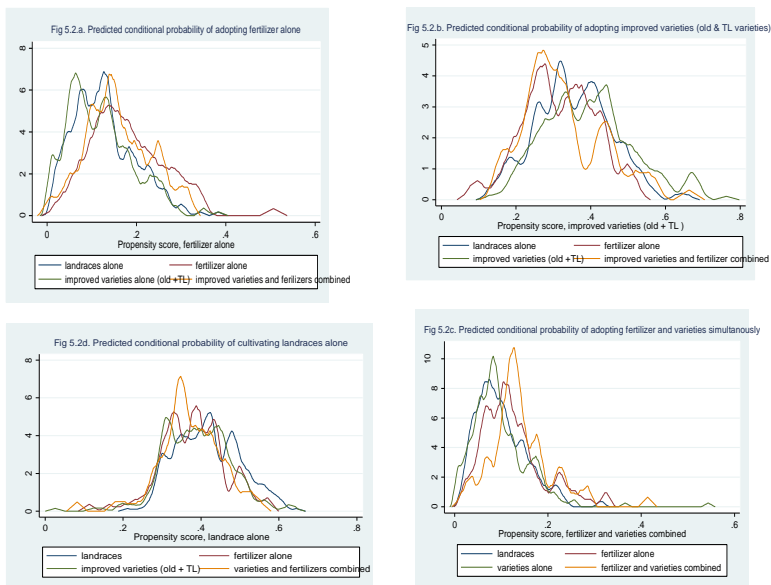


Figure 5.2a-d Test for common support after IPWRA with treatment being varieties & fertilizer technological package

5.3.2 Average treatment effects using IPWRA

After ensuring the common support area and verifying the matching quality of our IPWRA model, we then analyzed the impact of the adoption of new/TL improved bean varieties on bean productivity to test whether these varieties were indeed superior to landraces and old improved varieties not promoted by the project. In the second round of analysis, we change the treatment variable from variety type to a package of multiple technologies. Specifically, we evaluated the impact for the adoption of fertilizer and varieties as a package or subcomponents on productivity, food consumption, dietary quality and consumption expenditure per adult equivalent. Estimates of the impact

of different new improved bean technology on productivity, household food consumption, dietary diversity and total per capita consumption expenditure are shown on Tables 5.3 and 5.4.

Table 5.3. Average treatment effects (ATE) of improved varieties on bean productivity

	Coef.	Std err	ATE	%	p>z
Effect of variety type on productivity					
Old improved only vs landraces	0.3	0.1	181.2	35.51	0.001
New/ TL improved varieties only vs landraces	0.41	0.11	259.21	50.8	0.001
Varieties unidentified by DNA vs landraces	0.35	0.09	216.66	42.46	0.001
Predicted yield landraces	6.23	0.08	510.28	na	0.001
Comparing yield of new/TL2 varieties with that of old improved varieties					
Landraces vs old improved varieties	-0.06	0.12	-46.08	-6.12	0.60
New/ TL improved varieties vs old improved varieties	0.35	0.15	312.66	41.54	0.02
Varieties unidentified by DNA vs old improved varieties	0.03	0.11	26.554	3.53	0.75
Predicted yield-Old improved varieties (control group)	6.62	0.010	752.63	na	0.001

Results indicate that adopters are better off than non-adopters. We first investigate the impact of improved bean adoption separating TL varieties from other improved varieties to test whether the project made any impact on household welfare by promoting these varieties. As it can be seen from Table 5.3, a move from landraces to improved varieties promoted under the TL leads to an increment in yield by 51%, while the average yield from old improved varieties is 36% higher than that of landraces if all farms moved to plant old improved varieties. In the third category, are the varieties in data whose identity was not validated by DNA analysis as the grain samples were missing? We keep this as a separate category of varieties and include in the analysis for purposes of controlling for it. Although the results lack any meaning full interpretation, we see that these varieties yield higher than landraces, which suggests that they may largely be a mixture of improved varieties. In other words, if all farms were growing these varieties, production per hectare will be 42% higher than that of those that grow landraces. We also compared the yield of TL varieties with that of old

varieties to test whether there are statistically significant differences in the performance of these varieties in farmers' fields. Results in Table 5.3 show an increment in yield above old varieties of 42%; providing evidence to reject the hypothesis that old and TL varieties provide same yield in farmers' fields.

Turning to technological package, yield effects are strongly significant and of large magnitude for the households that adopted fertilizer and varieties combination as compared with landraces. Relative to households that grew landrace, the yield from fertilizers and improved variety combination is higher by 48% and 60% among the adopters of fertilizers only (Table 5.4). Surprisingly, the yield effect was positive but not statistically significant for improved varieties. We suspect that this is because we combined new and old varieties while ignoring the unidentified varieties, and some of these unidentified varieties might be improved. This could also have affected the estimated effect on fertilizer /variety combination downs. The results confirm the yield advantage of improved bean technologies over the traditional technologies.

Bean is a source of food for a significant number of households and/or source of income that can be used to buy food. Accordingly, technologies that increase its productivity are expected to impact positively on food security. In line with this expectation, results shows that bean production intensification with improved seed and fertilizers has positive effect on the daily dietary diversity score (Table 5.4). This implies that increases in productivity due to adoption of improved varieties and fertilizers increases food consumption. Households that simultaneously adopted fertilizer and variety combinations were found to have reduced the share of expenditure on food and increased the budget share on nonfood items.

Table 5.4. Average treatment effects of improved variety and fertilizer adoption on bean production and indicators of household well being

	Coef.	Std err	ATE	%	p>z
Effect on productivity					
Fertilizer only vs Non-adopters (landrace+ unidentified varieties)	0.47	0.1	389.3	60.5	0.0
Improved varieties only vs Non-adopters (landrace+ unidentified varieties)	0.11	0.1	73.06	11.4	0.2
Fertilizer/improved variety combination vs Non-adopters (landrace+ unidentified varieties)	0.39	0.1	311.2	48.4	0.01
Non-adopters (Predicted mean)	6.47	0.1	643.5	na	0.001
Effect on food consumption score					
Fertilizer only vs Non-adopters (landrace+ unidentified varieties)	0.08	0.1	4.14	8.26	0.10
Improved varieties only vs Non-adopters (landrace+ unidentified varieties)	0.10	0.1	5.14	10.2	0.05
Fertilizer/improved variety combination vs Non-adopters (landrace+ unidentified varieties)	0.05	0.1	2.75	5.47	0.48
Non-adopters (landrace+ unidentified varieties) (Predicted mean)	3.92	0.02	50.20	na	0.001
Effect on household daily dietary diversity (24 hr recall)					
Fertilizer only vs Non-adopters	0.43	0.2	0.43	7.45	0.04
Improved varieties only vs Non-adopters	0.46	0.2	0.46	7.92	0.02
Fertilizer/improved variety combination vs Non-adopters	-0.11	0.3	-0.11	-	0.73
Non-adopters (Predicted mean)	5.76	0.1	5.76	1.95	0.001
Effect per consumption expenditure					
Fertilizer only vs Non-adopters (landrace+ unidentified varieties)	0.14	0.1	626.2	14.5	0.09
Improved varieties only vs Non-adopters (landrace+ unidentified varieties)	0.01	0.1	43.79	1.01	0.91
Fertilizer/improved variety combination vs Non-adopters (landrace+ unidentified varieties)	0.24	0.1	1193.4	27.6	0.02
Non-adopters 9 landrace+ unidentified varieties) (Predicted mean)	8.37	0.04	4318.1	na	0.001
Effect on share of budget to non-food items					
Fertilizer only vs Non-adopters (landrace+ unidentified varieties)	0.01	0.03	0.31	1.49	0.60
Improved varieties only vs Non-adopters (landrace+ unidentified varieties)	0.02	0.02	0.31	1.75	0.34
Fertilizer/improved variety combination vs Non-adopters (landrace+ unidentified varieties)	0.10	0.03	0.40	10.1	0.00
Non-adopters (landrace+ unidentified varieties) (Predicted mean)	0.29	0.01	0.29	na	0.00

5.3.2 Econometric result from the METE

The model was estimated using maximum likelihood with simulations of 400 draws. Diagnostic test results confirm that the model fits the data very well with the Wald test, $\chi^2 = 784.22$; $p > \chi^2 = 0.000$. Thus, the null hypothesis that all the regression coefficients are jointly equal to zero is rejected. Before embarking on the presentation of the econometric results, we discuss briefly the first stage results as our aim was to estimate impact of adoption on welfare outcomes.

5.3.2.1 Factors explaining use of fertilizer and improved seed in bean production

Table 5.5 reports the results derived from the first stage of the model estimation (METE), whereby the base category against which the results are compared is the non-adoption. The adoption of improved varieties is influenced by demand and supply factors. On the demand side of the market, households experiencing land shortage are likely to adopt improved varieties and manage improved varieties with fertilizer. The results also demonstrate that adoption of varieties alone or in combination with fertilizer is positively influenced by agro-ecological conditions; being higher in location where these conditions are favorable. For example, there is a positive and significant association between average rainfall amounts and the likelihood that a household chose to grow improved varieties alone. The effect is of large magnitude—16% increase in the probability of adopting improved varieties for one percent increase in the average amount for rainfall. A few factors that promote use of varieties alone also increase adoption of a combination of varieties and fertilizers, while the two groups of adopters are distinguished by the status of the soil fertility on their farms, demographic factors, and location with respect to the place of residence. Distance from the village to the nearest agricultural output market is positively correlated with the probability of using improved varieties only. This was surprising as we expected that farmers close to grain markets would access new varieties from first adopters and be able to adopt themselves. Compared to Amhara regional state, farmers in SNNP and Oromia regional states were more likely to adopt fertilizers and apply it on landraces, but less likely to adopt fertilizer and improved varieties combined. While soil fertility does not matter

for adoption of varieties only, farmers cultivating beans on plots of medium to poor soil fertility were less likely to adopt a combination. Farmers in Ethiopia also often cultivate beans in plots far away from their residences.

Three variables, village average farm size, contact with research/NGO and the average distance from residence to crop fields were included in the first stage model as instruments. The consistency of estimates requires that instrumental variables be statistically correlated with the endogenous regressor (i.e., technological package), but uncorrelated with the error terms in the structural equation (i.e. ε_i) of the welfare outcomes. Results reveal a significant relationship between the adoption of fertilizer and improved varieties and variables included as instruments, confirming that these variables are relevant in the model of bean technology adoption and thus suitable as instrumental variable (IV).

There is a positive correlation between adoption of varieties and contact with researchers or NGO. Consistent with literature (Larochelle and Alwang 2013), adoption of varieties and/or fertilizers in bean production is negatively correlated with average distance from the residence to the crop fields. We used the average distance of all crop fields to ensure exogeneity from the bean production decisions.

Table 5.5 Factors explaining adoption of improved varieties and fertilizers in bean production, Ethiopia 2016

Explanatory variables	Fertilizer only		Improved varieties (old +new)		Improved varieties (old + new) and fertilizer combined	
	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Education of HH head in years	-0.003	0.004	0.004	0.006	-0.001	0.004
Education of spouse in years	0.002	0.005	-0.003	0.008	-0.002	0.005
Age HH head	0.000	0.001	-0.001	0.002	-0.002*	0.001
Gender HH	0.070	0.067	-0.016	0.072	-0.080**	0.040
Household asset index	0.025**	0.011	0.031**	0.016	0.015*	0.009
Agricultural equipment index	0.001	0.002	-0.002	0.003	0.000	0.004
Income from HH assets	0.000	0.000	0.0001**	0.000	0.000	0.000
Income from non-farm activities	0.000	0.000	0.000	0.000	0.000	0.000
Household size	-0.004	0.006	-0.003	0.008	-0.004	0.005
Livestock units per adult equivalent	0.001	0.005	0.000	0.010	-0.004	0.019
Landholding per adult equivalent	-0.034	0.029	0.026*	0.014	-0.026	0.021
Dummy irrigation in kebele	0.010	0.028	-0.057	0.038	0.000	0.025
Herfindahl_gp	-0.033	0.030	0.058	0.039	-0.016	0.026
Log rainfall	-0.012	0.061	-0.160*	0.087	0.067	0.065
Quality of soil in kebele						
Medium	0.054	0.045	-0.085	0.073	0.155*	0.082
Poor	-0.008	0.080	0.071	0.092	0.058	0.098
Regional dummies						
BNSG	0.192	0.152	-0.106	0.107	0.131	0.092
Oromia	0.244**	0.105	-0.406***	0.053	0.066	0.045
SNNP	0.381***	0.105	-0.463***	0.060	0.030	0.048
Log average wage rate in kebele	0.009	0.029	-0.029	0.041	0.067***	0.025
Dummy if kebele has a market place	0.012	0.027	0.029	0.037	-0.041*	0.024

Explanatory variables	Fertilizer only		Improved varieties (old +new)		Improved varieties (old + new) and fertilizer combined	
	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Number of group memberships	0.007	0.015	-0.029	0.019	0.010	0.012
Extent of soil erosion						
Medium	0.018	0.031	0.043	0.039	-0.054*	0.029
Severe	-0.059	0.052	0.084	0.057	-0.078*	0.044
Log average landholding in kebele	-0.025	0.019	-0.051**	0.024	-0.069***	0.018
Contact with researcher/NGOs	-0.012	0.059	0.060	0.072	0.131***	0.032
Distance of market for inputs	0.000	0.000	0.001***	0.000	-0.001**	0.000
Log price of urea lagged one yr	0.041	0.090	-0.145	0.144	-0.041	0.093

NB: ***, **, * denote significant at 1, 5 & 10% level

The exogeneity of the instrumental variables (IV) in welfare outcome equations was tested using two approaches to check and ensure that our instruments are robust. First, we employed an `ivreg2` command with the robust options to test for joint significance of excluded instruments and over identification restriction hypotheses³⁵. Test results show that a Hansen J statistic p-value of 0.446 and the Kleibergen-Paap rk Wald F statistic value of 19.5—which are all indicators that our instruments were effectively excluded from the outcome models. To check for robustness of these test results, we also included all the IV in the outcome equations and regress each outcome on them together with covariates for only the subsample of non-adopters. The results did not reveal any evidence as to reject the hypothesis that the IV are individually or jointly significantly important in explaining outcomes.

In the second stage of the METE model, we estimate how household total consumption expenditure changes in response to adoption of each technological option. We considered three technological options that have been promoted to farmers for increasing yield. The options deal with adoption of improved varieties only, fertilizer only and for combination of fertilizer and improved varieties. Results are reported in Table 5.6 demonstrate that the coefficients on the latent factor loadings were all significant at 1%. The factor on the adoption of fertilizer only shows a negative sign while those on improved varieties only and that on the adoption of fertilizer and variety combination were negative. This indicates that the selection and productivity equations are not independent, which means that there are unobserved factors that tend to decrease productivity, but increase the likelihood of adopting improved varieties.

³⁵ The AR test is weak instrument robust test of a joint test of the structural parameter and the over identification restrictions and can be decomposed into the LM statistic, which tests only the structural parameter, and the J statistic, which tests only the over identification restrictions. A variable is a valid selection instrument, if it will affect the decision to switch from growing landraces only to growing improved varieties only, fertilizer applied to landraces and or fertilizer applied to improved varieties. However, a valid instrument will not affect the welfare outcomes of the farming families' households that did not adopt.

Table 5.6. Marginal effects of adoption of improved varieties & fertilizers and hypothesized factors on common bean yield

	Coeff.	Std. Err.	z	P>z
Fertilizer only	0.34	0.17	1.97	0.05
Improved varieties only	0.3	0.12	2.42	0.02
Improved varieties + fertilizer	0.42	0.18	2.28	0.02
Log seeding rate	0.36	0.05	7.86	0
Log pre harvest labour/ha	0.04	0.03	1.24	0.21
Soil fertility				
Medium	-0.08	0.06	-1.25	0.21
Poor	-0.22	0.1	-2.29	0.02
Dummy weed control	0.04	0.07	0.5	0.61
Dummy variety=climber	-0.09	0.07	-1.31	0.19
Household asset index	-0.03	0.03	-1.3	0.19
Intercropping	-0.41	0.1	-4.07	0
Presence of irrigation in kebele	0.17	0.06	2.65	0.01
Value of livestock (ETBirr)	0	0	1.82	0.07
Dummy average rainfall amount				
Moderate	0.08	0.07	1.17	0.24
High	0.36	0.11	3.29	0
Education in years	0.01	0.01	1.53	0.13
Log age	0.03	0.11	0.24	0.81
Gender	0.18	0.11	1.71	0.09
Regional dummies				
BSNG	-0.48	0.18	-2.68	0.01
Oromia	-0.02	0.1	-0.19	0.85
SNNP	-0.02	0.12	-0.19	0.85
Dummy if variety unidentified	0.04	0.07	0.57	0.57
Distance to market for agric produce	0	0	-2.58	0.01
Constant	4.54	0.47	9.7	0
/lnsigma	-0.45	0.11	-4.12	0
/lambda_catego~2	-0.08	0.13	-0.61	0.54
/lambda_catego~3	-0.34	0.1	-3.48	0
/lambda_catego~4	-0.14	0.14	-0.99	0.32
Sigma	0.64	0.07		
Number of observation	714			
Wald chi2(92)	598.67			
Log pseudo likelihood	-1349.36			
Prob chi2	0.001			

Yield effects

Results on the estimated effect of adoption on productivity from the METE estimator are qualitatively similar to estimates from IPWRA,

which demonstrates that our results are robust. The estimated average effects for fertilizer and a combination of fertilizer and varieties are consistently significant in both estimators (Table 5.6). The METE suggests the following effects from each of the adoption option: fertilizer only increase yield by 34% while adoption of improved varieties only increases yield by 30%. Results further shows that simultaneous use of improved varieties and fertilizers increases yield by 42%. Varieties are more productive when managed with fertilizers. Thus, yield effects are higher when varieties and fertilizers are adopted simultaneously.

Welfare effects

Table 5.7 presents results of the average effects of improved bean technology adoption on per capita consumption expenditure. The model was significant with Wald statistic of 772 that was significant at $p < 0.01$. All lambdas are significant but with different signs. It is positive for fertilizer only and negative for varieties only or varieties combined with fertilizers. These results suggest that unobserved factors that positively increase the likelihood of using fertilizers are also likely to increase household consumption expenditure. On the other hand, those unobserved factors that encourage use of improved varieties are associated with lower household wellbeing, thus negatively correlated with household consumption spending. Controlling for all other factors, adoption of improved varieties only is associated with a positive increase in per capita consumption expenditure. More specifically, replacement of landraces with improved varieties only (i.e., improved varieties without fertilizers) increases per capita expenditure by about 24 percent points and by 36% points when improved varieties are adopted in combination with fertilizers (Table 5.7). Thus, promotion of improved varieties contributes to improving food security in Ethiopia. Household welfare represented by food consumption score, daily dietary diversity and per capita consumption expenditure is also positively associated with education of the household head, an index of household assets and agro-ecological attributes. The result demonstrates that if all farmers were to adopt improved varieties, their food security measured by food consumption score and 24 hour dietary diversity score would increase. On the other hand, per capita consumption is

lower among households with larger number of members and those headed by females.

Table 5.7. Marginal effects of adoption of improved varieties and fertilizers and hypothesized factors on household aggregated annual per capita consumption expenditure

Variables	Coefficients.	Robust Std. Err.	z	P values
Fertilizer only	0.047	0.087	0.55	0.585
Improved varieties only	0.237	0.074	3.19	0.001
Improved varieties + fertilizer	0.362	0.083	4.38	0
Education in years of HH head	0.022	0.008	2.78	0.005
education in years for the spouse	0.015	0.010	1.5	0.133
Age of the household head	0.002	0.003	0.73	0.465
Gender of HH head	0.164	0.101	1.62	0.105
Household asset index	0.059	0.025	2.33	0.02
Agricultural Index	0.002	0.001	4.13	0
receive cash from assets	0.000	0.000	3.64	0
off farm income	0.000	0.000	0.91	0.363
Household size	-0.068	0.011	-6.07	0
Livestock units per adult equivalent	-0.002	0.002	-1.29	0.197
Landholding per adult equivalent	0.006	0.006	1.08	0.28
Presence of irrigation in kebele	0.078	0.051	1.53	0.126
Herfindahl index for group membership	-0.031	0.059	-0.52	0.603
log rainfall amounts	-0.304	0.124	-2.45	0.014
Quality of soil in kebele				
Medium	0.023	0.083	0.27	0.786
Poor	0.002	0.113	0.02	0.984
Regional dummies				
BSNG	0.242	0.157	1.54	0.123
Oromia	0.241	0.094	2.57	0.01
SNNP	0.074	0.108	0.69	0.492
Log average wage rate in kebele	-0.082	0.050	-1.63	0.104
Dummy if kebele has a market place	-0.014	0.057	-0.25	0.799
Number of group memberships	-0.058	0.027	-2.14	0.032
Extent of soil erosion				
Medium	0.056	0.068	0.82	0.41
Severe	-0.076	0.085	-0.9	0.369
constant	10.699	0.974	10.98	0
/lnsigma	-1.039	0.090	-11.5	0
/lambda fertilizer only	0.097	0.042	2.29	0.022
/lambda improved variety only	-0.326	0.057	-5.7	0
/lambda varieties + fertilizer combination	-0.369	0.043	-8.56	0
sigma	0.354	0.032		
Number of observation	679			
Wald chi2(108)	771.79			
Log pseudo likelihood	-1264.04			
Prob > chi2	0			

6. Summary, Conclusions and Policy Implications

Following the concerted effort and several years of collaborative bean improvement research between Ethiopian Institute Agricultural Research and the International Center for Tropical Agriculture (CIAT), this study was commissioned by donor to evaluate the impact of the interventions. Thus, the study was designed to measure the adoption of improved bean varieties and associated management practices promoted under the project;—and analyze the impacts of adoption. The study used primary data from a sample of bean growing households selected to be representative at national and regional level. Findings show that bean growing households in Ethiopia are generally poor; majority (75%) living in modest housing units of 1-2 rooms and on average each accommodating 5-6 household members. A bigger proportion of household income comes from sale of agricultural assets such as crops and livestock and food transfers. However, landholdings are small, and fragmented. Households use both local and improved bean seed, which they source from formal and informal channels.

Results indicated that improved bean varieties have been widely adopted, covering up to 65% of the bean area in 2016. When choosing these varieties, bean growers consider yielding capacity and shorter maturity among the production traits while the processing and marketing traits considered are mainly ease of shelling, storability, grain pricing, and grain market demand. This re-enforces the fact that farmers in Ethiopia are market oriented in the way they do bean farming. Among the consumption traits, cooking time, bean size, grain taste and nutrition value are highly preferred by farmers and influence varieties currently grown. In addition to growing improved varieties, we found that 42% of the households were applying chemical fertilizer and the regional distribution was uniform across the country. Additionally, 33% of the households had adopted row planting of beans away from the traditional broadcasting methods while 80% of them were using controlling weeds.

Results further show that the project made a significant progress in terms of increasing farmers' knowledge about the improved varieties

and their adoption. The period between 2006 and 2016 marked significant awareness of the released varieties, possibly due to concerted efforts under seed systems that was scale up during TL LL/III project. However, there is still slow rate of varietal replacement in a context of so many varieties released periodically as indicated by a varietal average age of 19. Moreover, it takes a respective 21 and 23 years for about 50% of the farmers to be aware and start to cultivate a new improved variety. This is a serious concern that needs to be improved significantly if farmers have to benefit without unnecessarily longer delays and if the return to investment on technology development and seed system has to be realized quickly. The intervention by the TL in Oromia and SNNP demonstrated that with concerted effort and public investment in seed systems, it is possible to shorten the period taken for larger proportion of farmers to adopt improved bean varieties. As a commodity less catered by the formal seed system, accelerating varietal turnover requires engaging informal seed systems to spur quicker access to new variety seed. However, informal seed systems are not without challenges. The study found that farmers that obtain seed from the informal seed sources outside their farms were less likely to identify the varieties in their gardens. It is possible that some farmers that go to informal seed sources may not receive the varieties they intent to plant if they cannot recognize the identity of the varieties in their hands. This implies that there is need to strengthen the capacity of the informal seed systems to supply quality seed. One option is to develop a strong reference library and use it to regularly monitor the identity of the varieties in seed supply chains.

This study revealed that adoption of improved bean varieties has contributed to the upward bean productivity trends. The highest gains occur when varieties are adopted simultaneously with fertilizers, which indicates that decision to buddle the varieties with good agricultural practices has benefited the farming families. As a result of bean productivity gains, adoption of varieties was found to increase food consumption, dietary diversity and per capita consumption expenditure. Majorly being a commercial crop, increase in bean productivity can affect household welfare via multiple pathways notably: direct consumption would increase if households produce more or additional harvest due to gain in productivity can be sold and income used to

purchase other foods or non-food items. The third pathways possibly relates with reallocation of land to other crops or agricultural activities, which contributes to more income of food to the household. Results did not provide any evidence to suggest that the adoption of improved varieties or fertilizers generally has had any significant effect on bean consumption nor on food expenditure share. This means that the positive effect on food consumption and dietary diversity could have been achieved through reallocation of resources to production of other food crops while income from bean sales was used to purchase non-food items.

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Appendices

Table A.1 List of released varieties in Ethiopia since 1980

S.N.	Name of variety	Attribute	Seed size and color	Year of release	Target ecology
Varieties for domestic consumption and market					
1	Gorossa	Large seeded, high yielding and resistant to common bacterial blight & halo blight	red mottled	2017	Central Rift Valley and other lowland areas
2	Kello	Large seeded, high yielding and resistant to common bacterial blight & halo blight, adaptable to low soil fertility areas	Large yellow	2017	Central Rift Valley and other lowland areas
3	Zo asho	Large seeded, high yielding and resistant to common bacterial blight & halo blight	Large red	2017	Central Rift Valley and other lowland areas
4	SER-119	Small seeded, high yielding and resistant to common bacterial blight and halo blight diseases	Red	2914	Central Rift Valley and other lowland areas
5	SER-125	Small seeded, high yielding and resistant to common bacterial blight and halo blight diseases	Red	2014	Central Rift Valley and other lowland areas
6	Ada	Medium seed size, early maturing suitable to terminal moisture stress area	Yellow	2013	Central Rift Valley and other lowland areas
7	Dandesu	Medium seed size, early maturing suitable to terminal moisture stress area	Red	2013	Central Rift Valley and other lowland areas
8	Morka (ECAB 0056)	Large seeded, high yielding and resistant to common bacterial blight & halo blight	Red mottled	2012	Central Rift Valley and other lowland areas
9	GLP-2	Large seeded, high yielding and resistant to leaf blight diseases	Red mottled	2011	Central Rift Valley and other lowland areas
10	Loko	Small seeded bean, high yielding and resistant to Anthracnose & angular leaf spot diseases	Cream	2009	Western Oromia
11	Hawassa	Small seeded, high yielding	Red	2008	Southern

S.N.	Name of variety	Attribute	Seed size and color	Year of release	Target ecology
	Dume	and resistant to common bacterial blight and angular leaf spot diseases			Ethiopia
12	Gabisa	Large High yielding and resistant to Anthracnose & angular leaf spot diseases	Cream	2007	Bako, Gute, Biloboshi (Western Oromia)
13	Hirna	Large seeded, high yielding and resistant to leaf blight diseases	Red	2006	East/West Hararghe (Eastern Ethiopia)
14	Fedis	Large seeded, high yielding and resistant to leaf blight diseases	Red mottled	2006	East/West Hararghe (Eastern Ethiopia)
15	Melk Dima	Large seeded, high yielding and resistant to common bacterial and halo blight diseases	Red	2006	Central Rift Valley and other lowland areas
16	Dinknesh (Bobe-red)	Large seeded High yielding and resistant to common bacterial and halo blight diseases	Red	2006	Central Rift Valley and other lowland areas
17	Haramaya	Medium seeded, high yielding and resistant to leaf blight	Cream	2006	East/West Hararghe (Eastern Ethiopia)
18	Anger	Small seeded, high yielding and moderately resistant to anthracnose, angular leaf spot and common bacterial blight diseases	Dark red	2005	Bako, Loko, Biloboshi
19	Batagonia	Large seed climber bean, high yielding and resistant to anthracnose and angular leaf spot	Red	2005	Sidama and Wolaita Mid highland areas
20	Tibe	Small seeded climber bean, high yielding and moderately resistant to common bacterial blight disease	Red	2004	East and West Welega (Western Ethiopia)
21	Nasir	Small seeded, high yielding and resistant to common bacterial and halo blight	Red	2003	National

S.N.	Name of variety	Attribute	Seed size and color	Year of release	Target ecology
		diseases			
22	Dimtu	Small seeded, high yielding and resistant to common bacterial and halo blight diseases	Red	2003	National
23	Wedo	Medium seeded, high yielding and resistant to common bacterial blight disease	White	2003	North and South Wello (Northern Ethiopia)
24	Ibado	High yielding and resistant to angular leaf spot, and common bacterial disease	Red	2003	Sothorn Ethiopia
25	Omo-95	High yielding and resistant to angular leaf spot, and common bacterial disease	Light red	2003	Sothorn Ethiopia
26	Tabor	Small seeded , modest yielding and moderately resistant to angular leaf spot and common bacterial blight diseases	Cream	1999	Sothorn Ethiopia
27	Zebra	Medium seeded high yielding and moderately resistant to common bacterial blight disease	Carioca	1999	Central Rift Valley and other lowland areas
28	Gobe Rasha	Large seeded, high yielding and moderately resistant to angular leaf spot and common bacterial blight diseases	Red mottled	1998	Jima and South western Ethiopia
29	Beshbesh	Small seeded, resistant to bean stem maggot insect and moderately resistant to common bacterial blight, halo blight diseases	Cream	1998	National
30	Atendaba	Large seeded, high yielding and resistant to common bacterial and halo blight diseases	Speckled	1997	National
31	Ayengew	Medium seeded , high yielding and moderately resistant to leaf blight diseases	Carioca	1996	East/West Hararghe (Eastern Ethiopia)
32	Gofta	Medium seeded, high yielding	Cream	1996	East/West

S.N.	Name of variety	Attribute	Seed size and color	Year of release	Target ecology
		and moderately resistant to leaf blight diseases			Hararghe (Eastern Ethiopia)
33	Roba-1	Small seeded, fast cooking, high yielding and moderately resistant to leaf blight diseases	Creamy	1990	National
Varieties mainly for international market					
1	Awash Mitin	Small seeded, suitable for canning, high Fe and Zn, high yielding and resistant to common bacterial blight and halo blight diseases	White	2017	Large seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases
2	Derash	Medium seeded, suitable for canning, extra early variety, high yielding and resistant to common bacterial blight and halo blight diseases	Speckled	2017	Large seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases
3	Ado (SAB-736)	Large seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases	White	2015	Central Rift Valley, Southern Ethiopia, East/West Hararghe (Eastern Ethiopia)
4	Tafach (SAB-636)	Large seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases,	Speckled	2015	Central Rift Valle, Southern Ethiopia, East/West Hararghe (Eastern Ethiopia)
5	Awash 2	Small seeded, suitable for canning, high yielding and resistant to common bacterial	White	2013	Central Rift Valley and other lowland areas

S.N.	Name of variety	Attribute	Seed size and color	Year of release	Target ecology
		blight and halo blight diseases			
6	Deme	Large seeded, suitable for canning, early maturing variety, high yielding potential and resistant to common bacterial blight and halo blight diseases,	Speckled	2008	Central Rift Valley, Southern Ethiopia, East/West Hararghe (Eastern Ethiopia)
7	Batu	Large seeded, suitable for canning, early maturing variety, high yielding potential and moderately resistant to common bacterial blight and halo blight diseases	White	2008	Central Rift Valley, Southern Ethiopia, East/West Hararghe (Eastern Ethiopia)
8	DRK (Dark red Kidney)	Large seeded, suitable for canning, early maturing variety, high yielding potential and moderately resistant to common bacterial blight and halo blight diseases	Dark red	2007	Central Rift Valley, Southern Ethiopia
9	Cranscope	Large seeded, suitable for canning, early maturing variety, high yielding potential and moderately resistant to common bacterial blight and halo blight diseases	Speckled	2007	Central Rift Valley, Southern Ethiopia,
10	Chore	Small seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases	White	2006	Central Rift Valley, Sothern, South East and Eastern Ethiopia
11	Chercher	Small seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases	White	2006	East/West Hararghe (Eastern Ethiopia)
12	Argene	Small seeded, suitable for canning, high yielding and resistant to common bacterial	White	2005	Central Rift Valley and other lowland areas

S.N.	Name of variety	Attribute	Seed size and color	Year of release	Target ecology
		blight and halo blight diseases			
13	Nazareth-2	Small seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases	White	2005	Central Rift Valley and other lowland areas
14	Awash Melka	Small seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases	White	1999	National
15	Awash 1	Small seeded, suitable for canning, high yielding and resistant to common bacterial blight and halo blight diseases	White	1990	Central Rift Valley and other lowland areas

Table A.2.1 Distribution of the actual sample used for the survey

Region	Number of Zone	Number of Wereda	Number of Kebele	Number of Farmer
Oromia	11	22	56	616
SNNP	6	8	24	264
Amhara	5	8	19	209
Benishangul Gumz	1	1	3	33
Total	23	39	102	1122

Table A. 2.2 Sampling weight assigned to sample weredas (districts)

District code	District name	Wereda Actual in the sample	Wered at sampling stage	Wereda Weight
1	East Belesa	EastBele	Belesa	2.3382
2	West Belesa	WestBele	Belesa	2.3382
3	Simada	Simada	Simada	1.1943
4	Dawent	Dawent	Dawntna	15.8622
5	Delanta	Delanta	Delanta Dawntna	15.8622
6	Kelala	Kelala	Kelala	16.9624
7	Goncha Siso Ense	GonchaSi	Goncha Siso Enese	3.605
8	Enarj Enawga	EnarjEna	Enarj Enawga	2.5189

District code	District name	Wereda Actual in the sample	Wered at sampling stage	Wereda Weight
9	Dibate	Dibate	Dibate	2.63
10	Mana Sibo	Mana Sibo	Mana Sibu	10.1984
11	Gawo Qabe	GawoQabe	Gawo Dale	6.392
12	Dale	Dale	Gawo Dale	6.392
13	Limu	Limu	Limu	5.8653
14	Bure	Bure	Bure	3.8501
15	Boset	Boset	Boset	0.7597
16	Adama	Adama	Adama	0.9942
17	Ada'a	Ada'a	Ada'a Liben	3.1681
18	Liben	Liben	Ada'a Liben	3.1681
19	Dugda	Dugda	Dugda Bora	1.1195
20	Bora	Bora	Dugda Bora	1.1195
21	Adamitulu-Jido- Kombolcha	Adamitulu	Adami Tullu Jido	0.9365
22	Siraro	Siraro	Adami Tullu Jido	2.5496
23	Shala	Shala	Siraro	2.5496
24	Sire	Sire	Dodota Sire	1.8281
25	Dodota	Dodota	Dodota Sire	1.8281
26	Serru	Serru	Seru	5.3392
27	Chiro	Chiro	Chiro	3.0899
28	Daro Labu	DaroLabu	Darolebu	5.5093
29	Goregutu	Goregutu	Goro gutu	4.9464
30	Moyale	Moyale	Moyale	2.1572
31	Bule Hora	BuleHora	Hagere Mariam	2.1766
32	Shebedino	Shebedino	Shebedino	0.9928
33	Aroresa	Aroresa	Aroresa	5.272
34	Damot Woyde	Damot Woy	Damot Woyde	2.0894
35	East Badawacho	East Bada	Badawacho	5.1557
36	West Badawacho	WestBada	Badawacho	5.1557
37	Gawata	Gawata	Gawata	20.096
38	Menit Goldiya	MenitGol	Menit Goldiya	21.2378
39	Derashe special wereda	Derashe s	Derashe Special	5.4408

Table A3.1: Sociodemographic characteristics of the sampled households

Variable	Mean (Std. Dev)				
	Pooled sample (N=1122)	Amhara (a) (n=209)	BNSG (b) (n=33)	Oromia (o) (n=616)	SNNP (s) (n=264)
Household size	6.25 (2.29)	5.56 (1.59)	6.36 (2.04)	6.49 (2.50)***a	6.22 (2.16)***a
Age of household head	42.94 (12.20)	45.11 (12.48)	42.79 (13.51)	42.70 (12.08) *a	41.80 (11.94)**a
Age of spouse	35.78 (9.97)	37.49 (11.11)	34.66 (8.11)	35.65 (9.95)	34.83 (9.10)***a
Gender of household head(male)	91.83	93.94	92.21	90.53	91.79
Household head marital status (married)	91.86	92.34	96.97	91.53	91.6
Number of years of household head at school	5.37 (2.76)	4.55 (1.93)	4.88 (2.28)	5.43 (2.85) *a	5.57 (2.81) *a
Household head can read and write	13.66	23.94	17.65	10.78	4.35
Sum of years of education in the HH	15.39	11.52	14.91	16.02	17.04
Mean years of education in the HH	2.96	2.38	2.91	3.09	3.15
Median years of education in the HH	2.64	1.99	2.41	2.78	2.88
Occupation of HH	Percentage of member farmers in a group				
Agricultural employment	96.97	97.12	100	96.92	96.59
Non-agric. self-employed	0.36	0	0	0.16	1.14
Hand craft/ weaving	0.18	0.48	0	0.49	0.38
Household chores	0.27	0	0	0.49	0
Agricultural wage labourer	0.09	0.48	0	0	0
Other	2.14	2.24	0	2.11	1.89
Type of group					
Input supply/farm coop.	61.68	71.77	60.61	61.53	54.17
Crop/seed producer & marketing	8.91	3.35	12.12	13.8	1.52
Irrigation association	12.21	19.14	6.06	12.34	7.2
Farmer research	0.71	0	6.06	0.65	0.76
Saving and credit	61.14	70.33	69.7	58.77	58.33
Local administration	91	97.13	93.94	91.72	84.09
Farmers' Union	13.19	4.31	15.15	20.13	3.79
Women association	61.05	65.55	72.73	59.25	60.23

Variable	Mean (Std. Dev)				
	Pooled sample (N=1122)	Amhara (a) (n=209)	BNSG (b) (n=33)	Oromia (o) (n=616)	SNNP (s) (n=264)
Merry-go-round	49.38	57.89	66.67	45.62	49.24
Religious	67.83	83.25	96.97	64.45	59.85
Communal labor group (Debo, Jigi)	80.39	88.52	81.82	79.06	76.89
Cell (1:5)	92.51	99.52	90.91	90.42	92.05
Burial group (Idir)	94.47	95.22	100	92.69	97.35
Seeking credit for:					
Purchase pesticide	0.27	0.48	0	0.16	0.38
Purchase agricultural equipment	2.94	2.39	0	4.38	0.38
Purchase seed	8.2	5.74	12.12	8.44	9.09
purchase fertilizer	18.18	25.36	63.64	15.26	13.64
Got credit for:					
Agricultural equipment	2.85	7.35	30.3	1.02	0
Seed	61.96	91.67	100	48.08	70.83
Pesticide	66.67	0	0	100	100
Fertilizer	80.39	96.23	95.24	67.02	83.33

Significance: ***1%, *5%, *10%.

Note: the letters next to the asterisk represent the region for the mean comparison BNSG refers to the region known as Benishangul Gumz

Table A3.2a Land tenure systems, Plot ownership, crops and livestock by region

	National (N=1,122)	Amhara (n=209)	BNSG (n=33)	Oromia (n=616)	SNNP (n=264)
Number of plots					
Tenure (Acquisition) of cultivated plots in bean growing households					
Number cultivated bean plots by land tenure	3,384	918	125	1,849	492
Owned (%)	81.86	74.73	50.4	85.24	90.45
Rented in (short term) (%)	10.37	9.37	35.2	10.82	4.27
Shared in (%)	7.65	15.9	14.4	3.73	5.28
Leasehold (Long term) (%)	0.12	0	0	0.22	0
Plot ownership within bean growing household (%)					
Total number of plots owned by households members who grew beans	2,774	686	63	1,580	445
Household head (%)	14.92	15.74	3.17	13.67	19.78
Spouse (%)	0.61	1.9	0	0.13	0.45
Head and Spouse jointly (%)	84.21	82.36	95.24	85.95	79.33
Other household members (%)	0.25	0	1.59	0.25	0.45
Plot decision maker					
Male headed HH					
Household head only	27.66	18.74	22.5	35.76	14.89

	National (N=1,122)	Amhara (n=209)	BNSG (n=33)	Oromia (n=616)	SNNP (n=264)
Number of plots					
Both the head and spouse	71.94	81.26	77.5	63.78	84
Other household members	0.41	-	-	0.46	1.11
Female headed HH					
Household head only	75.98	85.42	20	72.9	79.55
Both the head and spouse	17.65	14.58	80	14.95	20.45
Other household members	6.37	-	-	12.15	-
All combined					
Household head only	30.57	22.22	22.4	37.91	20.65
Both the head and spouse	68.67	77.78	77.6	60.95	78.34
Other household members	0.77	-	-	1.14	1.01
Crops	Area share (%) of cultivated land allocated to major crops				
Bean	16.5	29.5	11.1	13.7	13
Maize	24.5	8.1	7.2	29.9	29.9
Tef	17.9	26.8	25.5	20	5.9
Wheat	4.7	6.3	0	6.8	0.4
Sorghum	8.3	17	4.9	7.6	3.4
Coffee	2.9	0	0	3.5	4.5
Combined	74.7	87.7	48.7	81.5	57.2
Major crops					
Beans	26	24	25	25	33
Maize	18	8	12	21	23
Teff	18	27	16	17	11
Sorghum	9	16	5	8	6
Others (40 crops combined)	28	25	42	29	26
Total plots sampled	4,842	1,118	170	2,760	794
Different types of livestock kept by the sample households (percentage)					
Oxen	70.86	82.3	90.91	72.89	54.55
Cow	67.74	64.59	72.73	69.16	66.29
Poultry	59.45	65.55	63.64	54.06	66.67
Donkeys	51.07	70.81	57.58	58.44	17.42
Calves	45.28	38.28	72.73	47.24	42.8
Goats	39.48	43.06	24.24	42.53	31.44
Heifer	34.76	33.49	48.48	37.01	28.79
Sheep	27.45	26.32	6.06	27.92	29.92
Bull	21.66	15.79	54.55	26.95	9.85
Horses	2.14	0.96	0	2.6	2.27
Camels	0.53	0	0	0.97	0
Mules	0.18	0	0	0.32	0

Table 3.2b Decision making regarding what crop to grow on a plot

Region	Sex of the Household head	Plot decision maker		
		Household head only	Both the head and spouse	Other household members
Amhara	Female	85.42	14.58	-
	Male	18.74	81.26	-
	Total	22.22	77.78	-
BNSG	Female	20	80	-
	Male	22.5	77.5	-
	Total	22.4	77.6	-
Oromia	Female	72.9	14.95	12.15
	Male	35.76	63.78	0.46
	Total	37.91	60.95	1.14
SNNP	Female	79.55	20.45	-
	Male	14.89	84	1.11
	Total	20.65	78.34	1.01
Total	Female	75.98	17.65	6.37
	Male	27.66	71.94	0.41
	Pooled	30.57	68.67	0.77

Table A3.3 Common bean planting time for meher season, household asset and input use across regional states

Planting Week	Percentage of households by regional states						
	National	Amhara	BNSG	Oromia	SNNP		
June 1st week	14.9	14.95	16.13	16	11.69		
June 2nd week	8.56	8.25	16.13	8.18	8.47		
June 3rd week	6.42	6.19	9.68	6.55	5.65		
June 4th week	14.09	17.01	12.9	15.64	11.69		
July 1st week	19	15.98	16.13	17.64	21.77		
July 2nd week	11.06	10.82	3.23	10.55	13.71		
% of HHs planted between 1 st wk Jun. & 2 nd wk of July (6 weeks' time)	74.03	73.2	74.2	74.56	72.98		
July 3rd week	5.71	5.67	3.23	6.73	4.84		
July 4th week	3.75	4.12	3.23	3.45	4.44		
August 1st week	4.64	2.58	6.45	4.73	5.65		
August 2nd week	3.48	4.64	-	3.27	3.23		
August 3rd week	2.41	4.12	3.23	2.18	1.61		
August 4th week	5.98	5.67	9.68	5.09	7.26		
Chi2(p value)	9.43 (0.024)						
Assets	Percentage of households					Chi2 (p value)/ F (p value)	
	Pooled	Amhara	BNSG	Oromia	SNNP		
Ox	70.86	82.3	90.91	72.89	54.55	54.92 (0.00)	
Cow	67.74	64.59	72.73	69.16	66.29	2.14 (0.54)	
Calves	45.28	38.28	72.73	47.24	42.8	15.78 (0.00)	
Heifer	34.76	33.49	48.48	37.01	28.79	8.42 (0.04)	
Bulls	21.66	15.79	54.55	26.95	9.85	57.14 (0.00)	
Goat	39.48	43.06	24.24	42.53	32.44	13.87 (0.00)	
Sheep	27.45	26.32	6.06	27.92	29.92	8.60 (0.04)	
Poultry	59.45	65.55	63.64	54.06	66.67	16.60 (0.00)	
Donkey	51.07	70.81	57.58	58.44	17.42	166.15 (0.00)	
Horse	2.14	0.96	0	2.6	2.27	2.76 (0.43)	
Camel	6	0	0	6	0	4.96 (0.18)	
Mule	2	0	0	2	0	1.65 (0.65)	
TLU (index)	5.65	2.93	4.27	8.11	2.15	0.77 (0.51)	
Cart	6.51	0	6.06	10.23	3.03	33.82 (0.00)	
Tractor	0.18	0	3.03	0.16	0	15.94 (0.00)	
	National	Amhara	BNSG	Oromia	SNNP	Female	Male
Percentage of common bean plots treated with the management practices (Input use in % plots)							
Chemical fertilizer***	42.16	36.95	30.59	44.86	49.79	43.31	43.79
Organic fertilizer***	10.71	13.56	4.71	10.52	8.44	10.86	9.74
Pesticides***	2.5	1.11	0.59	3.83	0.56	2.69	2.23
Herbicides***	19.08	2.99	19.41	29.31	8.72	20.58**	17.46
Irrigated plot (%)	2.95	1.48	0	4.2	1.48		

Table A3.4. Family and hired labor (in adult man equivalent) used for different field operation on plots cultivated in different crops, by region sex of the household head

Operations	Labor source	Labour in man-days per ha Mean (Std. Dev)					F test statistics (p value)	Labour in man-days per ha			t test statistics (p value)
		Amhara (a)	BNSG (b)	Oromia (o)	SNNP (s)	National		Mean (Std. Dev)			
		Femal	Male	Total							
Land preparation and planting	Family	16.05 (19.46)	29.52 (42.26)	28.36 (53.68)	21.09 (43.61)	24.35 (46.16)	14.09 (0.00)	27.15 (46.39)	24.20 (46.15)	24.35 (46.16)	0.83 (0.41)
	Hired	0.36 (4.31)	1.29 (6.6)	0.93 (8.04)	1.10 (14.48)	0.87 (9.23)	1.02 (0.38)	2.37 (9.42)	0.79 (9.21)	0.87 (9.23)	2.21 (0.03)
Weeding (cultiva-tion)	Family	32.97 (48.64)	33.27 (52.23)	39.93 (87.90)	34.26 (66.11)	36.96 (75.31)	2.03 (0.11)	38.85 (56.75)	36.86 (76.20)	36.96 (75.31)	0.34 (0.73)
	Hired	1.21 (8.08)	4.50 (14.56)	5.85 (33.55)	2.17 (13.64)	4.05 (25.81)	7.06 (0.00)	2.03 (8.38)	4.16 (26.43)	4.05 (25.81)	-1.07 (0.29)
Harvesting	Family	24.51 (32.49)	33.5 (57.09)	31.28 (56.72)	32.47 (64.12)	30.26 (54.55)	3.39 (0.02)	26.02 (53.80)	30.49 (54.59)	30.26 (54.55)	-1.06 (0.29)
	Hired	2.15 (9.82)	4.87 (15.42)	7.57 (51.58)	1.84 (16.44)	5.10 (38.88)	5.47 (0.00)	5.08 (14.70)	5.10 (38.88)	5.10 (38.88)	-0.01 (0.99)
Threshing	Family	12.78 (17.99)	26.18 (51.52)	20.31 (33.27)	17.08 (29.14)	18.38 (31.31)	13.78 (0.00)	18.41 (37.00)	18.38 (30.97)	18.38 (31.31)	0.01 (0.99)
	Hired	0.69 (3.48)	0.87 (3.78)	1.40 (12.00)	0.56 (2.86)	1.05 (9.04)	1.99 (0.11)	1.00 (4.12)	1.05 (9.23)	1.05 (9.04)	-0.07 (0.95)
For all operations	Family	86.30 (108.4)	122.47 (174.7)	119.88 (193.8)	104.90 (164.6)	109.95 (172.8)	6.86 (0.00)	110.43 (159.8)	109.93 (173.49)	109.95 (172.79)	0.04 (0.97)

Operations	Labor source	Labour in man-days per ha Mean (Std. Dev)					F test statistics (p value)	Labour in man-days per ha			t test statistics (p value)
		Amhara (a)	BNSG (b)	Oromia (o)	SNNP (s)	National		Mean (Std. Dev)			
		Femal	Male	Total							
		ab ³ ,ao ¹									
	Hired	4.40 (16.44)	11.54 (27.94)	15.75 (83.66)	5.67 (30.23)	11.07 (63.55)	7.59 (0.00)	10.48 (25.57)	11.10 (64.99)	11.07 (63.55)	-0.13 (0.9)
		ao ¹		os ¹							
Proportion to total lab (family + hired) required for all operations	Family	0.96 (0.12)	0.9 (0.18)	0.9(0.22)	0.95 (0.14)	0.92 (0.19)	21.62 (0.	0.88 (0.23)	0.92 (0.18)	0.92 (0.19)	-2.77 (0)
		ab ¹ ao ¹	bs ²	os ¹							
	Hired	0.04 (0.12)	0.1 (0.18)	0.1 (0.22)	0.05 (0.14)	0.08 (0.19)	21.62 (0)	0.12 (0.23)	0.08 (0.18)	0.08 (0.19)	2.77 (0)
Proportion of hired to family lab for all operation		ab ¹ ao ¹	bs ²	os ¹							
		0.08 (0.30)	0.21 (0.62)	0.26 (1.03)	0.11 (0.49)	0.19 (0.81)	11.62 (0.00)	0.29 (0.76)	0.19 (0.81)	0.19 (0.81)	1.64 (0.1)
		ao ¹		os ¹							

Table A3.5 Diets, food consumption, bean consumption and aggregated consumption expenditure disaggregated by region and sex of household head

	Pooled sample	Amhara	BNSG	Oromia	SNNP	Sex HH head	
						Male	Female
24 hour Household Dietary Diversity Score (HDDS)							
Mean	5.90	5.24	6.21	6.24	5.60	5.29	5.95
Std.Dev	1.62	1.58	1.75	1.47	1.82	2.12	1.60
% of HH below a minimum threshold of 5 score	18.32	29.95	12.12	10.00	28.05	17.17	25.68
7 day Household Dietary Diversity Score (HDDS)							
Mean	6.72	5.91 ^{***b,s}	7.07	7.11 ^{***a}	6.42 ^{***o}	6.74	6.43
Std. Dev.	1.8	1.6	2.04	1.66	2	1.78	2.047
Per capita bean consumption (kg/yr)							
Mean	17.66	9.64	2.53 ^{**SNNP}	17.05 ^{***Amhara, SNNP}	22.16 ^{***Amhara}	17.9	6.32 ^{***}
Std. Dev.	18.52	10.17	8.49	16.79	23.87	18.61	8.07
Food Consumption Score (FCS)							
Mean	56.8	51.6	61	60.5	51.2	54.5	57
SD	18.4	14.9	16.9	17.6	21	20.1	18.2
% HH							
Poor	1.9	0.7	0	0.7	6.6	5.9	1.6
Borderline	7.8	4.1	7	5.2	18.8	6.9	7.9
Acceptable	90.3	95.2	93	94.1	74.5	87.3	90.5
Household annual consumption expenditure	24733.7 (22238.2)	22512.19 (15579.1)	17680.4 (13050.6)	29794.9 (27012.9)	17189.0 (12788.9)	24485.4 (19752.3)	26934.95 (40319.69)
Food expenditure share	71%	70%	61.9%	70.5%	71%	70%	74%
Annual Per capita consumption expenditure	6888.559 (7352.5)	6610.9 (5333.7)	5030 (1596.1)	8359.5 (9212.9)	4527.4 (3513.7)	6645. (5883.008)	9793.237 (16769.6)

Significance: ^{***}1%

Table A3.6a Scores given to production, marketing and consumption traits by respondents (score 1-5)*

Attributes	Amhara		BNSG		Oromia		SNNP		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Production traits										
Yield	4.0	0.8	3.9	0.8	3.8	1.0	4.0	0.9	3.9	0.9
Maturity period	4.1	0.6	4.1	0.6	3.7	0.9	3.9	0.7	3.8	0.8
Excess tolerance	RF3.7	0.8	3.4	1.0	3.2	1.0	3.6	0.8	3.4	1.0
Drought tolerance	3.3	1.2	2.8	1.2	3.4	1.1	3.5	1.0	3.4	1.1
Fertilizer requirement	2.7	1.4	2.6	1.4	3.0	1.0	3.4	1.0	3.0	1.1
Pest tolerance	3.0	1.3	2.8	1.3	3.4	1.2	3.4	1.1	3.3	1.2
Disease tolerance	3.1	1.2	2.9	1.2	3.3	1.2	3.4	1.0	3.3	1.1
Marketing and processing traits										
Ease of shelling	4.3	0.7	4.4	0.7	3.5	0.9	3.6	1.0	3.7	1.0
Storability	3.5	1.1	3.3	1.2	3.3	0.9	3.4	0.8	3.4	1.0
Market demand	3.9	0.9	4.0	0.8	3.8	1.0	3.9	0.8	3.9	1.0
Grain price	3.6	1.1	3.7	1.2	3.8	1.1	3.8	0.9	3.7	1.0
Consumption										
Cooking time	3.6	0.9	4.2	0.7	3.5	0.8	3.7	0.8	3.6	0.9
Color of beans	3.8	0.6	3.8	0.8	3.6	0.9	3.7	0.7	3.7	0.8
Size of beans	3.8	0.7	4.0	0.6	3.5	1.0	3.8	0.7	3.6	0.9
Taste of beans	3.5	1.1	4.2	0.6	3.6	0.9	3.8	0.7	3.6	0.9
Taste of green pod	1.9	1.0	2.7	1.3	2.9	1.2	3.2	1.2	2.8	1.3
Overnight keeping quality	2.6	1.2	2.8	1.2	3.3	0.9	3.2	1.0	3.2	1.0
Nutrition value	3.4	0.9	3.7	0.6	3.7	1.0	3.8	0.8	3.6	0.9

*1=least important, 5=most important

Table A3.6b Farmers rating of most preferred bean varieties (currently being cultivated and those they recently stopped cultivating) for production, marketing and consumption traits*

TRAIT	Amhara		BNSG		Oromia		SNNP		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Production traits	Rating of currently grown varieties									
Yield	15.3	4.7	15.9	5.6	16.6	6.8	18	5.3	16.6	6.2
Maturity	16.1	4.6	16.2	2.8	15.5	6.1	16.7	5	15.9	5.5
Excess RF tolerance	13.3	4.8	11.9	5.8	11.1	6.1	13	4.5	11.9	5.7
Drought tolerance	10.1	6	8.1	5.3	12.6	7.1	12.4	6.5	12	6.8
Fertilizer requirement	9.3	6.7	6.9	6.4	9.7	5.8	11.3	5.7	9.8	6
Pest tolerance	8.3	5.3	8.1	7.2	12.7	7.3	12.2	5.7	11.7	7
Disease tolerance	8.3	4.6	8.4	6.6	12	7	12.2	5.5	11.3	6.5
Marketing and processing traits										
Ease of Shelling	17.8	5.3	18.7	5.2	13.4	5.6	14.6	6.4	14.6	5.9
Storability	12.4	5.9	9.7	4.6	11.9	5.8	11.7	5.4	11.9	5.7
Market demand	14	6.3	15.5	5.3	16.2	6.7	17.1	5.7	15.9	6.5
Grain price	12.2	6.1	13	7.7	15.7	6.8	15.8	5.6	15	6.7
Consumption and phenotypic										
Cooking time	12.8	4.6	17	4.6	13.4	5.1	14.9	5.7	13.7	5.2
Color of beans	14.8	3.8	15.5	4.1	14.3	5.3	16	5	14.7	5
Size of beans	13.1	3.7	14.6	3.8	13.5	5.8	14.3	4.6	13.6	5.2
Taste of beans	12	5.7	17	4.3	14.6	5.6	15.6	5.6	14.4	5.7
Taste of green pod	3	2.9	7.2	5.8	10	7.2	9.3	8.1	8.5	7.2
Overnight keep quality	6.4	4.5	8.3	7.3	11.8	5.4	10.3	6	10.4	5.8
Nutrition value	11.3	5	12.8	3.9	15.1	6.2	16.8	6.5	14.6	6.2
Production traits	Rating of varieties recently abandoned									
Yield	12.5	5.2	13.2	4.7	12.8	6.3	11.7	6.5	12.6	6.1
Maturity	14.2	3.8	14.9	3.4	12.8	6.2	12.1	6.8	13	5.9
Excess RF tolerance	11.9	4.7	11	4.3	9.8	6.1	9.3	4.7	10.1	5.7
drought tolerance	8.8	5.3	7.5	5.3	10.3	6	9.5	6.4	9.8	6

TRAIT	Amhara		BNSG		Oromia		SNNP		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Fertilizer requirement	8.6	6.2	7.1	6	8.8	5.4	9.1	6.2	8.7	5.7
Pest tolerance	8.1	5.5	5.1	4	10.2	6.8	9.5	6	9.5	6.4
Disease tolerance	8	4.5	5.8	3.8	9.8	6.3	9.4	5.6	9.2	5.9
Marketing and processing traits										
Ease of Shelling	16.4	5.5	16.3	4.8	11.6	5.9	11.8	8	12.7	6.5
Storability	11.1	5.3	9.6	4	10.4	5.7	8.9	5.4	10.3	5.6
Market demand	8.8	4.4	10.4	6	11.2	5.7	10.4	5.6	10.6	5.5
Grain price	7.4	4.2	8.5	5.9	10.9	5.7	9.8	5.3	10	5.6
Consumption trait										
Cooking time	12.2	4.3	13.6	5.6	11	5	11.8	7.1	11.5	5.4
Color of beans	12.8	3.8	13	4.3	11.4	5.2	11.8	6.7	11.8	5.3
Size of beans	13	4.1	13.6	3.5	10.7	5	11.1	6.3	11.3	5.2
Taste of beans	11	4.6	12.2	5	11.1	5.1	11.3	6.3	11.2	5.2
Green pod taste	2.7	2	5.5	4.5	7.9	5.5	8.5	7.5	7	5.8
Keeping quality	6.1	3.5	6.4	4.7	9.5	4.6	7.6	5.3	8.5	4.8
Nutrition value	10.3	4.3	11.3	3.7	11.7	5.5	12	6.9	11.5	5.5

*The original scale (score) of the traits (1-5) are weighted by the value (score) given to the trait itself. The weighted score ranges from 1-25; 1= least important, 25 = most important

Table A3.7 Average awareness and adoption lag of improved bean varieties grown by sample farmers and number of reported years farmers cultivated different bean varieties (DNA based)

Bean Variety	Year of Release	Time to Awareness			Time to Adoption			Average number of years variety grown				
		Mean (#Obs)			Mean (# Obs.)			Mean (# Obs.)				
		Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3	ALL	AMHAR A	BNSG	OROMI A	SNN P
Lehode	2010	-2.4 (82)	2.6 (44)	5.1 (44)	-1.1) (82)	2.8 (55)	4.9 (82)	7.2 (6.5)	6.4		7.7	2
Hawasa Dume	2008	0.7 (18)	3.9 (12)	4.9 (18)	2.4 (18)	5.7 (12)	5.1 (18)	6.2 (4.4)	10		4.8	6.2
Cranscope	2007	5 (5)	5 (5)	5 (5)	6.1 (8)	6.1 (8)	6.1 (8)	3.8 (2.4)			3.6	5
Anger	2005	4.1 (28)	5.9 (24)	6 (28)	5.7 (28)	7.3 (25)	7.3 (28)	5.9 (5.8)	6.8	5.3	5.1	6.5
Argene	2005	7 (1)	7 (1)	7 (1)	7 (1)	7 (1)	7.0 (1)	4			4	
Nazareth	2005	5.3 (3)	5.3 (3)	5.3 (3)	7 (3)	7 (3)	7 (3)	17.7 (18.7)			17.7	
Nasir	2003	1.9 (7)	7.5 (4)	7.4 (7)	3 (7)	7 (5)	7.7 (7)	10.6 (8.2)		17.5	5	8.5
Awash melka	1999	14.5 (2)	14.5 (2)	14.5 (2)	15 (2)	15 (2)	15 (2)	3.5 (3.5)	3.5			
Awash_1	1990	16 (74)	18.7 (68)	18.3 (74)	17.1 (74)	19.9 (68)	19.5 (74)	8.2 (8.1)	6	3	9.7	4.2
Roba_1	1990	19.9 (17)	19.9 (17)	19.9 (17)	20.6 (17)	20.6 (17)	20.6 (17)	6.1 (5.9)		5	7.4	4.7

Bean Variety	Year of Release	Time to Awareness			Time to Adoption			Average number of years variety grown				
		Mean (#Obs)			Mean (# Obs.)			Mean (# Obs.)				
		Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3	ALL	AMHAR A	BNSG	OROMI A	SNN P
Lyamungu_85	1985	27.2 (6)	27.2 (6)	27.2 (6)	28.3 (6)	28.3 (6)	28.3 (6)	3 (1.3)			2.6	5
GLP585	1982	21.9 (81)	21.9 (81)	21.9 (81)	24.1 (81)	24.1 (81)	24.1 (81)	9.5 (6.8)	9.4	7	12.5	8.4
Mexican142	1973	34.6 (221)	34.8 (220)	34.6 (221)	36.1 (221)	36.1 (221)	36.1 (221)	7.3 (6.3)	5.9	6	8.8	5
KWP9								7.3 (2.30)			8	6
ADP40_KATWELA								5 (.)			5	5
All improved		20.3 (548)	23.7 (490)	22.1 (548)	21.8 (548)	24.5 (504)	23.3 (548)					
landrace								8.3 (7.3)	7.5	4.5	8.9	7.2
Unknown(no seed sample)								8.1 (7.2)	6.1	12.4	8.8	6.7
Over all mean (SD)							-	7.9 (7)	6.8 (5.8)	8.7 (8.1)	8.7 (7.7)	6.7 (5.4)

Table A5.1 Definition and description statistics of the explanatory variables in METE model

Variable	Non-adopters	Fertili-zer	Varieties	Combi-ned	All
Education (years ahousehold head spent formal schooling)	3.19	3.71	2.53	3.34	3.07
	3.31	3.52	3.19	3.60	3.36
Education (years spouse spent in formal schooling)	1.23	1.71	0.64	1.50	1.03
	2.59	2.89	1.84	2.58	2.34
Age (household head)	43.32	41.88	43.57	42.28	43.01
	11.86	11.34	12.51	11.60	11.98
Gender of household head (1=male, 0 otherwise)	0.92	0.94	0.92	0.88	0.92
	0.27	0.24	0.27	0.33	0.27
Index of household consumer durable goods)	-0.07	0.20	-0.08	0.30	0.00
	1.23	1.69	1.15	1.51	1.30
Index of agricultural equipment	-0.83	-1.87	-2.02	-1.95	-1.57
	22.20	2.35	2.09	2.26	13.14
Income (ETBIRR from household assets e.g trees,)	1455.81	2278.	708.4	946.96	1200.
	7038.43	10	5		22
		7971.	3028.	4092.5	5530.
		33	17	6	32
Income (RTBIRR) from nonagricultural activities	1055.28	726.7	887.4	544.83	890.7
		6	2		3
	5383.43	3555.	4068.	2627.9	4387.
		18	80	6	44
Household size	6.28	6.38	6.09	6.17	6.21
	2.14	2.72	2.25	2.03	2.26
Total livestock in tropical units adults equivalent	1.39	0.89	1.99	0.71	1.45
	9.25	1.09	19.67	0.70	12.96
Adult equivalent of per capita landholding (Ha)	0.78	0.52	0.77	0.41	0.70
	1.16	0.44	3.95	0.57	2.45
Dummy=1 if kebele uses Irrigation, 0 otherwise)	0.47	0.48	0.47	0.39	0.46
	0.50	0.50	0.50	0.49	0.50
Herfindahl~p	0.59	0.59	0.57	0.57	0.56
	0.43	0.44	0.44	0.41	0.44
Log precipitation	7.05	7.01	6.93	6.98	6.98
	0.31	0.26	0.24	0.21	0.28
Soil quality rate (base=good					
Medium	0.78	0.89	0.77	0.93	0.81
	0.41	0.32	0.42	0.25	0.40

Variable	Non-adopters	Fertilizer	Varieties	Combined	All
Poor	0.07 0.26	0.03 0.17	0.12 0.33	0.05 0.23	0.08 0.27
Regional dummies (base=Amhara)					
BNSG	0.03 0.17	0.01 0.09	0.03 0.18	0.02 0.15	0.03 0.17
Oromia	0.59 0.49	0.46 0.50	0.48 0.50	0.64 0.48	0.55 0.50
SNNP	0.28 0.45	0.52 0.50	0.15 0.36	0.22 0.41	0.23 0.42
Log agricultural wage rate lagged one year	4.18 0.51	4.24 0.55	4.29 0.41	4.57 0.57	4.27 0.50
Dummy=1 if kebele has a market place for agricultural produce	0.45 0.50	0.53 0.50	0.36 0.48	0.34 0.48	0.42 0.49
Number of groups a HH belongs to	1.47 0.91	1.39 0.81	1.52 0.99	1.55 0.99	1.49 0.93
Proportion of agricultural plots moderately eroded	0.22 0.40	0.26 0.42	0.30 0.44	0.21 0.37	0.25 0.42
Proportion of agricultural plots severely eroded	0.10 0.30	0.08 0.27	0.10 0.29	0.07 0.23	0.09 0.28
Log of average landholding in kebele	0.49 0.80	0.12 0.84	0.16 0.70	-0.12 0.75	0.26 0.79
Dummy=1 if HH had contact with NGO or researcher	0.03 0.18	0.06 0.24	0.04 0.20	0.14 0.35	0.05 0.22
Long average distance from residence to agricultural plots	2.44 1.19	2.10 1.14	2.65 1.20	2.07 1.09	2.47 1.19

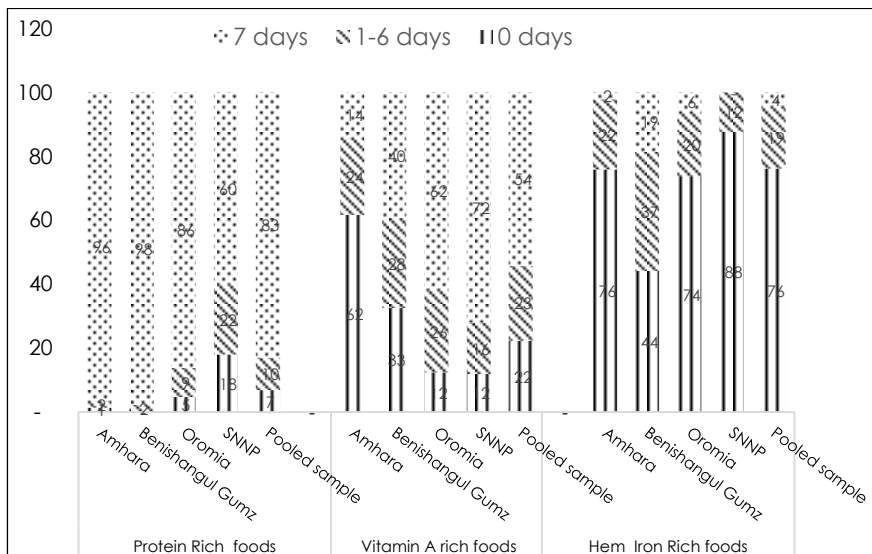


Figure A3.5a: Percentage of households showing frequency of consumption of Protein, Vitamin A and Hem iron rich foods by region

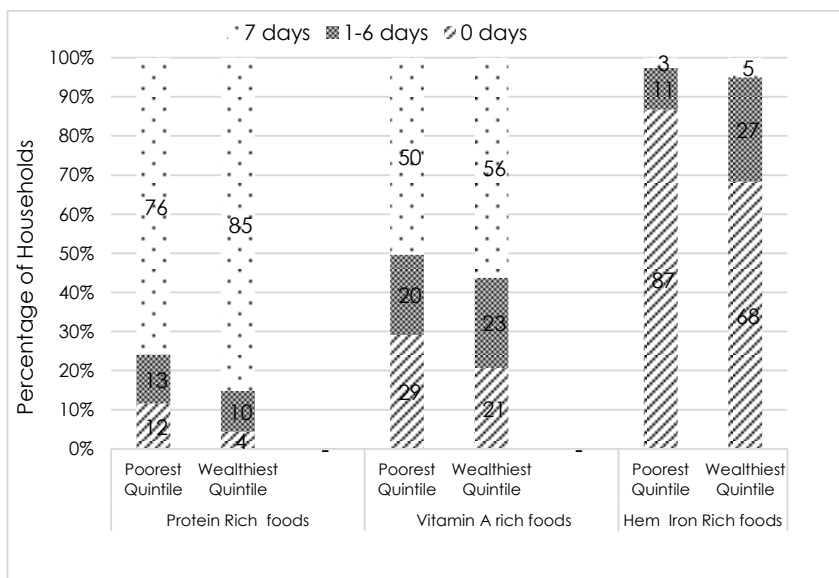


Figure A3.5b Consumption of food groups by poorest and richest wealth quintile

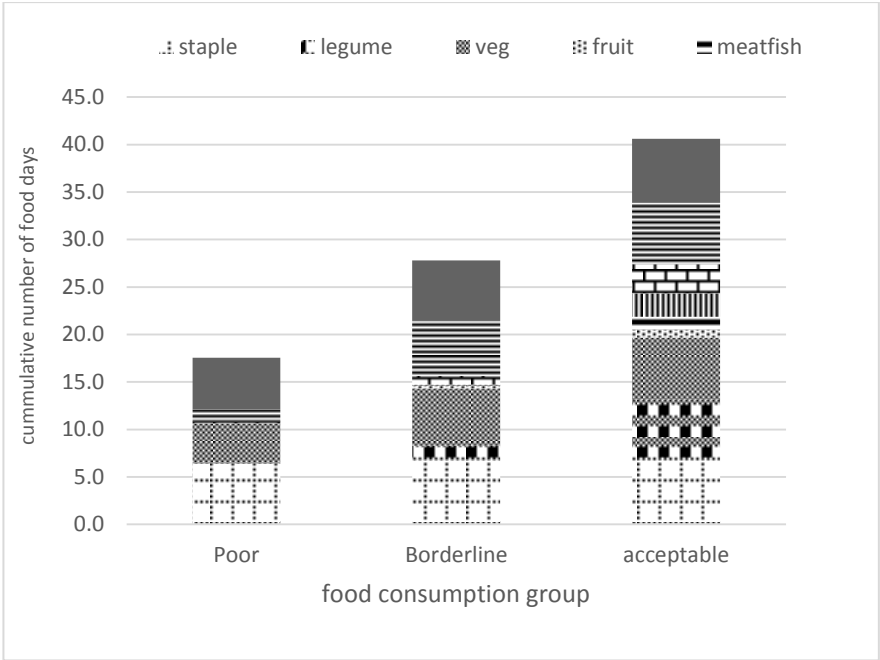
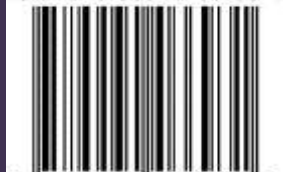


Figure A3.5c. Frequency of food group consumption by food consumption groups



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