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Innovation Opportunities for Wheat and Faba Bean Value Chains in Ethiopia

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FARA serves as the technical arm of the African Union Commission (AUC) on matters concerning agricultural science, technology and innovation. FARA has provided a continental forum for stakeholders in AR4D to shape the vision and agenda for the sub-sector and to mobilise themselves to respond to key continent-wide development frameworks, notably the Comprehensive Africa Agriculture Development Programme (CAADP).

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Executive Summary

Production and supply of food crops is underpinned by various factors starting from pre-planting to postharvest farming activities. Productivity of available resources, development of new crop varieties adapted and resistant to multiple agroecologies, crop diseases and other underlying constraints, and the need to design relevant policy interventions required to bring about technical progress in respective sectors and subsectors appear to be the basic structural features of crop research and production in Ethiopia.

This study is designed to assess the adoption, production, productivity, efficiency and supply of two major crops widely produced in Ethiopia (wheat and faba bean). It is particularly aimed to analyze and validate (1) major crop production constraints and their incidence, prevalence and intensity of crop damage; (2) production, intensity of input use, adoption of improved inputs, supply and participation in output markets; (3) productivity, efficiency, and underlying sources of efficiency differentials and inefficiency effects among producers; and (4) agricultural innovations, yield gaps, and technical change in wheat and faba bean production.

The study makes use of three major sources of data (cross-sectional and timeseries) and primary data (collected form key experts). One of the datasets is Living Standards Measurement Survey (LSMS) obtained from Central Statistical Agency (CSA) collected in 2013/14. It is a socioeconomic survey of about 5262 households operating on about 30000 fields of all crops produced in the country. For this study, data on households, crop fields, input use, crop output, production shocks and crop damage, market participation and supply, and other covariates on 1387 wheat and 475 faba bean fields are considered. Data related to development and release of new crop technologies are obtained from Ministry of Agriculture and Natural Resources (M0ANR). Timeseries data on patterns of production, yield, and supply available at the global database of FAOSTA since 1961 are also utilized.

The study has employed methods supposed to be more relevant and rigorous. Systematic review of existing studies undertaken since 2007 in Ethiopia have been critically conducted with rigorous review procedures including formulation of the research questions, identification of relevant publications and their quality assessment, summary and interpretation of the review findings.

Analysis and interpretation of secondary data has also been extensively used to allow for empirical support to the review findings. Adoption of improved inputs (seed and fertilizer) for wheat production and the determinant factors thereof are identified by a seemingly unrelated (SUR) bivariate probit model. Market participation and intensity of participation by smallholder wheat and faba bean producers is analyzed by Heckman sample-selection models. Stochastic production frontier (SPF) models with half normal distribution are employed to estimate the productivity of factor inputs used for wheat and faba bean production by smallholder farmers. Efficiency scores are predicted from the frontier models, analyzed across different sets of covariates, and accordingly stylized and documented. Two-limit Tobit model is used to identify the underlying sources of efficiency differentials and inefficiency effects for both wheat and faba bean. Time trend growth model of wheat and faba bean yield is analyzed to estimate the technical change attained in wheat and faba bean production. Gap between attainable and actual

yields of new crop varieties is analyzed and compared by their yield performance and resistance to diseases on research stations.

The review process and analysis of the datasets have revealed policy-relevant findings. Constraints of wheat and faba bean production are identified and categorized into three as diseases, environmental and pests with their spatial distribution across the country. The incidence and prevalence of crop damage caused by the top ten constraints are identified for both wheat and faba bean crops. Shortage of rainfall, crop diseases, and excessive rainfall were the top three covariate shocks causing crop damage in 2013/14. About 36 percent of wheat fields and 37 percent of faba bean fields were adversely affected by production constraints. The intensity of crop damage was about 35 and 38 percent, respectively, for wheat and faba bean with significant variation across regional states, agroecology and soil type.

Use of improved inputs for wheat and faba bean production is found to be generally very low but with considerable difference among regional states and production inputs. On average, only 12 percent of wheat and 0.1 percent of faba producers used improved seed in 2013/14. Though wheat production increased exponentially over the last 22 years, per capita supply of wheat in Ethiopia has undergone substantial downturn, particularly in the last decade. The SUR bivariate probit model outputs of adoption of improved seed and chemical fertilizer have resulted in policy-relevant findings. Adoption of improved seed of wheat by smallholder farmers in Ethiopia is only 9 percent; whereas farmers are more likely to use fertilizer (66%) for wheat production. The likelihood of adopting both inputs for wheat production is very low (7.3%). The probability of farmers in using neither of the inputs is surprisingly high (32.7%). It is worrisome that wheat farmers in Ethiopia are 80.5 percent likely to use chemical fertilizer without improved seeds.

The sample-selection model outputs reveal that wheat and faba bean producers in Ethiopia are essentially non-commercial, where only 38 percent of wheat producers and 28 percent of faba bean producers have participated in the output markets, with variation across covariates and constraints. Factors determining market participation of wheat and faba bean producers are also identified. The likelihood of participation of producers in the output markets of wheat and faba bean predicted from the model is estimated at 40 and 33 percent, respectively.

The SPF model outputs show that improved seed used for wheat production (o.76%) and labor used (0.49%) for faba bean production are inputs with the highest productivity. The returns to scale in wheat and faba bean production, respectively, are decreasing (0.89) and constant (1.02). The mean technical efficiency of wheat and faba bean producers is about 70 percent of their potential output for both crops, but with substantial variation across regional states, agroecology, soli type and plot slope. The factors contributing to inefficiency differentials among producers of both crops are characterized and the mean technical inefficiency is computed to be 46 percent.

Agricultural innovations related to crop production and marketing in Ethiopia are also characterized and analyzed. Until 2016, 74 varieties of bread wheat, 34 varieties of durum wheat, and 31 varieties of faba bean have been released for production Ethiopia. These varieties are characterized by high yield gaps between potential and actual both on research stations and farmers' fields. The average yield gap in recently released varieties is 36 for bread wheat, 29 for durum wheat, and 75 percent for faba bean. The level and pattern of yield in Ethiopia is compared to top 20 countries of strikingly high yield improvement globally. Ethiopia appears to be 31st in wheat production and 67th in wheat yield. Interestingly, Ethiopia, with surprisingly low yield improvement, however, is the world's second producer of faba bean in 2013/14, next to China.

New and high yielding wheat and faba bean cultivars resistant to diseases are very few in the country. In this study, only 21 varieties of wheat are identified and validated to be resistant to the major wheat disease in Ethiopia (stem rust, leaf rust, yellow rust, septoria, and Ug99). The overall index of resistant to these major diseases is only 39 percent. To the extreme, there only four faba bean varieties resistant to the major faba bean diseases in Ethiopia (chocolate spot, rust, and ascochyta blight).

Technical progress attained in wheat production is 2.8 percent per year, which is a cumulative progress of 112 percent in the last 40 years (1975-2014). Technical progress in faba bean production is relatively low (2.2%), a cumulative progress of 88 percent in 40 years period. However, there was 35 percent technical regress in faba bean production in the current policy regime of 22 years (1992-2014), an annual regress of 1.6 percent.

In addition to the technical innovations described above, key experts of wheat and faba bean research have validated few other innovations. One of these innovations is institutional innovation on agricultural marketing in Ethiopia, identified to be establishment of the Ethiopia Commodity Exchange (ECX) in 2007. This institutional innovation is thought to be a breakthrough in the performance of agricultural marketing systems in Ethiopia which has been intended to substantially manage risks of operation, credit, market, liquidity, and reputation of all actors.

Many crop management innovations are considered new to most of the smallholder farmers in Ethiopia. As perceived by key experts of wheat and faba bean research in Ethiopia, adoption of these innovations by smallholder farmers is now getting momentum. These existing management innovations identified by the key experts include (1) treatment of acidic and black soils; (2) use of new seed and fertilizer recommendation rates; (3) row plating; (4) establishment and strengthening of marketing cooperative unions; (5) creation of market linkages between smallholder producers and other market actors; (6) establishment of fertilizer blending centers; and (7) wheat self-sufficiency program initiated by the government.

The findings of this study clearly reveal policy relevant implications on the multiple production constraints and their adverse effects, intensity of input use and adoption, yield improvement, productivity, efficiency, and market supply of crop outputs. The results generally suggest the need to characterize and control for production constraints with enhanced development and release of new agricultural technologies adapted to diverse agroecologies and resistant to crop diseases, adoption of existing technical and management innovations, and supply of improved inputs.

INTRODUCTION

Agriculture appears to be the mainstay of the Ethiopia economy contributing to 79.3 percent of employment, 42 percent of GDP (FAO, 2106). Crop production, in particular, is the main agricultural activities of smallholder producers in sedentary mixed farming system of Ethiopia covering 40 percent of the country's area and nearly 90 percent of the total population. For Ethiopia to feed its 97 million population, boosting agricultural production and productivity appears to be one of the viable options of securing food and nutrition and manufacturing input supply.

However, crop production in Ethiopia is constrained by multiple factors of climate, agroecology, technology, institution, infrastructure, marketing, and policy, among others. One of the major challenges in transforming the traditional smallholder agriculture is lack of agricultural innovations and their dissemination among smallholder producers. Policy focus and intervention on development and adoption of new and high yielding crop cultivars with strategic importance in addressing challenges of production appears to be imperative. Wheat and faba bean are the two major crops widely produced, traded and consumed in Ethiopia.

Wheat is one of the major cereal crops grown in the Ethiopian highlands dominated by two wheat species. About 80 percent of wheat produced in Ethiopia is bread wheat *(Triticum aestivum)* of which 60 percent is grown in spring seasons (Wheat Atlas, 2016). Ethiopia is also considered to be the center of genetic diversity of durum wheat *(Triticum turgidum L var durum),* which is grown on heavy black clay soils (Vertisols) of the central and northern highlands of Ethiopia between 1800-2800 masl. At present, wheat is produced solely under rainfed conditions. Durum wheat, differentiated by its big size and weight, is mainly suitable for pasta, macaroni, *pastini* and other manufacturing products.

The world's top three wheat producers are China, India and Russia; whereas Ethiopia is the largest wheat producer in Sub-Saharan Africa (SSA) (MoANR, 2016; FAO, 2016)). Though Ethiopia ranks 31st in the world with 4.2 million quintals produced on 1.7 million hectares of land, it is the 67th country in wheat yield, even far below many SSA countries. This production volume covers 5.8 percent and 16.2 percent of the total wheat production in the world and in Africa.

Faba beans (also known as broad beans, horse beans, or field beans), on the other hand, is the third most important grain legume in the world (Singh et al., 2013). It is the first pulse crop in terms of both area coverage and volume of production in Ethiopia (Biruk, 2009). China, Ethiopia, and Australia are the top three faba bean producers in the world with 14.3, 8.4 and 3.3 million quintals of production cultivated on 0.7, 0.4 and 0.2 million hectares of land (FAO, 2016). Africa's faba bean production is concentrated in Ethiopia where 60.1 percent is produced. It also covers about 20.3 percent of the global faba bean production. Area cultivated for faba bean production in Ethiopia covers about 15 percent of the total area cultivated in the world.

The major regions producing faba bean in Ethiopia are Tigray, Gondar, Gojjam, Wollega, Wollo, Gamo, Gofa and Shoa. In addition, it is grown in pocket areas in the rest of the country's highland and semi-highland regions with altitudes ranging from 1800-3000 masl (MoANR, 2016). Due to its nitrogen fixing capacity, it is used in crop rotation with the nationally important cereal crops like wheat, *teff* and barley.

To address the overriding need for boosting food production and input supply in Ethiopia, critical assessment of the opportunities and constraints along the value chains of such selected commodities is of paramount importance. This study identifies, characterizes, evaluates, and validates promising agricultural innovations on wheat and faba bean crops along their value chains. It particularly addresses the following four research questions:

- What constrains are likely to adversely influence efficiency, productivity, marketability, and market performance of wheat and faba bean in Ethiopia?
- What is the level and sources of efficiency and productivity of smallholder wheat and faba bean producers?
- Which innovations are promising to enhance *productivity* and profitability of wheat and faba bean along the value chains?
- How do innovations on wheat and faba bean accelerate technical progress to improve market supply, performance, governance, and sustainability of the value chains? Which market and policy interventions are relevant?

Research Methodology

This study utilizes acritical review of existing studies and collection and analysis of primary, secondary, cross-sectional and timeseries data.

Systematic review

Review of literature on agricultural innovations on wheat and faba bean value chains was conducted by employing systematic review of existing studies. The systematic review was designed to collect and to look at multiple studies on wheat, faba bean and related issues with a particular focus on the research questions. The systematic review was aimed at providing an exhaustive summary of current literature relevant to the five research questions of the study.

The systematic reviews were conducted with strict adherence to the following five steps:

- Formulation of problems/questions for the review:
- The first step in the review process was formulation of research/review questions to be addressed by the study. The problems were specified in the form of structured questions before beginning the review work.
- Identification of relevant publications:
- Relevant studies conducted in Ethiopia (and abroad) were searched extensively, including both electronic and printed.
- Quality assessment of the studies:
- Quality assessment of studies was an integral part at each step of the review process. Though the minimum acceptable level of design is described by the question formulation and study selection criteria, the selected studies were subjected to a more refined quality assessment by

the use of critical appraisal guides and quality checklists at this stage. The quality assessment generally used the following set of generic selection criteria:

- Methodological rigor: Research design, as a means to ensure reliability of results, employed in the studies were evaluated for their methodological adequacy.
- Relevance: Thematic areas treated in the studies under review should have covered one or more of the research questions stipulated above.
- Recency: With the exception of a few methodological and analytical frameworks, all studies under consideration, recent undertaken in the last decade, since 2007.
- Reputability: All data and related evidence used in this study are obtained from official and reputable resources.

- Summary of the evidence: Data synthesis was consisting of checklist of study characteristics, quality and effects, and use of statistical and econometric model outputs used in the studies for exploring differences between studies and combining their effects. All studies used in these cases have been summarized by their common underlying characteristic features suitable for interpretation.
- Interpretation the findings: At this final stage, the issues highlighted in each of the four steps above were met, where the risk of publication and other related biases were explored. Exploration for heterogeneity was helpful to determine whether the overall summary could be trusted.

Dataset

This study employs systematic review of existing empirical studies published on reputable journals. It has also utilized both primary and secondary data.

Secondary data

The secondary data used in this study are both cross-sectional and timeseries. The major cross-sectional datasets were obtained from official and reputable sources including Central Statistical Agency (CSA), Ministry of Agriculture (MoA), Ministry of Agriculture and Rural Development (MoARD), Ministry of Agriculture and Natural resources (MoANR) of Ethiopia; and the global database of Food and Agriculture Organization (FAO) of the United Nations called FAOSTAT.

Central Statistical Agency:

The Living Standard Measurement Survey (LSMS) data collected by the Central Statistical Agency (CSA) uses five questionnaires: household, community, post-planting agriculture, post-harvest agriculture and livestock questionnaires. The sample is a two-stage probability sampling. The first stage of sampling entails selecting primary sampling units, which are a sample of the CSA enumeration areas. The second stage of sampling is the selection of households to be interviewed in each enumeration area. A sample weight with post-stratification adjustments is calculated for the households and this weight variable is included in all the datasets.

The cross-sectional used in this study is collected from representative sample households in rural and urban areas of the four major regional states of the country: Tigray, Amhara, Oromia and SNNP (Southern Nationals, Nationalities and Peoples) regional states. It is the second round LSMS data collected by the CSA in 2013/14 in collaboration with the World Bank. It is a socioeconomic survey of about 5262 households with 24000 family members across the country. The dataset includes about 30000 fields of all crops produced in the country covering post-planting to postharvest surveys. For this study, data on households, crop fields, production and market supply of the two crops in the four regional states were utilized. Accordingly, about 1387 and 475 crop fields of wheat and faba bean production, respectively, were selected.

FAOSTAT:
The timeseries data obtained from FAOSTAT are input use, production, yield, supply, consumption, and related issues on Ethiopia and other countries used for comparison. It covers various period since 1961.

MoA, MoARD, MoANR:
The major datasets obtained from MoA, MoARD, and MoANR are new wheat and faba bean varieties released for production in Ethiopia. The dataset on the new varieties include all attributes of the new cultivars. The varieties included in the analysis are only those released in the last decade (since 2007).

Wheat Atlas:
Data gaps related to wheat varieties and rust diseases at the MoA, MARD and MANR were filled by secondary data obtained from Wheat Atlas.

Primary data
In order to fill the information gap identified in the systematic review of empirical literature and analysis of secondary data, primary data was also collected and analyzed. Two structured questionnaires on wheat and faba bean were prepared and distributed to 16 key experts of wheat and 10 experts of faba bean research in Ethiopia, to a total of 26 experts. The experts were selected by their previous and current research works. They were contacted to respond on the major agricultural innovations in wheat and faba bean value chains in Ethiopia. Thirteen of the contacted key experts (50%) have responded to the questions.

Methods of Data Analysis

This study has employed standard methodological and analytical frameworks to investigate (1) adoption of improved inputs; (2) market participation, intensity of participation and commercial behavior of farmers; (3) efficiency and productivity of wheat and faba bean producers; (4) sources of efficiency differentials and inefficiency effects among producers; (5) gap between potential and actual yield of producers; (6) technical change attained which cannot be captured by efficiency and productive analysis.

Determinants of adoption

To identify the factors determining the adoption of improved inputs with relatively more adoption rate, parametric analysis was employed. Adoption of one type of technology is assumed to affect the adoption of another. Because resources like land and other inputs are scarce, adoption of one technology is not intendent of adoption of the other. Accordingly, adoption of improved seed and fertilizer were estimated simultaneously by using a seemingly unrelated (SUR) bivariate probit model (Long and Freese, 2005; Cameron and Trivedi, 2010):

$$\begin{aligned} y_{1i}^{*} &= \mathbf{x}_1^{'}\boldsymbol{\beta}_1 + v_{1i} \\ y_{2i}^{*} &= \mathbf{x}_2^{'}\boldsymbol{\beta}_2 + v_{2i} \end{aligned} \tag{1}$$

where y_{1i} and y_{2i} are the adoption of improved seed of improved wheat variety seed and use of chemical fertilizer, respectively; and v_{1i} and v_{2i} are their respective error terms.

Accordingly, the latent variables, observed and unobserved, can be specified as:

$$\begin{aligned} \mathrm{y}_{1\mathrm{i}} &= \begin{cases} \mathrm{y}_{1\mathrm{i}}^{*} = \mathbf{x}_1^{'}\boldsymbol{\beta}_1 + \mathrm{v}_{1\mathrm{i}} & \text{if } y_{1\mathrm{i}}^{*} > 0; \\ 0 & \text{if } \mathrm{y}_{1\mathrm{i}}^{*} \leq 0. \end{cases} \\ y_{2i} &= \begin{cases} y_{2i}^{*} = \mathbf{x}_2^{'}\boldsymbol{\beta}_2 + v_{3i} & \textit{if } y_{2i}^{*} > 0 \\ 0 & \textit{if } y_{2i}^{*} \leq 0 \end{cases} \end{aligned} \tag{2}$$

Table 1: Determinants of adoption of improved inputs and working hypotheses

Covariates	Measurement	Expected effect
Literacy status	Dummy (1 if literate, 0 otherwise)	-
Household size	Counts of family members	+
Sex	Dummy (1 if male, 0 otherwise)	+-
Household size	Counts of family members	+
Plot area cultivated	Continuous (hectare)	+
Access to credit	Dummy (1 if accessed to credit, 0 otherwise)	+
Extension service	Dummy (1 if accessed to extension service, 0 otherwise)	+
Distance to market	Continuous (kilometers, ln)	-
Distance to main road	Continuous (km, ln)	-
Plot elevation	Continuous (meters, ln)	-
Regional dummies	Categorical	+-
Soil type	Categorical	+-
Agroecology	Categorical	+-

Source: Author's definition and measurement (2016).

Market participation

Smallholder producers in Ethiopia face multiple constraints of production and marketing. The production and marketing constraints include crop diseases, environmental factors, pests, markets, prices and related demographic and socioeconomic constraints (for details see section 3). Because of these deterrents, crop producers are not equally likely to produce and to participate in output markets. Such populations from which samples are drawn are expected to be distorted where samples lack representativeness. This phenomenon of sampling is said to have sample selection bias. Heckman (1976) had developed sample-selection model to correct for such selection bias. It is a means of correcting for not having a randomly selected sample (i.e. the sample is no more representative of the group we want to study). Application of both Ordinary Least Squares (OLS) methods and censored models in this case lead to biased parameter estimates. This error can be corrected by introducing an adjustment to the equation that takes into account the probability of selling.

In order for farmers to produce and supply their crops to the market, they should make two decisions, the decision to sell and how much to sell. The two decisions can be represented by two equations, participation equation for the binary decision (technically known as selection equation) and outcome equation for intensity of participation. The issue here is whether or not these decisions are interdependent. If the two decisions are assumed to be interdependent, the equations must be estimated simultaneously. If they are assumed to be independent household decisions, the two equations may be estimated separately.

The Heckman selection model assumes that there exists an underlying regression relationship (Heckman 1976, 1979),

$$y_i = \mathbf{x}_i\boldsymbol{\beta} + u_{1i} \tag{3}$$

where y is the outcome variable (or quantity of sales in this case); $\mathbf{x}$ is a vector of explanatory variables determining marketed supply; $\boldsymbol{\beta}$ is a vector of parameters to be estimated; and u_1 is the error.

In the selection equation, the dependent variable for observation i is observed if

$$\mathbf{Z}_i\boldsymbol{\gamma} + u_{2i} > 0 \tag{4}$$

Where
$$u_1 \sim N(0,\sigma)$$
$$u_2 \sim N(0,\,1)$$
$$Corr(u_1,\,u_2) = \rho$$

where ρ is the correlation between the residuals from the outcome and the selection equations. When $\rho \neq 0,$ standard regression techniques applied to the first equation yield biased results.

Heckman procedure provides consistent, asymptotically efficient estimates for all the parameters in such models. The potential determinants of wheat and faba bean market participation are hypothesized in Table 2 below.

Table 2: Hypothesized determinants of market participation

Covariates	Measurement	Expected effect on	
		Participation	Supply
Household size	Counts of family members	-	-
Labor input	Continuous (man-days, ln)	+	+
Seed input	Continuous (kg, ln)	+	+
Plot area	Continuous (ha, ln)	+	+
Dap fertilizer	Continuous (kg, ln)	+	+
Access to credit	Dummy	+	+
Ownership of phone	Dummy (1 if owned phone, 0 otherwise)	+	+
Distance to market	Continuous (km, ln)	-	-
Crop damage	Dummy (1 if crop damaged, 0 otherwise)	-	-
Tigray region	Dummy	+-	+-
Amhara	Dummy	+-	+-
Oromia region	Dummy	+-	+-

Source: Author's definition and measurement (2016).

Efficiency and productivity analysis

In order to investigate the productivity of inputs and efficiency of smallholder wheat and faba bean producers, Cobb-Douglas stochastic production frontier (SPF) models were employed. The stochastic frontier model with inefficiency component of half-normal distribution was estimated for both wheat and faba bean producers specified below (Kumbhakar and Lovell, 2000).

A producer represented by production function with a set of factor inputs $\mathbf{z}_i$, the i^{th} firm would produce

$$y_i = f(\mathbf{z}_i, \boldsymbol{\beta}) \quad (5)$$

In a stochastic frontier analysis, it is assumed that each firm potentially produces less than it might due to a degree of inefficiency specified as

$$y_i = f(\mathbf{z}_i, \boldsymbol{\beta})\varsigma_i \quad (6)$$

where y_i is the output for firm i, ς_i is the level of efficiency in the interval (0; 1]. If $\varsigma_i = 1$, the firm is achieving the optimal output with the technology represented by the production function. When $\varsigma_i < 1$, the firm is not making the most of the inputs given the technology embodied in the production function. In this case, the output and the degree of technical efficiency are assumed to be strictly positive.

The output is also assumed to be subject to random shocks, v_i, implying that

$$y_i = f(\mathbf{z_i}, \boldsymbol{\beta})\xi_i \exp(\mathbf{v}_i) \quad (7)$$

Taking the natural log of both sides of the above equation results in the following model:

$$\ln y_i = \ln\{f(z_i, \beta)\} + \ln(\xi_i) + v_i \quad (8)$$

If there are k inputs and if the production function is linear in logs, then

$$\ln y_i = \beta_0 + \sum_{j=1}^{j=k} \beta_j \ln(z_{ji}) + v_i - u_i \quad (9)$$

Where $u_i = -\ln(\xi_i)$

Because u_i is subtracted from $\ln y_i$, restricting $u_i \geq 0$ implies that $0 < \xi_i \leq 1$ as specified in the above equation. The frontier model that was actually fitted in this study is

$$\ln y_i = \sum_{j=1}^{j=k} \beta_j \ln z_{ji} + v_i - su_i \quad (10)$$

$$\textit{where } s = 1, \textit{ for the production function.}$$

Technology could have an impact on the magnitude of the partial elasticities of inputs. The combined impact of fixed factors on the production function, known as return to scale, can be computed as

$$\beta_0 = \sum_{j=1}^{j=n} \beta_j \ln z_{ji} \quad (11)$$

The definition and measurement of production inputs is summarized in Table 3 below. The major production inputs used for wheat production are labor, area of land cultivated, seed used, chemical fertilizer used (DAP and Urea), and oxen as source of draught power. Urea fertilizer was not used in faba bean producers for the fact that faba bean plant fixes nitrogen.

Table 3: Definition and measurement of outputs and inputs

Variables	Measurement (natural log)
Output	Kilograms per hectare
Labor	Man days per hectare
Field area	Hectares
Seed	Kilograms per hectare
Dap fertilizer	Kilograms per hectare
Urea fertilizer	Kilograms per hectare
Oxen	Oxen days per hectare

Source: Author's definition and measurement (2016).

Inefficiency effects

The sources of technical inefficiency differentials among smallholder wheat and faba bean producers were identified by estimating the two-limit Tobit model of technical inefficiency scores on a set of covariates as follows (Tobin, 1958; Long, 1997; Cameron and Trivedi, 2010):

$$y_i = \mathbf{x\beta} + \varepsilon_i \tag{12}$$

$$y_i = \begin{cases} \mathbf{x\beta} + \varepsilon_{i_i}, & if \quad y_i^* > 0 \\ 0 & if \quad y_i^* < 0,\ y_i^* > 1 \end{cases} \tag{13}$$

where y_i is the inefficiency score observed (y_i^*) when positive, and the $\mathbf{x}$'s are vectors of covariates determining the inefficiency differentials among producers (Table 4).

Table 4: Measurement of inefficiency variables and working hypotheses

Covariates	Measurement	Expected effect
Literacy status	Dummy (1 if literate, 0 otherwise)	-
Sex	Dummy (1 if male, 0 otherwise)	+-
Household size	Counts of family members	+
Access to credit	Dummy (1 if accessed to credit, 0 otherwise)	-
Prevention of soil erosion	Dummy (1 if soil erosion prevented, 0 otherwise)	-
Crop rotation	Dummy (1 if crop rotation used, 0 otherwise)	-
Extension service	Dummy (1 if accessed to extension service, 0 otherwise)	-
Distance to market	Continuous (kilometers, ln)	+
Distance to administrative center	Continuous (kilometers, ln)	+
Soil type:		
Leptosol	Dummy (1 if Leptosol, 0 otherwise)	+-
Cambisol	Dummy (1 if Cumbisol, 0 otherwise)	+-
Vertisol	Dummy (1 if Vertisol, 0 otherwise)	+-

Luvisol	Dummy (1 if Luvisol, 0 otherwise)	+-
Agroecology:		
Tropic cool/Semi-arid	Dummy (1 if semi-arid, 0 otherwise)	+-
Tropic cool/Sub-humid	Dummy (1 if sub-humid, 0 otherwise)	+-
Tropic cool/Humid	Dummy (1 if humid, 0 otherwise)	+-
Climatic:		
Precipitation	Continuous (annual precipitation, mm, ln)	-
Temperature	Continuous (degree Celsius, ln)	+
Plot elevation	Continuous (meters, ln)	-
Soil quality:		
Good	Dummy (1 if good soil, 0 otherwise)	-
Fair	Dummy (1 if fair soil, 0 otherwise)	-
Poor	Dummy (1 if poor soil, 0 otherwise)	+
Region:		
Tigray	Dummy (1 if plot is in Tigray, 0 otherwise)	+-
Amhara	Dummy (1 if plot is in Amhara, 0 otherwise)	+-
Oromia	Dummy (1 if plot is in Oromia, 0 otherwise)	+-
SNNP	Dummy (1 if plot is in SNNP, 0 otherwise)	+-

Source: Author's definition and measurement (2016).

Yield gap

Yield has various definitions with different implications. *Potential yield* is the yield of a current cultivar when grown in environments to which it is adapted; with nutrients and water non-limiting; and with pests, diseases, weeds, lodging, and other stresses effectively controlled (Evans and Fischer, 1999). *Attainable yield* is the best yield achieved through the use of the best available technology, which proxies potential yield. *Actual yield* reflects the current state of soils and climate, average skills of the farmers, and their average use of technology. *Yield gap* is the difference between two levels of yield.

Yield benchmarking and gap analysis can be undertaken by using four approaches or methods: (1) comparing actual yields with maximum yields measured in high-yielding farmer's fields or experimental stations; (2) comparisons of actual yield, but instead of a single yield benchmark, yield is expressed as a function of one or few environmental drivers in simple models; (3) simple to complex modeling of yield; and (4) methods combining remote sensing, actual data, GIS, and models of varying complexity (FAO, 2015).

This study employs the first approach to compare actual yields of recently released wheat and faba bean varieties on research station, as a proxy for potential yield. The yield gap analysis between potential and actual on research station in this study allows for identification of production constraints, trade-offs and opportunities for improvement of yield gap.

Technical change

Technical change is any shift in the production frontier. It is a change in the technology index measured over time t which affects the relationship between inputs and output. If technological change allows to produce more output with the same quantity of inputs (i.e. positive technical change), it is known as technical progress. The rate of technical change measures the relative change in output due to the partial effect of the technology index t. Technical change can be measured by (a) the rate of technical change which can be estimated from the production function, the cost function or from the profit function; (b) partial productivity indexes; and (c) total factor productivity (TFP) indexes (Kumbhakar et al. 1999; Baltagi and Griffin, 1988; Myyra et al. 2009).

In this analysis, technical change is captured by the rate of technical, change estimated from a time trend model of wheat and faba bean yield growth. It is a proxy variable capturing the rate of technical change or the shift in the production over time producing smooth technological changes (Myyra et al., 2009; Kifle, 2016). When technological change is expected to merely increase average output or average yield, including the time trend in the model is sufficient. The trend model can also include a vector of dummy variables. The time trend model results in a smooth shift in the production function over time, while time dummies capture erratic or policy changes over time. The latter model sheds less restrictive and preferable when capturing the variation in crop production in Ethiopia.

The pattern of yield growth of wheat and faba bean has approximately followed an exponential pattern in the past 54 years. As a result, the annual yield timeseries can be approximated by an exponential growth equation:

$$y_t = y_0 \exp(\Delta y_{t-h} + e_t); \quad t = 1, \ldots, T; \tag{14}$$

where y_t is the yield (kg/ha) in year t; y_0 is the initial yield; Δy_{t-h} is the rate of yield growth at time $t-h$; h is the lag length; T is the sample size; and e_t is the corresponding error term with zero mean and constant variance.

Taking the logarithmic transformation of these exponential specifications, we get,

$$\ln y_t = A + \sum_{h=1}^{h=k} \alpha_j \ln \Delta y_{t-h} + \beta t + \varepsilon_t \tag{15}$$

The first differences of the log transform of yield were computed as follows:

$$\Delta y_t = y_t - y_{t-1}, \quad t = 1, \ldots, T; \tag{16}$$

where y_t is the log of yield; y_{t-1} is the lagged value of yield in year $t-1$; and Δy_t is the annual yield growth rate fluctuating around the longrun annual growth rates of the original time series (Dickey and Fuller, 1979).

Parameters of the yield growth model were estimated by Prais-Winsten and Cochrane-Orcutt regression using the generalized least-squares method in which the errors are serially correlated

(Davidson and MacKinnon, 1993; Judge et al. 1985). The rate of technical change per year in yield be computed by the partial derivative of yield with respect to time as

$$\beta = \frac{\partial \ln y_t}{\partial t}. \qquad (17)$$

Production Constraints

Typology of Constraints

Crop production is direct or indirect affected by multiple constrains prevalent at different stages of the value chain. Potential constraints of crop production can be grouped into meaningful categories by their level of analysis (Table 5). These factors could be categorized into six as (1) individual level, (2) farm level, (3) household level, (4) community level, (f) regional level, and (6) country level.

Individual characteristics: Crop production characteristics attributable to individuals are grouped as individual level characteristics. These characteristics include age or farming experience, literacy or education, marital status, involvement in off-farm activity, health status, religion, and ethnicity of the individual member in the household.

Farm characteristics: Farm-or plot-specific characteristics are one of the most important factors explaining significant proportion of inefficiency differentials among smallholder crop producers. These factors include plot/field size, slope of plot, soil fertility, and prevalence of crop damage. Managing plot level characteristics would enhance smallholder crop production efficiency. In short-run, particular focus on the effective ways of managing input supplies for improving land fertility are important to boost production and supply. Some of such efforts may be grouping of fragmented plots into clusters, adoption of improved farming practices, and adequate and efficient supply of production inputs, including mechanization services and other modern inputs.

Household characteristics: Household-specific characteristics considered by most of the studies are family size, gender of household head, education of household members on average, asset holdings, membership to groups, access to off-farm activities, age/farming experience of household head, age dependency ratio, education/training, asset holdings, group membership, technology adoption status, off-farm activity, and health of household members on average. Policy interventions designed to improve preferred characteristics of farm households may include family planning, farm literacy and training, and income generating activities for increasing asset holdings of households, and enhancing adoption rate of agricultural technologies at household level.

Community characteristics: Access to production and marketing infrastructure like input and output markets, financial markets, land distribution, access to public services, consumption habit or demand for various crops, and social structure are the major constraints and/or opportunities of crop production and marketing. Smallholders' access to such improved services would reduce the adverse effects of constraints and will enable smallholders' crop producers to exploit their production potential.

Table 5: Typology of crop production constraints

Level of analysis	Characteristics
Individual level	• Age or farming experience • Education • Marital status • Off-farm activity • Health status • Ethnicity • Religion
Farm level	• Plot size • Slope of plot/field • Fertility of land • Location/distance from household and infrastructure • Prevalence of crop damage
Household level	• Size of household • Age dependency ratio • Gender of head, or of household adults on average • Assets (e.g. size of land holding, farm tools, housing, other means of production) • Group membership • Off-farm activity • Health and education of household members on average • Technology adoption status
Community level	• Infrastructure (e.g. market information, piped water, access to all weather roads, irrigation, credit, crop insurance) • Land distribution • Access to public goods and services (e.g. market information, proximity to research centers, development stations) • Consumption habit • Social capital
Regional level	• Isolation or remoteness from infrastructure (e.g. markets and other services • Natural capital or resource endowments (e.g. availability and quality of land and labor) • Weather and environmental conditions (e.g. droughts, altitude, rainfall, humidity, precipitation, temperature) • Inequality differentials among regions • Regional governance and management • Regional policy

Country level	• Agricultural price policy • Import and export policy • Incentives/disincentives to production of specific crops • Technical constraints

Source: Author's classification (2016).

Regional characteristics: Crop production constraints and opportunities requiring interventions at regional level include isolation or remoteness, resource endowment, weather and environmental factors, income inequality, and regional governance and policy. Environmental constraints are the major regional deterrents of crop production in Ethiopia for the fact that farming is primarily rain-fed and subsistence.

Country characteristics: Agricultural price and marketing policy, import and export incentives/disincentives and production programs designed to specific crops of a country are major potential constraints and/or opportunities of crop production. Agricultural policies need to be designed to towards improving production and productivity through generating high-yielding varieties adapted to diverse agroecological constraints and susceptibilities, improving marketing performance, and consumption of crops.

Constraints of wheat production

Specific constraints of wheat production in Ethiopia are categorized into three by the type of stress they have on the crop. Crop disease, environmental factors and pests are the major constraints of wheat production in Ethiopia. The prevalence of these constraints can be treated itt0 three as common, rarely and occasionally observed (Wheat Atlas, 2016).

Diseases

Wheat diseases are one of the primary production constraints for which breeding programs are primary designed. Table 6 summarizes the common wheat production diseases and their spatial distribution in agricultural research centers (ARC). The breeding programs in these research centers are particularly intended to generate wheat varieties adapted to such diseases prevailing across various agroecologies.

Agricultural research centers in Ethiopia and other institutions and researchers have undertaken various research activities related to yield performance, suitable farming practices, effectiveness of agro-chemicals, and resistance to common diseases of wheat and faba bean across agroecologies in Ethiopia. The research programs have developed some wheat and a few faba bean variates resistant to disease and adapted to various agroecologies in the country. Wheat rusts like stem rust, leaf rust, and stripe rust, septoria are the major wheat diseases attracting the particular focus of breeding programs in Ethiopia.

Table 6: Spatial distribution of common diseases of wheat in Ethiopia

Name of disease	Spatial distribution across farms/ARC
Barley yellow dwarf virus	Sinana ARC, Kulumsa ARC
Black molds	Sinana ARC
Black point	Sinana ARC
Common root rot	Sinana ARC
Crown rot	Sinana ARC
Eyespot	Sinana ARC
Fusarium leaf blotch	Jamma
Leaf rust	Sinana ARC, Jamma, Geregera, Kokate, Hossana, Bulle, Angacha Halaba, Inseno, Kulumsa ARC, Holetta, Debre Zeit ARC
Loose smut	Adet ARC, Motta, Sinana ARC, Jamma, Geregera
Powdery mildew	Sinana ARC
Scab (head blight)	Sinana ARC
Sclerotium wilt	Sinana ARC
Septoria	Adet ARC, Debre Tabore, Motta, Sinana ARC, Jamma, Geregera, Kulumsa ARC, Holetta
Sharp eyespot	Sinana ARC
Spot blotch	Kokate, Hossana, Bulle, Angacha, Halaba, Inseno
Stem rust	Sinana ARC, Kokate, Hossana, Bulle, Angacha, Halaba, Inseno, Kulumsa ARC, Debre Zeit ARC,
Stripe rust	Adet ARC, Debre Tabore, Sinana ARC, Kokate, Hossana, Bulle, Angacha Halaba, Inseno, Kulumsa ARC, Holetta
Take-all	Adet ARC, Debre Tabore, Sinana ARC
Wheat streak mosaic virus	Kulumsa ARC

Source: Compiled from data in Wheat Atlas (2016).

In response to these constraints, Alemayehu et al. (2015) evaluated the reaction of 12 commonly grown bread wheat varieties by artificial inoculation against the major virulent races at seedling stage in green house. Varieties *Hoggana* and *Huluka* that showed resistance to virulent races were recommended as sources of resistance in wheat breeding program. Haile et al. (2013) investigated the grain yields of improved and local varieties of bread wheat in the highlands of eastern Ethiopia and found significant difference in yield performance and diseases resistance. *Digalu* and *Danda'a* were unaffected by diseases compared to the other varieties.

Tesfaye et al. (2007) conducted research on two durum wheat varieties, called *Ilani* (DZ 2234) and *Oda* (DZ 2227), which were released for production in agro-ecologies similar to Bale highlands. They were proved to have resistance to stem, yellow and leaf rusts. Yield stability and higher yield performance in all environments was demonstrated, compared to the commercial durum wheat cultivars in Ethiopia (*Foka*, *Cocorit-71* and *Ingiliz*). Moreover, Wubshet and Chemeda (2016) found that variation in the environmental factors significantly affecting wheat varieties' yellow rust resistance and yield performance in southeastern Ethiopia.

Environmental constraints

The major environmental factors responsible to the largest proportion of efficiency of smallholders' crop production are agroecology determining yield performance of crops. Production efficiency and yield performance are significantly different across agroecologies because of the diverse effects of climatic factors like rainfall, humidity, precipitation, and altitude. These factors in turn aggravate the incidence of other crop production constraints (e.g. diseases). Development and release of improved varieties adaptable to specific agroecological zones and resistant to various diseases can improve efficiency of smallholder wheat producers. Drought, acidic soils and water lodging, and phosphorous and nitrogen deficiency are the major environmental challenges of wheat production in Ethiopia (Table 7).

Table 7: Spatial distribution of common environmental constraints of wheat production

Stress type and name	Spatial distribution across farms
Acidic soil	Adet ARC, Sinana ARC, Kulumsa ARC, Holetta
Drought	Sinana ARC, Jamma, Geregera, Kulumsa ARC, Holetta
Hail	Sinana ARC
Low temperature	Sinana ARC, Holetta
Nitrogen deficiency	Debre Tabore, Sinana ARC, Jamma, Geregera, Kulumsa ARC, Holetta
Phosphorous deficiency	Debre Tabore, Sinana ARC, Jamma, Geregera, Kulumsa ARC, Holetta,
Water lodging	Adet ARC, Sinana ARC, Jamma, Kulumsa ARC, Holetta, Debre Zeit ARC

Source: Compiled from data in Wheat Atlas (2016).

Altitude, weather conditions, terrain, and plant health appear to be the major sources of efficiency differentials among crop producers in Ethiopia (Mann and Warner, 2015). Districts produce between 10 and 87 percent of their potential wheat output per hectare given their altitude, weather conditions, terrain, and plant health. The findings of the latest studies on environmental constraints of wheat production in Ethiopia are critically reviewed and selected as reported in Table 8.

Table 8: Research findings on common environmental constraints of wheat production

Author (year)	Findings and recommendations
Assefa et al. (2015)	Grain yield, plant height, effective tiller number/m2 and biomass yield of bread wheat variety increased linearly with planting density and nitrogen fertilizer rate in vertisols of Tigray. More grain for Emba-Alaje and Ofla, respectively, was recorded from the interaction effects of nitrogen with planting density for variety Mekelle-3.
Mann & Warner (2015)	Districts in the four major regions of Ethiopia produce between 9.8 and 86.5% of their potential wheat output per hectare given their altitude, weather conditions, terrain, and plant health. Amhara, Oromiya, SNNP, and Tigray produce 48.6, 51.5, 49.7, and 61.3% of their local attainable yields, respectively. Determinants of wheat output are population density, distance from Addis Ababa, elevation, fertilizer used, improved seed used, crop damage, slope of plot, land covered by wheat
Misganaw (2016)	Stability of bread wheat genotypes was evaluated in north-western Ethiopia. The performances of genotypes grain yield were highly affected by environment and the genotype. The highest variation was accounted for location (29%) followed by genotype (18%) and location by year (18%) and genotype by year (12%) effects. Ogolcho, Gambo, Shorima, and Tsehay were relatively stable genotypes across the test environments than the checks (TAY and Kubsa). Recently released genotypes Gambo, Ogolcho and Tsehay and relatively older genotypes Shorima and TAY were recommended for production at the test environments in Western Amhara Region.
Mossa et al. (2016)	Significant difference among genotypes for water stress tolerance of wheat varieties was found in Tigray. Danda, Mekelle-3 and Mekelle-4 had higher relative water content, excised leaf water retention, initial water content, yield stability index and stress tolerance index than Hawii, Shina and Medawalabu. Total grain yield per plant, spike length, seed per spike and 1000-seed weight was also higher in the same wheat varieties, which placed it as a good candidate for selection in wheat breeding program for drought resistance. Traits like relative water content, excised leaf water retention, initial water content, and days to flowering were recognized as beneficial water stress tolerance indicators for selecting a stress tolerant variety. Incorporation of these physiological traits as selection criterion in breeding program for screening water stress tolerance wheat cultivars was recommended.
Negash & Grausgruber (2011)	Variation in morphological traits of hexaploid wheat accessions across different regions and altitudes was evaluated in 3 zones of Amhara region. Average regional diversity indices for all traits ranged from 0.47 (for accessions from Gojam and Gonder) to 0.57 (for accessions from Shewa). Traits diversity in altitude ranged from 0.44 for altitudes > 2800 masl to 0.63 for altitudes ≤ 2200 masl. Within regions and within altitudes diversity accounted for 89% and 93% of the total variation, respectively.

Zewdie et (2014)	Farm level survey in Ethiopia showed low spatial diversity of wheat where only a few dominant varieties appeared to occupy a large proportion of wheat area. The five top wheat varieties were used by 56% of the sample farmers and these varieties were planted on 80% of the total wheat area. The weighted average age of wheat varieties was high with an average of 13.8 years for bread wheat, showing low temporal diversity or varietal replacement by farmers. The coefficient of parentage analysis showed that average and weighted diversity of bread wheat was 0.76 and 0.66, respectively. Cluster analysis based on agro-morphological traits grouped modern varieties and landraces into separate clusters. The variation among modern varieties and landraces offered opportunities for using genotypes with desired agronomic characters in plant breeding to develop varieties suitable for different agro-ecological zones in the country

Source: Author's review results (2016).

Pests

The major pests of wheat production in Ethiopia are summarized in Table 9. These pests include aphids, armyworms, rodents and birds, and shoot fly. Depending on the nature of climatic factors suitable to them in various agroecologies, these pests cause significant crop damage in Ethiopia.

Table 9: Spatial distribution of common pests of wheat in Ethiopia

Stress type and name	Spatial distribution across farms
Aphids	Sinana ARC, Jamma, Geregera,
Armyworms/cutworms	Sinana ARC, Jamma, Geregera
Cereal leaf beetle	Adet ARC, Debre Tabore, Motta
Crickets	Sinana ARC
Grasshoppers	Sinana ARC
Rodents and birds	Adet ARC, Debre Tabore, Motta, Sinana ARC, Jamma, Geregera, Kulumsa ARC
Shoot fly	Sinana ARC, Jamma, Geregera
Thrips	Sinana ARC
White grubs	Sinana ARC

Source: Compiled from data in Wheat Atlas (2016).

Constraints of Faba Bean Production

Diseases

Breeding programs on faba bean have focused on the common faba bean diseases like chocolate spot, gall, and rust. The study by Tamene et al. (2015) on 11 faba bean varieties released estimated the genetic progresses made in 33 years of faba bean breeding for development of disease-resistant varieties in Ethiopia. Mean performance at all the test environments on year of varietal release showed negative relationship for chocolate spot. The average cumulative gains over 33 years of breeding was 8.9 percent decline in chocolate spot resistance.

The adaptation, high-yielding and disease resistance of nine faba bean varieties under rain-fed condition were evaluated and identified in north Gondar by Tewodros et al. (2015). *Obse* and *Motie* were found to have maturity to have early maturity date; whereas *Hachalu* had late maturity, good height, resistance to disease, largest 1000-seed weight and the highest yield (24.3 kg/ha). *Hachalu* was best fitted to the agroecology by providing above average yield performance.

The distribution and intensity of epidemic faba bean gall disease and other diseases affecting faba bean in the major growing areas of central and northern part of Ethiopia was assessed by Endale et al. (2013). The mean prevalence of faba bean gall (ascochyta blight), chocolate spot and rust were about 49, 64, 95 and 2, percent respectively. The mean incidence of all diseases were 15, 30, 42 and 0.1 in their previous order. Based on severity scale, mean disease severity of ascochyta blight and chocolate spot were 1.9 and 1.5, respectively. Mean severity of faba bean gall and faba bean rust were 6.4 and 0.1. The disease was more sever in Amhara region (22%) followed by Tigray (11%) and Oromia region (8%. Faba bean gall disease was found to be the most devastating and widely disseminated in the study areas within a few years.

Ermias and Addisu (2013) experimented the best combination of sowing date and fungicide frequencies for the management of chocolate spot of faba bean in Bale highlands of Ethiopia. The results revealed significant differences among the treatments for most of the parameters tested, including grain yield and thousand kernel weight. For highland areas of Bale in Ethiopia, early sowing integrated with fungicide treatment was recommended for effective management of chocolate spot on faba bean.

Tamene and Tadese (2013) developed the faba bean variety named *Gora which* was best adapted to altitudes ranging between 1900 to 2800 masl in Ethiopia. It is mainly characterized by a heavier seed with a weight of 17 percent heavier than that of the standard check. *Gora* showed relatively better grain yield performance and stability across a range of environments and years. This variety is moderately resistant to the major faba diseases (chocolate spot and rust) and could be cultivated across a number of locations in the mid and high altitude areas of Ethiopia.

Environmental constraints

Ashenafi and Mekuria (2015) evaluated the yield performance of eight high yielding faba bean varieties (*Mosisaa*, Moti, *Gebelcho*, *Hachalu*, *Shallo*, *Tumsa*, *Wolki* and *Degaga*) in Bale area of southeastern Ethiopia. There was a variation between the varieties for most of yield and yield components. The maximum pods per plant were recorded from *Degaga* variety (20.4 and 22.6) and the maximum 100 grain weight was recorded from *Gebelcho* variety (94.3). The maximum harvesting index (%) and grain yield were recorded for *Shallo* variety with 45, 4, and 4886.8 kg/ha and 4701.6 kg/ha at Agarfa and Sinana areas, respectively. *Shallo* variety was identified to have better yield performance recommended to the local farmers.

Girma and Haile (2014) experimented supplemental irrigation at moisture stress periods in south-east Ethiopia to evaluate faba bean varieties for their yield and physiological parameters response. Among the seven faba bean varieties tested, *Degaga*, *Bulga-70* and *Messay* gave higher yield; CS20-DK and NC-58 were tolerant to moisture stress; *Shallo*, *Degaga* and Bulga-70 were moderately tolerant to moisture stress; and *Tesfa* and *Messay* were relatively more susceptible to moisture stress. Their results generally found that supplemental irrigation significantly improved yield components except harvest index and thousand seeds weight.

Tafere et al. (2012) conducted participatory variety selection to evaluate the performance of 10 improved faba bean varieties and to select better varieties in Dabat district of Amhara region, Ethiopia. Their results indicated significant differences among varieties in plant height, number of pods per plant, number of nodes per plant, number of pods per node, 100-seed weight and grain yield per hectare. The mean yield of *Selale* (24.9 qt/ha), *Wayu* (22.0 qt/ha) and *Dosha* (13.2 qt/ha) varieties were identified to be the top yielding faba bean varieties. Based on the stakeholders' selection criteria, *Dosha*, *Wolki* and *Wayu* varieties were found to be promising to condition similar to the study area.

There are other few studies on other constraints of faba bean production and marketing in Ethiopia. Effects of integrated climate change resilient cultural practices on faba bean productivity were assessed in Hararghe highlands by Hatamu et al. (2015). Three on-farm-based climate change resilient cultural practices (intercropping, compost application and furrow planting alone) and in integration with the other practices were evaluated using *Degaga* and *Bulga-70* faba bean varieties and *Melkassa-IV* maize variety. Integrated climate-resilient cultural practices were found to substantially increase productivity of the crop as a result of enhancing contents of soil nutrients, soil moisture, soil organic carbon, and regulating soil and canopy temperatures as well as through buffering the root environment

Crop Damage

Incidence and prevalence of crop damage

The very cost of production contracts is crop damage. The reviews on the major constraints of wheat and faba bean production in Ethiopia have revealed potential production constraints and research findings addressing such constraints. Empirical evidence on the actual incidence, prevalence, and distribution of crop production constraints across spaces, agroecologies, and plot characteristics has policy relevant implications.

The LSMS data of CSA (2014) has been used in this study to investigate the prevalence and intensity of crop damage caused by the various production constraints in Ethiopia Table 10). Analysis of the survey data revealed that about 36 and 37 percent, respectively, of wheat and faba plots cultivated in 2013/14 faced incidence of crop damage. Faba bean production was relatively more susceptible to production constraints and crop damage.

The top three wheat production constraints in Ethiopia in 2013/14 were shortage of rainfall (9.5%), crop diseases (9.5%), and excessive rainfall (6.3%). But crop diseases, excessive rainfall and shortage of rainfall are the top three causes of faba bean crop damage.

Table 10: Top 10 Causes and incidence of crop damage in Ethiopia, 2014

Causes of crop damage	Wheat (N=1387)		Faba bean (N=475)	
	Incidence	Prevalence rate	Incidence	Prevalence rate
Shortage of rainfall	139	10.0	30	6.3
Crop diseases	132	9.5	34	7.2
Excessive rainfall	88	6.3	34	7.2
Depletion of soil	35	2.5	6	1.3
Weeds	22	1.6	23	4.8
Hail	22	1.6	18	3.8
Insects	20	1.4	10	2.1
Wild animals	11	0.8	5	1.1
Frost	10	0.7	3	0.6
Spoiled seeds	10	0.7	-	-
Other causes	14	1.6	12	2.5
Total	503	36.3	175	36.8

N: Sample size.

Source: Author's computation from data in CSA (2016).

Other production constraints, in order of prevalence, include depletion of soil, weeds, hail, insects, wild animals, frost, and spoiled seeds. The distribution of theses incidences is useful information for targeted policy interventions of crop protection. Table 11 summarizes the regional and agroecological distribution of incidence of crop damage caused by wheat and faba bean production constraints.

The total damage caused on wheat and faba production was nearly similar, 36.3 and 36.8 percent, respectively. Amhara region ranks first in terms of prevalence of crop damage in wheat and faba bean production. About 10.3 percent of incidence of damage on wheat crop was in Amhara region followed by Tigray region (9.9). Similarly, crop damage in faba bean production is relatively more prevalent in Amhara region (13.9%) followed by Oromia region (9.1%). Incidence of wheat crop damage appears to be more likely in sub-humid agroecology (18.2%); whereas semi-arid areas are more damaging in faba bean production (18.1).

Table 11: Regional and agroecological distribution of crop damage in Ethiopia, 2014

Variable	Wheat (N=1387)		Faba bean (N=475)	
	Incidence	Prevalence rate (%)	Incidence	Prevalence rate (%)
Region				
Tigray	137	9.9	36	7.6
Amhara	143	10.3	66	13.9
Oromia	135	9.7	43	9.1
SNNP	88	6.3	30	6.3
Total	503	36.3	175	36.8
Agroecology				
Semi-arid	206	14.9	86	18.1
Sub-humid	252	18.2	57	12.0
Humid	45	3.2	32	6.7
Total	503	36.3	175	36.8

N: Sample size.

Source: Author's computation from data in CSA (2016).

Intensity of crop damage

The prevalence rate of causes of crop damage is not indicative of the extent of damage caused on crop output. The impact of crop damage on smallholders output and income can easily be revealed if the intensity of crop damage caused by production constraints and its spatial distribution is assessed. The intensity of damage on wheat and faba bean output and its distribution across regions, agroecological zone and soil type is summarized in Table 12.

There is significant difference in the intensity of crop damage across regions, agroecologies, and soil type in the production of both crops. In 2013/14, about 35 percent of wheat and 38 percent of faba bean output was damaged by production constraints. The intensity of crop damage is more severe in semi-arid and sub-humid agroecologies, respectively, in wheat (35.5%) and faba bean (40.9%) production. Farm plot with Cambisols were more disastrous for production of wheat (71.3%) but Luvisols and Vertisols are damaging soils in faba production (40%). Out of the total expected output, the mean proportion of crop damage caused in 2013/14 was about 35 percent on wheat plots and 38 percent on faba bean plots. The results consistently indicate the relative severity of crop damage observed in wheat and faba bean production. With the existing technology and factors of production, if there were interventions which could reduce the proportion of crop damage to zero, wheat and faba producers would have increased their output by 35 and 38 percent, respectively.

Table 12: Intensity and distribution of crop damage in Ethiopia (%), 2014

Variable	Wheat (N=1387)	Faba bean (N=475)
Region		
Tigray	37.3	37.7
Amhara	36.1	34
Oromia	36.5	40.7
SNNP	25.6	41.7
Total	34.7	37.7
Chi-squared	34.3***	62.1***
Agroecology		
Semi-arid	35.5	35.0
Sub-humid	35.2	40.9
Humid	28.3	39.4
Total	34.7	37.7
Chi-squared	52.6***	66.3***
Soil type		
Leptosol	27.7	34.0
Cambisol	71.3	30.0
Vertisol	31.4	39.5
Luvisol	36.9	39.7
Mixed type	31.1	22.1
Chi-squared	37.5***	10.6*

Source: Author's computation (2016).

The findings clearly imply that development of new and high-yielding varieties may not lead to increased production and productivity, given these constraints. It is of policy imperative to give due focus to both pre- and post-harvest losses caused by production constraints. These constraints are determines production inefficiency interfering with our efforts towards improving production and productivity growth.

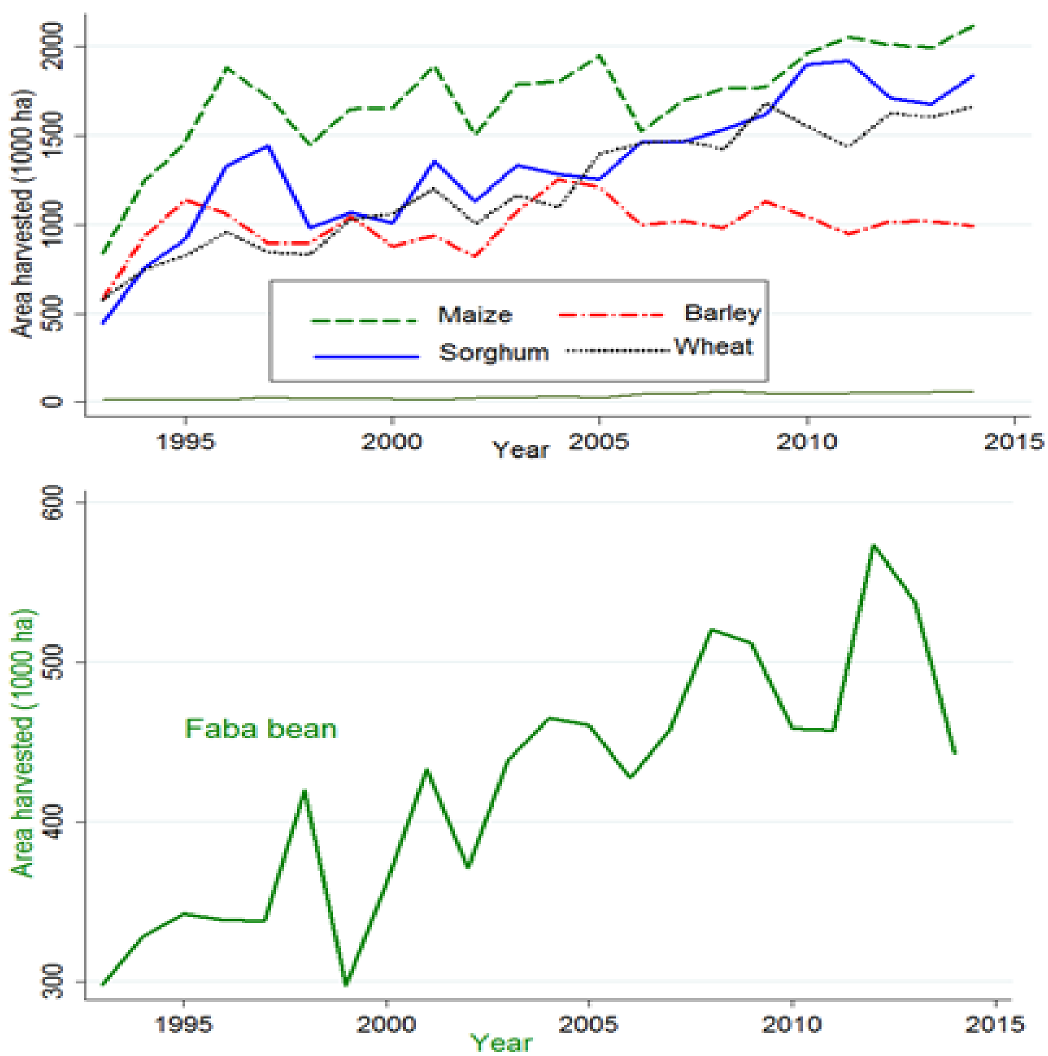
Production and Market Supply

Importance of the Crops

Wheat is the most widely grown cereal crop in the world and staple food for more than 35 percent of the human population. Wheat contributes to 19 percent of human total available calories (FAO, 2016).

The first four cereal crops widely produced and consumed in Ethiopia are maize, sorghum, wheat and barley, respectively. The allocation of scarce resources, such as land, among production of various crops is the primary decision made by smallholder farmers. Figure 1 depicts the pattern of land allocation among production of these crops and faba bean in the past 22 years (1992-2014). Though there has been growth in total land allocation to wheat and faba bean production, the proportion has not undergone significant change. Wheat is still the third cereal crop next to maize and sorghum; whereas faba bean is the crop given the least focus.

Faba bean is the third most important grain legume in the world (Singh et al., 2013). China, Egypt, and Ethiopia rank the top three faba bean production in the world with 1.4, 1.3 and 0.8 million tons of production from 0.7, 0.4 and 0.4 million hectares land covered with faba bean (FAO, 2016). China is the largest producer of faba bean in the world (43%) which is about 39 percent of the total area allocated to faba bean production globally. In Ethiopia, faba production covers about 15 percent of the total area allocated globally. It is the first pulse crop in terms of both area coverage and volume of production (Biruk, 2009).

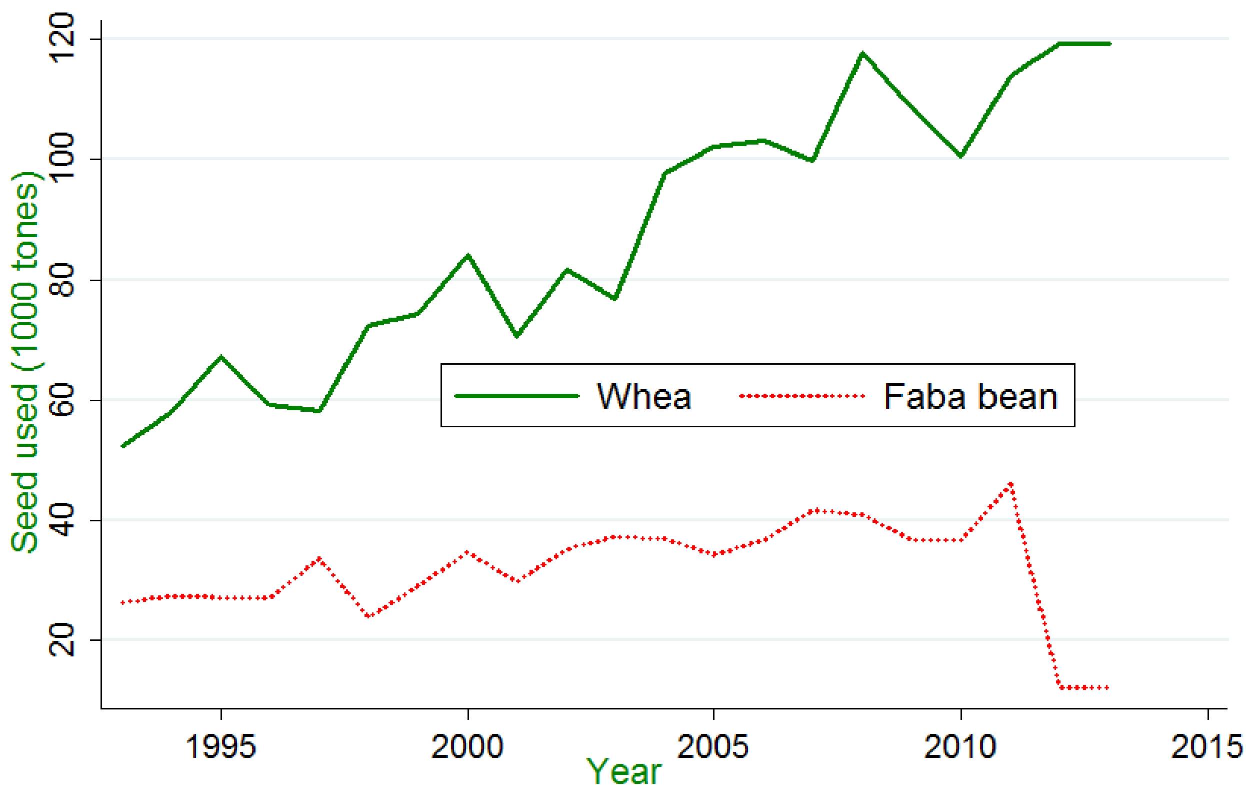


Source: Author's plot from data in FAO (2106).

Figure 1: Patterns of land allocation to production of major cereals and faba bean

Pattern and Intensity of Input Use

The production and consumption of wheat in Ethiopia, particularly seed, appears to be affected by supply and use of improved inputs. The pattern of improved seed utilization for wheat and faba bean production in Ethiopia is depicted in Figure 2. There is a general rise in the use of improved seed for wheat production in Ethiopia. However, the supply and use of seed for faba bean production has rather undergone significant decline in the last few years. Apparently, lack of high-yielding variety, multiplication, supply and of inputs and promotion of the crop faba bean are relatively more prevalent constraints of faba bean production in Ethiopia.



Source: Author’s plot from data in FAOSTAT (2016).

Figure 2: Trends of wheat and faba bean used for seed in Ethiopia (1000 tones)

However, the proportion of wheat and faba bean producers using improved inputs for production of these crops is considerably low (Table 13). The proportion of farmers using improved seed for wheat production in 2014 was below 12 percent but with significant variation across regional states (CSA, 2014). The majority of wheat producers (88%) and almost all of faba bean producers use traditional seed for production of these crops. Apparently, there is significant difference in utilization of all input among regions, as verified by the chi-squared test. With the exception of DAP, there is no significant difference among regions in input use for faba production.

The majority of farmers in Ethiopia use chemical fertilizers and fungicide for wheat production. About 72 and 58 percent of the producers use Dap and Urea fertilizers for production of wheat. The great majority of wheat producers (88%) use herbicide for protecting their crop from weeds competing for nutrients. However, producers using other improved inputs, like fungicide for protecting their crops from common disease of wheat such as rusts, is low (only 5%). To the extreme, there is no significant use of improved seed and other inputs for faba bean production in Ethiopia.

Table 13: Utilization of improved inputs for wheat and faba bean production (%), 2014

Inputs	Tigray	Amhara	Oromia	SNNP	Samples	All users (%)	Chi2
Wheat							
Improved seed	27.6	9.7	3.9	13.1	1660	11.8	109.5***
Dap	82.2	53.8	84.3	52.5	785	71.5	85.0***
Urea	72.0	49.4	61.9	39.4	776	57.6	41.2***
Pesticide	12.5	1.4	15.5	3.4	733	10.2	31.8***
Herbicide	76.9	50.1	97.1	100.0	743	87.8	239.9***
Fungicide	10.3	0	6.8	2.8	734	4.9	14.4***
Faba bean							
Improved seed	0	0	0.7	0	540	0.1	2.6
Dap	86.4	44.7	61.3	50.8	223	55.2	13.4***
Pesticide	-	-	-	-	51	-	4.0
Herbicide	-	-	-	-	51	-	-
Fungicide	-	-	-	-	50	-	

Source: Authors computation form data in CSA (2016).

There is high demand for improved varieties of wheat in Ethiopia. About 49 percent of wheat producers are buyers of improved seed for wheat production (Dawit and Zewdie, 2016). In order to supply adequate volume of improved seeds, there is an overriding need to intensively engage in multiplication of improved seeds. There are drivers and actors promoting farmer-based seed multiplication such as genetic resource conservation and seed security, improved access and adoption of new crop varieties, increased seed production and profitability, and promotion of local seed enterprises (Dawit, 2011).

The other important issue is the sources of improved seed. The great majority of wheat producers (52%) in Ethiopia use seed from their own sources and the remaining (32%) purchase from local sources. For establishment of sustainable marketing system in the seed sector, there are key factors to be taken into account, particularly the factors determining farmers' commercial behavior in wheat seed such as land fragmentation, ownership of various resources, access to various services, and wheat yield achieved by producers (Dawit and Zewdie, 2015).

Adoption of Improved Inputs

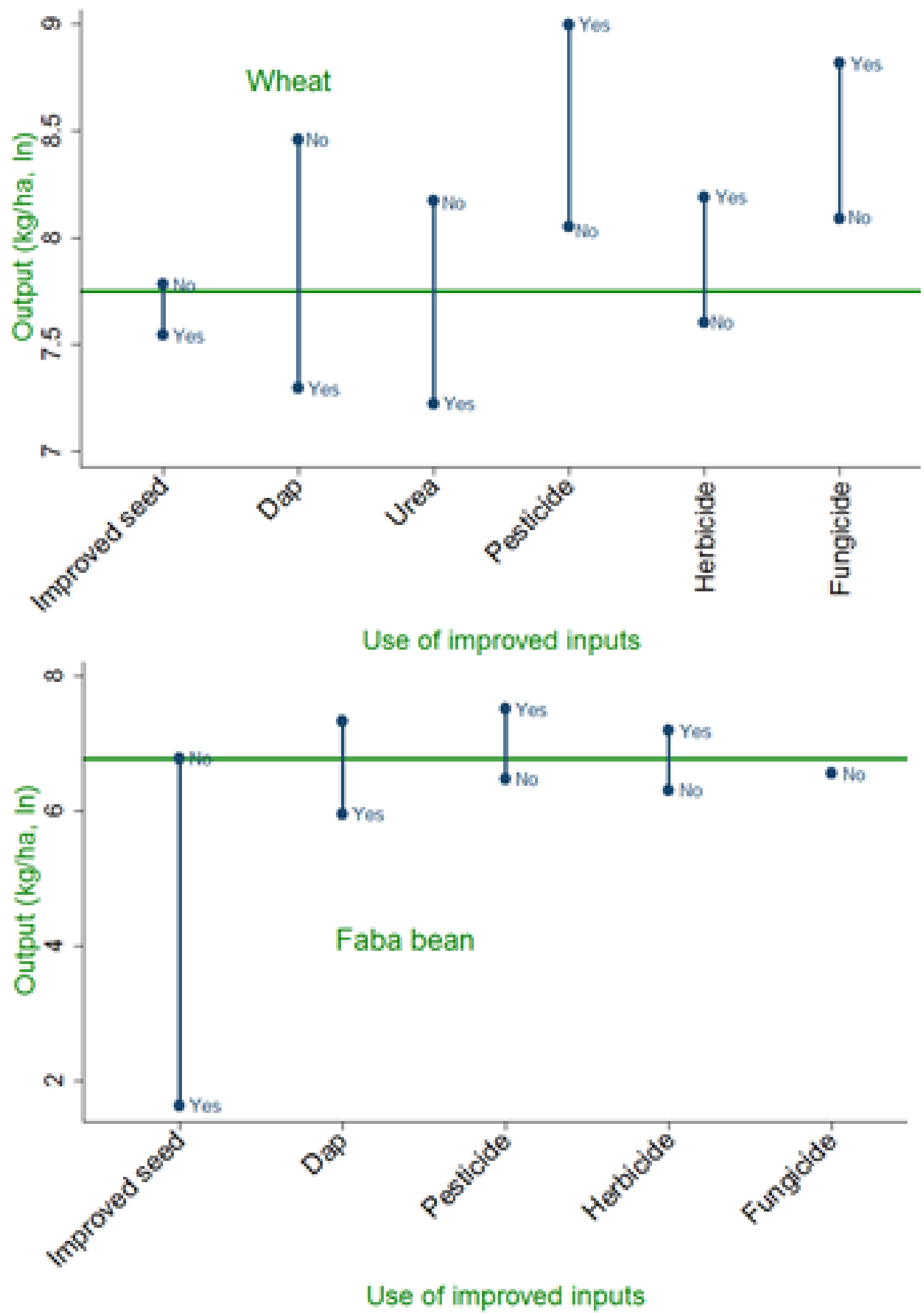
Intensity of input use

The participation of producers in using improved seeds is not adequate to secure increased production and productivity of the crops. The use of improve inputs should lead to more production volume per unit input with the expected efficiency level. The relative effects of improved inputs used on wheat and faba bean outputs per hectare is illustrated in Figure 3. The length of the vertical lines between users and non-users of the inputs suggests the intensity of the differential effects on mean outputs attained.

As expected, the mean output of wheat producers using pesticide, herbicide and fungicide is above the mean value of wheat output compared to their counterparts producing without these inputs. However, the effects of some inputs on outputs are exceptionally low and unexpected. The use of improved seed, DAP and Urea has resulted in output below the mean output of all samples of wheat fields in Ethiopia. This might be related to the ineffective use of inputs (e.g. use of fertilizers above or below recommendations rates) or due to other production constraints, such as climatic, terrain, agroecology and other socio-economic determinants, which interfere with the efficiency of input use (see details of production constraints in the next sections).

Similarly, the effects of improved inputs on faba bean output is indicated in the lower part of the figure. The output effect of improved seed and DAP is lower than that of non-users of these inputs. To the extreme, there is no faba bean field cultivated with fungicide, may be because fungus is not a problem of faba bean production by the sample farmers. The effects of other improved inputs (DAP, pesticide, and herbicide) used for faba bean production is negligible as represented by the short length of the vertical lines. There is no significant output differential between users and non-users of these inputs for the fact that they are used by negligible number of producers.

The findings on the effects of input use are in line with the findings of other studies in Ethiopia. For instance, districts in Ethiopia produce between 10 and 87 percent of their potential wheat output per hectare given their altitude, weather conditions, terrain, and plant health (Mann and Warner, 2015). Wheat output is determined by various factors including population density, distance to markets and other population centers, inputs used, incidence of crop damage, slope of plot, and acreage of land cultivated. Variation in the environmental factors adversely affect disease resistance and yield performance of wheat varieties (Wubshet and Chemeda, 2016).



Source: Author's plot form data in CSA (2016).

Figure 3: Group mean of outputs and use of improved inputs

Determinants of adoption

The factors determining adoption of improved wheat seed and chemical fertilizer and their marginal effects analyzed by the SUR bivariate probit regression model are reported in Table 14. As verified by the likelihood-ratio test, decisions related to the adoption of the two inputs are found to be significantly interdependent (5% level) with the expected signs of all covariates. Household size, plot area, access to credit and extension service, distance to main roads, and Oromia regional dummy jointly determine the adoption of both inputs. Some factors (literacy status of household heads, number of oxen held, Tigray and SNNP regional dummies, and sub-humid agroecology) are significant determinants of adoption of each input but turned out to be marginally insignificant.

Table 14: SUR bivariate probit model outputs of adoption of improved inputs

Covariates	**Coefficient**		**Marginal effects**		
	Improved seed	**Fertilizer**	**Improved seed**	**Fertilizer**	**Joint effect**
Literacy status	0.231	0.205**	0.016	0.073**	0.014
Household size		0.085***	-	0.030***	0.001***
Sex	-0.196	-	-0.013	-	-0.011
oxen	-0.044	-0.086**	-	-0.031**	-0.003
Plot area cultivated	1.339***	0.455*	0.089***	0.163*	0.076***
Access to credit	0.541***	0.114	0.042***	0.040	0.035***
Extension service	1.469***	0 .147	0.091***	0.053	0.074***
Distance to road	-0.170***	-0.081**	-0.011***	-0.029**	-0.010***
Regional dummies:					
Tigray	0.017	0.886***	-0.001	0.264***	0.004
Oromia	-1.100***	0.420***	-0.057***	0.144***	-0.043***
SNNP	-0.049	0.429***	-0.003	0.143***	0.000
Agroecology					
Sub-humid	-0.354*	0.191	-0.025	0.069	-0.018
Constant	-2.279***	-0.551***			
/athrho	0.209**				
Likelihood-ratio test of rho=0	4.08**				
Observations	773				
Wald chi2	154.8				

Note: There is no parametric analysis of adoption of improved inputs for faba bean production because only insignificant proportion of plots use improved inputs like seed (below 1%). *, ** and ***, respectively, denote 10%, 5% and 1% level of significance.

Source: Author's computation form data in CSA (2016).

As expected from the limited intensity of adoption of improved inputs, the estimated marginal effects are generally low for all the variables, falling between the ranges 1.1-9.1 percent in improved seed and 3.0-26.4 percent in the use of fertilizer. The most important factors with the largest partial effect are plot area (8.9%) and Tigray region (26.4%) on the adoption of improved seed and fertilizer, respectively. Farmers with wider plot cultivated for wheat production are more likely to use improved inputs, suggesting the need to reduce land fragmentation for accelerated adoption of agricultural technologies in Ethiopia.

The top three factors jointly and significantly influencing the adoption of both inputs are plot area cultivated, access to extension and credit services, respectively. A unit percentage increase in plot area cultivated increases the likelihood of adoption of improved seed and fertilizer by 7.6 percent. Similarly, access to extension and credit services, respectively, improves the probability of adopting improved seed and fertilizer by about 7.4 and 3.5 percentage points. The findings clearly point out the need for proactive design and implementation of policies particularly enhancing effective agricultural extension services and lessening farmers' financial constraints.

The likelihood of adoption of the two improved inputs are predicted and summarized in Table 15. Adoption of improved seed of wheat by smallholder farmers in Ethiopia is surprisingly low (only 9%). But farmers are relatively more likely to use chemical fertilizer with a probability of about 66 percent. The results also clearly indicate how wheat farmers in Ethiopia are rarely using improved inputs without agricultural extension services. The probability of adopting both inputs simultaneously for wheat production is only 7.3 percent. To the extreme case, farmers are highly likely (32.7%) to adopt neither of the inputs for wheat production.

The other finding with a very important policy imperative is the separate use of inputs. Adoption of agricultural technologies requires the use of recommended package of inputs with expected technical services provided by agricultural extension service providers. Unfortunately, wheat farmers in Ethiopia are highly likely (80.5%) to use chemical fertilizer without improved seed. This spontaneous use of inputs substantially undermines the expected productivity and efficiency of agricultural inputs. Farmers adopting improved seeds without fertilizer, however, are less likely (10.2%). This is possibly because farmers are allowed by the seed supplier and/or distributor if they are willing to adopt the package of inputs recommended for that improved seed.

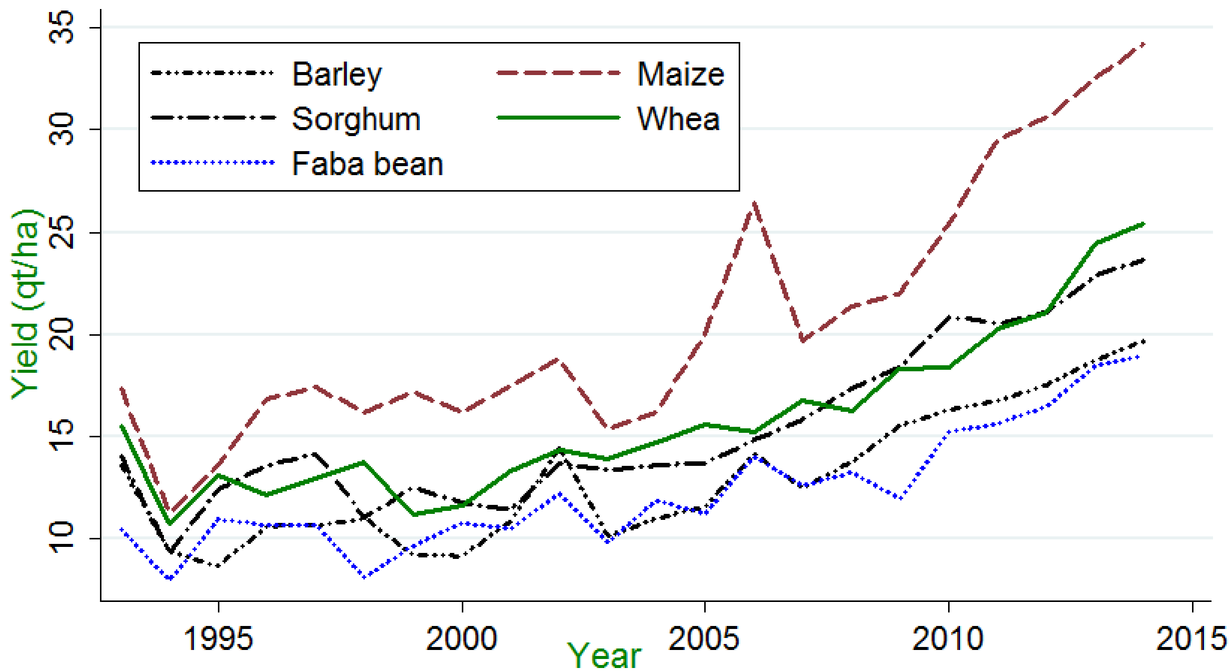
Table 15: Likelihood of adoption of improved inputs for wheat production

Adoption decisions	Predicted probability	Standard deviation
Improved seed	0.090	0.126
Fertilizer	0.656	0.151
Improved seed and fertilizer	0.073	0.109
Neither improved seed nor fertilizer	0.327	0.150
Improved seed without fertilizer	0.102	0.135
Fertilizer without improved seed	0.805	0.116

Source: Author's computation form data in CSA (2016).

Crop Yield

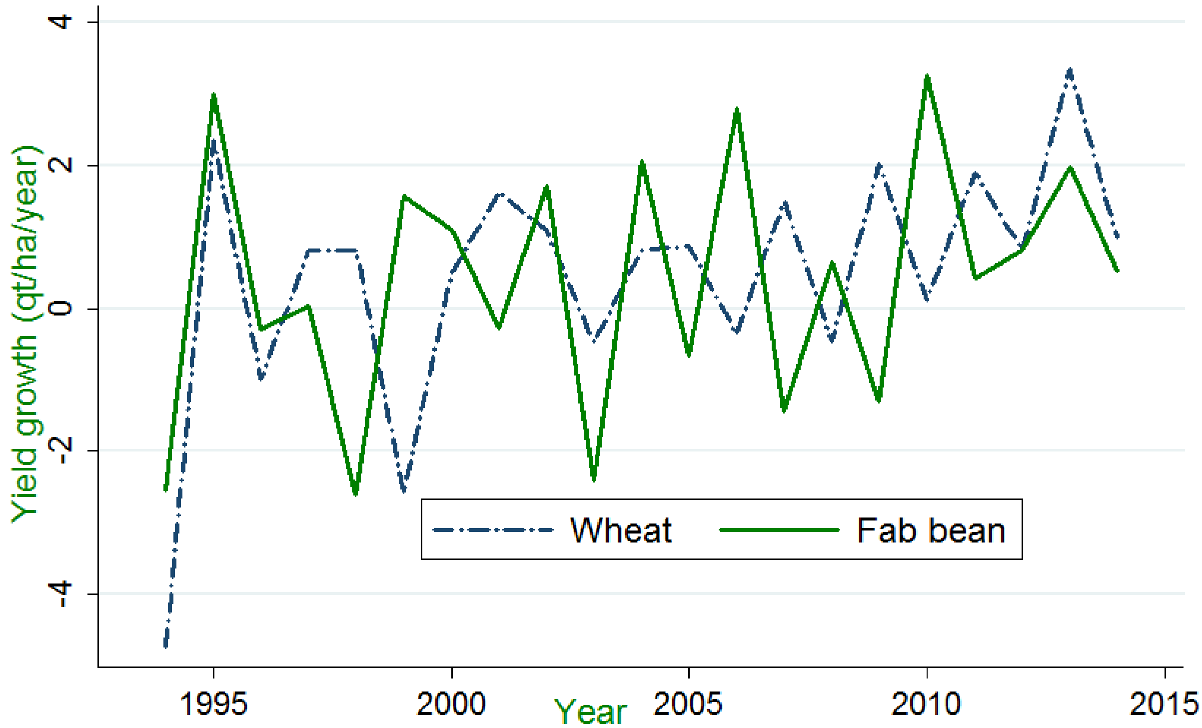
Given multiple production constraints in Ethiopia, there is significant fluctuation of yield performance from year to year. The true picture of productivity growth can be illustrated by using the timeseries plots of yield performance of four major corps and faba bean in Ethiopia as depicted in Figure 4. Yield in Ethiopia was growing exponentially for major crops in the past 22 years (1992-2014). The highest and the least yield performance is recorded for maize and faba bean, respectively.



Source: Author's plot from in FAOSTAT database (2016).

Figure 4: Productivity patterns of major crops in Ethiopia

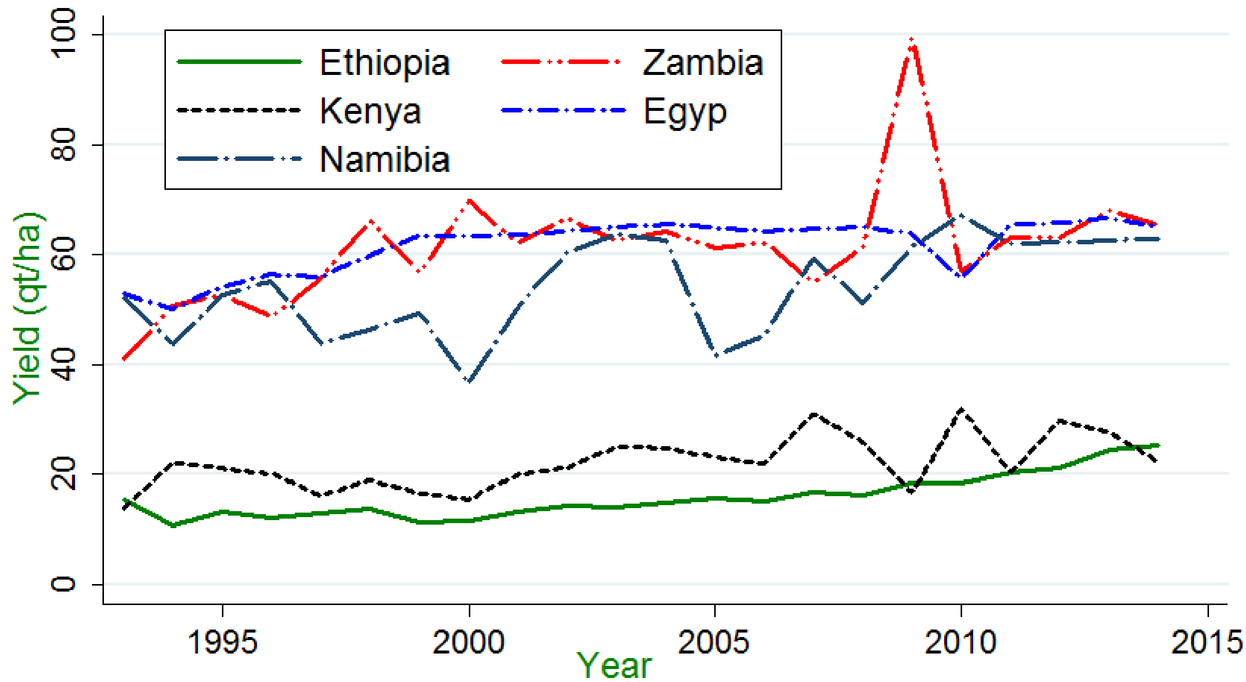
If the annual growth rates of wheat and faba bean yield are singled out as indicated in Figure 5, the pattern of their productivity growth appears to be increasing with significant yearly fluctuations. This is primarily the functions of multiple constraints prevalent in the production of crops in Ethiopia's agriculture. Yield growth of the two crops move in opposite direction possibly because of random movement of different and crop-specific production constraints, calling for the need to conduct research and control for such constraints.



Source: Computed and plotted from data in FAOSTAT database (2016).

Figure 5: Yield growth rates of wheat and faba bean in Ethiopia

Yield improvement in Ethiopia in the production of wheat was also compared to other three SSA African countries (Namibia, Zambia, and Kenya) and Egypt where wheat is widely produced (Figure 6). The yield gap between Ethiopia and its counterparts is surprisingly high. Ethiopia requires a productivity growth of about threefold to reach at the current productivity level of wheat attained by Zambia, Namibia and Egypt. This huge gap may be taken as a great opportunity by researchers and policy makers for designing and implementing proactive innovation schemes in wheat research on productivity growth.



Source: Author's plot from data in FAOSTAT (2016).

Figure 6: Productivity growth trends of wheat in selected countries of Afric

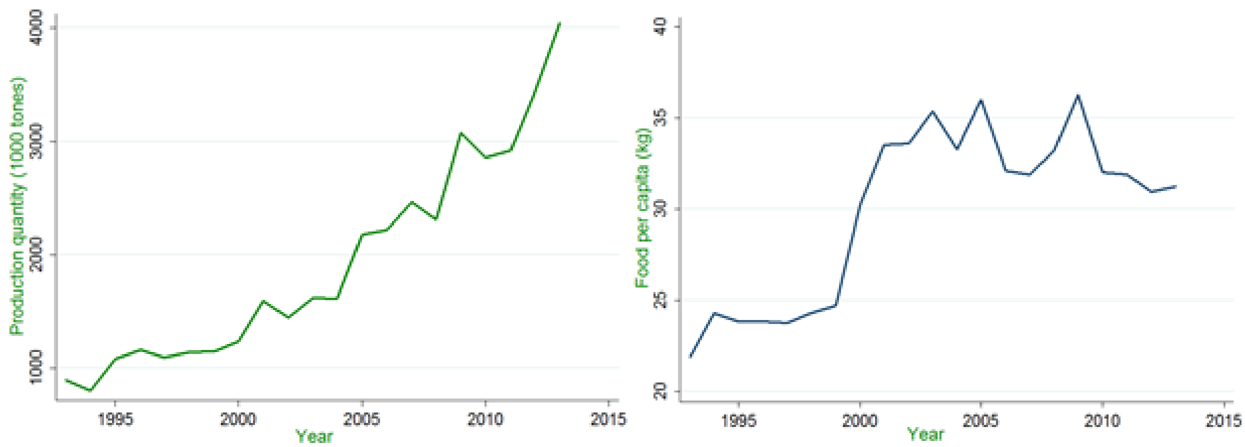
Productivity growth in faba bean is substantially low. The genetic progresses made in 33 years (1977-2007) of faba bean breeding in Ethiopia was evaluated by Tamene et al. (2015). They found highly significant differences among genotypes and test environments for all faba bean traits considered in their analysis. Mean performance at all environments on year of varietal release showed positive relationship for grain yield and seed size. The annual rates of genetic progresses were 8.7 kg/ha and 8.1 g per 1000 seeds for grain yield and seed size, respectively. The average cumulative gains over 33 years of breeding was 8 percent for grain yield and 51 percent for seed size.

The findings in this study generally suggest the need for efficient production and supply of improved inputs for wheat and faba bean production requiring investment on generating new and high-yielding varieties adaptable to multiple environments and resistant to various crop diseases, multiplication of selected varieties in order for meeting the high demand for improved seeds and establishment of efficient seed market to supply for efficient distribution.

Supply Trends and Market Performance

The current pattern of wheat supply determines the opportunities and incentives available for more production and productivity. If there are market and policy incentives attracting producers and actors in the value chain, there will be more innovation opportunities leading to increased production and productivity. In order to highlight the long-term supply patterns, the annual timeseries data of food per capita supply of wheat in Ethiopia is depicted in Figure 7.

The 22-year timeseries data obtained from the FAOSTAT global database of FAO depicts exponential growth in wheat production. However, this quantity growth of wheat output is not adequate to meet the demand for food in Ethiopia as clearly seen from the declining trend of wheat food per capita supply in Ethiopia. Coupled with the existing food and nutrition security problem in the country, this declining trend of wheat per capita supply should be backed up by policy interventions and investment alternatives. There is urgent need to policy makers and other stakeholders to create enabling environment for accelerated food production and supply in Ethiopia.



Source: Author's plot from data in FAOSTAT (2016).

Figure 7: Wheat production and per capita supply in Ethiopia

Various studies recently conducted to investigate the performance of wheat and faba bean markets in Ethiopia have identified multiple problems related to supply, structure, conduct, and performance of these markets.

Hasen (2016) found the concentration ratio of the largest four traders operating in Sagure wheat market in Arsi to be 30 percent indicating loose oligopoly market structure. The producers'' share and the profit margin for other actors were significantly differentiated across wheat marketing channels used by farmers to sell their output. Similarly, the gross marketing margin shared by marketing agents ranges from 1.5 to 32.3 percent. Tobit model was employed to identify factors that determine the supply of wheat by smallholder farmers. The mean market supply of wheat producers was 17 quintals. Family size, access to credit, off- farm income, livestock holding, oxen ownership, and perception of farmers towards wheat market price significantly influenced wheat market supply. The study by Tadele et al. (2016) suggests education, quantity produced, access to credit, and price of related commodities as the major determinants factors of affecting wheat market supply.

The impact of market orientation on market participation of smallholder cereal farmers in Ethiopia was examined by Abafita et al (2016) using Ethiopian Rural Household Survey (ERHS) data. Market orientation was found to strongly enhance market participation of wheat producers. Their findings verify that higher level of crop production, land size, access to credit and all-weather roads enhanced market participation; whereas age of household head and family size reduced market participation.

Tura (2015) identified constraints hindering the development of production and marketing of wheat in Arsi to lack of improved wheat variety, diseases, theft, and price setting problems. Wheat markets were characterized by monopolistic competition market structure with concertation ratio of 27 percent in Eteya and 38 percent in Asela. The highest benefit was taken by wheat processors (56%) followed by producers (34%) of the total value; whereas others in the value chain obtained a profit margin ranging from two to four percent. Value adding activities, livestock holding, access to credit, family size, access to non-farm income, type of wheat variety used, perception on lagged price, cultivated land for wheat, and district dummy significantly influenced the amount of wheat marketed surplus in the study area.

Beza (2014) investigated faba bean markets in western Shewa and found that average faba bean production (1.5 quintals), yield (6 quintals per hectare) and quantity supplied to markets (29%) were very low. The highest value added in faba bean value chains was ETB 45 per quintal. Next to producers (35.6%) assemblers (12.6%), urban retailers obtained the highest share of gross profit (10.5%) in the value chain. The major constraints identified in the value chains include time taken between order and placement and quality of inputs, high price of seed and fertilizers, low fertility of soil, absence of standard quality assessment, unlicensed traders, and unstable prices. Moreover, the study conducted by Muhammed (2011) in Halaba area of SNNP region reported that 49 percent of the total wheat output by smallholder farmers was marketed. Alaba Qulito market was inefficient, characterized by oligopolistic market structure overwhelmed by information asymmetry with low degree of market transparency.

Husmann (2015) identified the presence of substantial shortage of improved seeds in Ethiopia. Based on the results of institutional economics theoretical framework, he found that transaction costs were high along the whole seed value chain and mainly born by the government, as ‘public organizations dominate the Ethiopian seed system, leaving little room for the private sector’. Demand for seed addressed by the government was 24 percent for wheat, 60 percent for faba bean, 4 percent for maize, 84 percent for field pea, and 49 percent for barley, verifying the huge shortfall in the production, supply and distribution of improved seeds.

Market participation of farmers

The commercialization of smallholder agriculture entails that farmers become market-oriented and base their production decisions on market signals, as well as selling a significant proportion of their produce in market. Of the total national production of wheat, 59.3 percent was utilized for household consumption, 19.5 percent for sale, while the balance was used for seed, wage in kind, animal feed and other uses (ECX, 2016).

Commercialization of smallholder producers is a key policy imperative possibly because agricultural transformation in requires market-oriented production decision. The evidence on smallholders' commercial behavior is a key for commercialization of Ethiopia's agriculture. As discussed before, there are multiple constraints which deter farmers from surplus production and market participation. The distribution of wheat and faba market participants across regions, agrology, soli type and plot slope are reported in Table 16.

As evidenced, farmers in SNNP region are relatively more commercial; about 49 percent of wheat producers and 48 percent of faba bean producers have sold their wheat and faba bean outputs, respectively. Wheat producers in sub-humid agroecology and faba bean producers in humid agroecology are more likely to participate in the output markets of wheat (45.5%) and faba bean (37.1%). This market participation is related to suitability of environmental conditions to produce marketable surplus of the commodities (see the effects of constraints on the efficiency and productivity of these crops). Wheat producers on Luvisols (42.4%) and faba bean producers on mixed soils (34.9%) are more likely to sell their outputs. As expected, wheat producers with flat plots (40.9%) are relatively more commercial in their marketing behavior. But about 35.5 percent of faba bean producers with moderately slop plots supply their output to the market.

The results generally show that wheat and faba bean production in Ethiopia is not market oriented and great majority of producers have non-commercial behavior. Small proportion of wheat (37.7%) and faba bean (28.4%) producers used to sell their output to the markets. The great majority of wheat (62.3%) and faba bean (71.6%) producers didn't sell their output mainly be because their outputs are not in excess of their household consumption. The evidences clearly verify that the majority of farmers in Ethiopia produce wheat and faba bean for household consumption.

Table 16: Distribution of farmers' market participation by production constraints

Variables	Wheat		Faba bean	
	Samples	Market participants (%)	Samples	Market participants (%)
Region				
Tigray	245	29.0	43	20.9
Amhara	430	30.9	174	20.1
Oromia	428	42.3	125	21.6
SNNP	284	48.6	133	48.1
Total	1387	37.7	475	28.4
Agroecology				
Semi-arid/ Tropic-cool	403	25.3	131	20.6
Sub-humid/Tropic-cool	759	45.5	220	28.2
Humid/ Tropic-cool	226	33.8	124	37.1
Total	1387	37.7	475	28.4
Soil type				
Leptosol	130	38.5	49	30.6
Cambisol	33	21.2	7	14.3

Vertisol	492	35.6	165	26.7
Luvisol	406	42.4	145	29.0
Mixed type	198	36.9	63	34.9
Plot slope				
Flat	831	40.9	232	30.6
Moderate slope	369	35.0	145	35.5
Steep	173	27.7	94	26.7
Total	1373	37.7	471	28.2

Source: Author's computation from data in CSA (2016).

Determinants of Market Participation

The commercial behavior of farmers was investigated by estimating their market participation and intensity of participation in crop output markets. The Heckman two-step sample-selection model outputs of wheat market participation and supply are reported in Table 17. As expected in the methodology, there is sample selectivity bias in the population from which these samples of farms are drawn. The indicator parameter, mills lambda, is strongly significant verifying that farmers are not equally likely to participate in output markets of wheat (see possible sources of selectivity bias in the methodology).

The findings show that the decision to participate in wheat markets and the extent of participation are interdependent decisions made by wheat farmers in Ethiopia. The common underlying factors determining both participation and intensity of participation are access to credit, distance to output markets, and Oromia regional dummy. These two decisions are also separately influenced by different set of covariates. The likelihood of producers to sell their wheat output is low, only 39.5 percent.

Table 17: Heckman two-step model outputs of wheat market participation

Covariates	**Intensity of participation**		**Participation decision**	
	Coefficient	**Standard error**	**Coefficient**	**Standard error**
Household size	-0.12	0.138	0.09***	0.02
Sex	-0.14	0.13	-	-
Labor input	-	-	-0.14***	0.06
Seed input	0.19	0.14	-	-
Plot area	-	-	0.08	0.07
Dap fertilizer	-	-	0.10***	0.04
Urea fertilizer	0.03	0.09	-	-
Access to credit	-0.97**	0.48	0.34***	0.09
Distance to market	0.66***	0.25	-0.15***	0.06
Tigray region	0.73	0.43	-0.61***	0.14
Amhara region	-0.70	0.27	-0.20	0.13
Oromia region	1.49***	0.58	-0.51***	0.13
Constant	5.65	1.64	-0.05	0.38
Mills lambda	-	-	-4.20***	1.33
Rho			-1.00	

Sigma	4.20
Wald chi2	36.82
Observations	987
Censored observations	599
Uncensored observations	388
Predicted probability of participation	39.50

Notes: *, ** and ***, respectively, denote 10%, 5% and 1% level of significance.
Source: Author's computation from data in CSA (2016).

The Heckman sample-selection model output for faba bean producers reported in Table 18 accepts the null that the two decisions are independent. This shows that there was no sample selectivity bias in the population from which sample faba bean fields were drawn. To account for misspecification errors in using the two-step Heckman procedure in the absence of sample selectivity bias, the model was estimated by maximum likelihood procedure, where mills lambda as an indicator of the bias was dropped. The findings verify that the decision to sell faba bean output and the decision of how much to sell are independent household decisions. Faba producers are not significantly different in terms of their access to faba bean production and marketing.

Participation of faba bean producers is positively and significantly affected by labor input, plot area, and DAP fertilizer used, but adversely influenced by household size, access to credit, and regional dummies. Farmers' intensity of participation in faba bean markets is significantly enhanced by household size, DAP fertilizer used, and access to credit but adversely affected by labor input, and regional dummies in Tigray and Oromia (compared to Amhara and SNNP).

The rate of market participation of faba bean producers is about 33.3 percent which is even lower by about six percentage points from that of wheat producers. Similarly, faba bean producers are not market oriented. They are subsistent producers and produce small quantities of output primarily for household consumption.

Table 18: Heckman ML model outputs of faba bean market participation

Covariates	Intensity of participation		Participation decision	
	Coefficient	Standard errors	Coefficient	Standard errors
Household size	0.12***	0.05	-0.07*	0.04
Labor input	-0.32***	0.08	0.29***	0.12
Seed input	-	-	-0.08	0.07
Plot area	-	-	0.37***	0.13
Dap fertilizer	0.45***	0.09	0.13*	0.07
Access to credit	0.42*	0.23	-0.31*	0.17
Ownership of phone	0.29	0.20	0.21	0.16
Distance to market	0.27	0.18	-0.16	0.12
Crop damage	-	-	0.24	0.17
Tigray region	-0.70*	0.41	-0.75**	0.32
Amhara region	-0.55**	0.25	-0.83***	0.21

Oromia region	-	-	-1.09***	0.23
Constant	0.92	0.93	0.10	0.77
/athrho			-0.38	0.31
/lnsigma			0.04	0.09
Rho			-0.37	0.27
Sigma			1.04	0.10
Lambda			-0.38	0.30
LR test of independence (Chi2)			1.53	
LR chi2			47.96***	
Observations			329	
Censored observations			220	
Uncensored observations			109	
Predicted probability of participation			33.33	

Notes: *, ** and ***, respectively, denote 10%, 5% and 1% level of significance.
Source: Author's computation (2016).

Efficiency and Productivity

Increasing efficiency and productivity of inputs is one of the primary options of boosting agricultural production with available resources. Efficient use of crop production inputs such as land, labor, seed, agrochemicals (fertilizer, pesticide, herbicide), and agricultural machineries (or agricultural mechanization) is expected to bring substantial and accelerated change in the production and supply of crop outputs by smallholder producers. Estimating efficiency levels and identifying the sources of efficiency differentials among smallholder producers is an input for designing policy interventions of boosting agricultural production and food supply.

Overview of Existing Studies

In this study, extensive review of previous studies on the efficiency and productivity of smallholder wheat and faba bean producers was conducted. The review findings suggest that nearly all studies have estimation problems arising from measurement and model specification errors, leading to biased and inconsistent results and erroneous conclusions. The major methodological problems observed in the studies include (a) measurement errors of outputs and inputs; (b) omission of relevant inputs; (c) inclusion of non-input factors in productivity models; and (d) inclusion of input factors in inefficiency effect models.

Having all these limitations in previous works in Ethiopia, this study tries to identify a few relevant studies on the mean technical efficiency (TE) of smallholder wheat producers in Ethiopia as summarized in Table 19. The studies cover nearly all wheat producing regions and locations in the country. As evidenced, the mean TE of wheat producers in these study areas range from 34 percent to 82 percent. There is huge gap in the efficiency of smallholder producers mainly attributable to crop diseases, environmental factors, pests, socioeconomic factors, and their interactions. With the available resources and existing technology, the review findings pointed out the potential of increasing smallholder wheat production in Ethiopia by about 18 to 66 percent.

According to Mann and Warner (2015), wheat producers at district level produce between 9.8 and 86.5 percent of their potential wheat output per hectare. This huge gap across districts and regions calls the need for research and innovation on the interaction of such production constraints and development of improved inputs which can accelerate crop productivity growth in the diverse agroecologies with multiple constraints prevalent in the country.

Table 19: Findings of wheat efficiency and productivity studies in Ethiopia

Author (year)	Study area	Sample size	Model	TE (%)	Returns to scale	Constant	Comments
Abate et al (2009)	Moretina-Jiru (northern Shoa)	198	CD SPF	80	0.775	6.0	-
Beyan et al (2013)	Girawa, eastern Ethiopia	200	CD SPF	82	0.241	10.2	Negative elasticities estimated
Essa (2011)	Central highlands	700	DEA, Tobit	79	-	-	Non-parametric
Fekadu & Bezabih (2008)	Machakel	120	CD SPF	72	1.32	1.10	Soil fertility as an input included
Hassen (2016)	South Wollo	68	CD SPF	78	1.20	3.9	
Kaleb & Workneh (2016)	4 major regions	2017	CD SPF & QR	66	1.048	4.9	
Mesay et al. (2013)	Arsi, Oromia	157	Translog	0.55	0.983	11.18	Costs used with physical inputs, negative elasticities
Tolesa et al (2014)	Arsi, Ormia	381	CD SPF	57-82	0.832	4.3-7.10	Negative elasticities in highlands estimated
Solomon (2014)	National	1477	OLS & CD SPF	67	0.675	6.93	
Minimum				***57***	***0.241***	***1.10***	
Maximum				***82***	***1.32***	***11.18***	

Note: CD, DEA, and QR, respectively, denote Cobb-Douglas, data envelopment analysis, and quantile regression.

Source: Author's review results (2016).

The return to scale estimated by these studies cover all scales. The returns to scale in wheat production vary from 0.24 in 2013 (eastern Ethiopia) to 1.32 (Gojam) in 2008. But it is evidenced by most of the studies that wheat production in Ethiopia exhibits diminishing returns to scale (DRS), as expected.

Productivity and Returns to Scale

The efficiency of wheat and faba bean producers in Ethiopia was investigated by using the LSMS data collected in 2013/14. In this study, the production inputs used to produce wheat and faba bean are labor, land, seed, chemical fertilizer, and oxen as source of draught power. The stochastic production frontier (SPF) model outputs of wheat and faba bean are reported in Table 20. The SPF model outputs suggest the presence of inefficiency component in the production functions. As verified by the link test, the two production functions are also correctly specified because the null that there is no specification error in the SPF models is accepted at one percent level. All parameter estimates are with the expected signs as well.

Labor: Labor is the major input in the production process of almost all agricultural activities in Ethiopia, though its partial effect on wheat output is insignificant. It has a significant effect in increasing productivity of faba bean, by about 0.5 percent. In order to bring major shift in the production and supply of food with the available resources, relatively abundant resources such, as labor, should be productive through improving the quality of human capital involved in agriculture.

Land: Unfortunately**, t**he productivity of land is insignificant in the production of both crops. Apparently, land, as a production input has various constraints adversely affecting its productivity. The major production constraints related to land are fragmentation, fertility, plot elevation and susceptibility to degradation, soil erosion, location and agroecology, which appear to be potential sources of inefficiency in crop production.

Seed: Seed is a productive input significantly increasing output by about 0.8 percent in wheat and 0.4 percent in faba bean production. The partial effect of seed on faba bean output is relatively lower for the fact that multiplication and distribution of faba bean seed is at its infant stage in Ethiopia (see details in the previous sections).

Chemical fertilizer: The chemical fertilizers widely distributed and applied to grain production in Ethiopia are DAP and Urea. DAP has a significant partial effect in increasing wheat and faba bean output nearly by equal rate (0.13% in wheat and 0.15% in faba bean). Though there is a need to compromise between organic and inorganic agricultural products in the longrun, the current effect of fertilizer on output should not be negligible. In addition, due to the diverse nature of climatic factors, agroecologies, soils, and terrain in Ethiopia, blanket recommendation of fertilizer application need to be replaced with appropriate application rate of relevant nutrients required to specific crops and soils with specific nutrient deficiency. This will increase the productivity of chemical fertilizers on cereal outputs. The current attempt to characterize the major soil types and preparation of fertilizer application rates accordingly is expected to improve the crop productivity of chemical fertilizers.

Table 20: Productivity of wheat and faba bean in Ethiopia

Input	Wheat (N= 693)		Fab bean (N=261)	
	Elasticity	**Standard error**	**Elasticity**	**Standard error**
Labor	0.032	0.040	0.487***	0.086
Area	-0.041	0.062	0.064	0.107
Dap	0.132**	0.059	0.146***	0.056
Urea	-0.072	0.055	-	-
Seed	0.761***	0.032	0.390***	0.051
Oxen	0.030	0.070	0.033	0.128
Constant	3.236***	0.212	2.721***	0.346
/lnsig2v	-0.857***	0.132	-0.963***	0.274
/lnsig2u	-0.373*	0.235	0.021	0.324
Sigma_v	0.652	0.043	0.618	0.085
Sigma_u	0.830	0.098	1.011	0.164
Sigma2	1.113	0.122	1.403	0.253
Lamda	1.273	0.134	1.635	0.238
Wald chi2	1684.22***		842.89***	
Likelihood-ratio test for inefficiency component (chi2)	10.07***		5.25***	
Link test for specification error, chi2)	12.75***		6.22***	
Returns to scale	0.893		1.023	

Notes: *, ** and ***, respectively, denote 10%, 5% and 1% level of significance.
Source: Author’s computation from data in CSA (2016).

Other inputs: There are many other inputs which should be used to increase production and productivity of crops in Ethiopia. These include agricultural machineries (for ploughing, harvesting and threshing), pesticides (for protecting crops from multiple diseases and pests), herbicides and fungicides. However, the application of these inputs is negligible at the smallholder crop producers in the country. These production inputs can be considered as important short run options for controlling multiple crop production constraints prevalent in Ethiopia.

The returns to scale represents the state of technology available in the society. The returns to scale estimated from wheat and faba bean SPF models are decreasing (0.89) and constant (1.02) for wheat and fab bean, respectively.

Sources of Efficiency Differentials

The mean technical efficiency level computed from the SPF models of wheat and faba bean are 69.9 and 70.3 percent, respectively, for wheat and faba bean producers (Table 21). Wheat and faba producers have a potential of increasing productivity by about 30 percent with the available inputs. This huge efficiency shortfall is an opportunity to boost crop production and supply in Ethiopia. The shortfall in production can be exploited if the major crop production constraints are controlled.

Technical efficiency (TE) levels computed from the SPF models and their distributions across covariates have implications for identifying production constraints and sources of inefficiency in wheat and faba bean production. The distribution of TE levels across regional states, agroecological zones, soil types, and by slope of plots have revealed important policy implications. As can be seen, there are large and systematic differences in TE levels of farmers across these covariates. In wheat production, the highest mean TE level is attained by farmers in Tigray region (78%) followed by farmers in Amhara (72%) and SNNP region (69%). Faba bean production is notably more efficient in Tigray (90%) followed by Oromia (75%) and Amhara region (67%).

The other environmental constraint potentially affecting TE is agroecology where crops are produced. Wheat producers in humid agroecology are relatively more efficient (76%) than their counterparts producing in semi-arid (74%) and sub-humid agrological zones (67%). However, faba bean productivity is relatively better in semi-arid agroecologies (74%).

Soil type, as an indicator of relative soil fertility, is the major production constraint determining efficiency differentials among producers. Farmers producing wheat on Cambisols are relatively more efficient (79%) while plots with Vertisols are the least efficient farms (67%). On the other hand, faba bean producers with Luvisols are more efficient (76%) than farmers with other soil types. Cambisols seem to be the unfavorable to faba bean production (47%). The findings suggest the need to design and implement intervention measures required to alleviate constraints related to soils.

Table 21: Technical efficiency levels across regions and plot characteristics

Region	Wheat		Faba bean	
	Mean TE	Standard deviation	Mean TE	Standard deviation
Region				
Tigray	0.778	0.355	0.904	0.281
Amhara	0.717	0.394	0.667	0.418
Oromia	0.638	0.424	0.754	0.403
SNNP	0.693	0.430	0.622	0.435
Agroecology				
Semi-arid/ Tropic-cool	0.742	0.371	0.739	0.403
Sub-humid/Tropic-cool	0.665	0.420	0.673	0.429
Humid/ Tropic-cool	0.756	0.409	0.726	0.392
Total	0.700	0.405	0.703	0.413
Soil type				
Leptosol	0.786	0.357	0.684	0.445
Cambisol	0.794	0.342	0.465	0.511
Vertisol	0.669	0.429	0.724	0.410
Luvisol	0.717	0.402	0.758	0.380
Mixed type	0.674	0.387	0.599	0.457
Plot slope				
Flat	0.672	0.423	0.709	0.408
Moderate slope	0.716	0.383	0.710	0.431
Steep	0.839	0.294	0.661	0.416
Total	0.699	0.405	0.703	0.414

Source: Author's computation from data in CSA (2016).

The results also clearly indicate that efficiency levels of farmers substantially differ by slope of their plots cultivated. Farmers with steep plots are more efficient (84%) possibly reflecting more involvement of these farmers in soil and water conservation for the fact that production on such steep plots without soil and water conservation would lead to total loss of output. However, farms with flat (71%) and moderate slope (71%) are preferred for efficient production of faba bean; whereas farmers producing on farms with steep plots are exceptionally less efficient (66%).

Inefficiency Effects

Technical inefficiency in crop production is attributable to a number of factors including individual and household level idiosyncratic features, farm-specific characteristics, regional, climatic and agroecological constraints interfering with productivity of inputs. These determinant factors of wheat and faba bean production are hypothesized and identified in this study. The determinants of technical inefficiency (TI) in wheat production identified by using two-limit Tobit model is summarized in Table 22. The signs of all the parameter estimates are in line with theoretical expectations hypothesized in the methodology.

Table 22: Outputs of technical inefficiency effects model of wheat

Covariates	Coefficient	Standard error	Marginal effect	Standard error
Literacy status	-0.18	0.13	-0.011	0.008
Prevention of soil erosion	-0.26*	0.14	-0.016*	0.009
Crop rotation	-2.31***	0.60	-0.142***	0.035
Extension service	0.08	0.15	0.005	0.009
Distance to administrative center	0.26**	0.13	0.016**	0.008
Soil type:				
Leptosol	-0.55***	0.23	-0.034***	0.014
Cambisol	-1.04	0.68	0.061	0.039
Vertisol	-0.31*	0.17	-0.019*	0.011
Luvisol	-0.40**	0.18	-0.025**	0.011
Agroecology: Sub-humid	0.28*	0.16	0.017*	0.010
Precipitation	-0.61**	0.32	-0.037**	0.020
Temperature	-0.67	0.99	-0.044	0.067
Plot elevation	-0.88**	0.45	-0.054**	0.028
Constant	12.23***	3.88		
/sigma	1.14	0.09		
LR chi2	70.20			
Pseudo R2	0.08			
Observations			451	
Left-censored observations			252	
Uncensored observations			120	
Right-censored observations			79	
Predicted level of mean TI			0.460	

Notes: *, ** and ***, respectively, denote 10%, 5% and 1% level of significance.
Source: Author's computation from data in CSA (2016).

The mean TI level predicted from the model is about 46 percent, indicating the huge production potential (54%) to be attained if the major wheat production constraints are controlled for. Factors significantly reducing TI in wheat production are prevention of soil erosion, crop rotation, production on farms with Leptosols, Vertisols and Luvisols, precipitation and plot elevation. The largest marginal contribution in reducing TI can be obtained from soil and water conservation (14.2%) followed by plot elevation (5.4%) and precipitation (3.7%).

However, distance to administrative centers and production in sub-humid agroecology are sources of TI in wheat production with comparable marginal contributions (1.6% and 1.7%), though some of the factors, such as agroecology and plot elevation are unavoidable.

The two-limit Tobit model of TI for faba bean is similarly indicated in Table 23. The predicted level of TI is not significantly different from the one estimated for wheat, which is 46.3 percent. Factors which can help in significantly reducing inefficiency or improving efficiency in faba bean production (with marginal contribution) are precipitation (11.3%), temperature (19.6%), plot elevation (16.6%), distance to market (1.5%), and regional dummies of Tigray (12.8%) and Oromia (4.4%).

Table 23: Outputs of technical inefficiency effects model of faba bean

Covariates	Coefficient	Standard error	Marginal effect
Household size	-0.05	0.05	-0.003
Cambisol	1.27***	0.62	0.084***
Luvisol	-0.22	0.21	-0.012
Precipitation	-1.98***	0.55	-0.113***
Temperature	-3.44**	1.58	-0.196**
Plot elevation	-2.91**	1.41	-0.166**
Access to credit	0.44**	0.22	0.025**
Prevention of soil erosion	0.29	0.22	0.016
Distance to market	-0.26*	0.16	-0.015*
Tigray region	-2.39***	0.59	-0.128***
Oromia region	-0.77***	0.25	-0.044***
Constant	55.09***	20.18	
/sigma	1.97	0.13	
LR chi2		48.01***	
Pseudo R2		0.103	
Observations		233	
Left-censored observations		126	
Uncensored observations		60	
Right-censored observations		47	
Predicted level of mean TI		0.463	

Notes: *, ** and ***, respectively, denote 10%, 5% and 1% level of significance.
Source: Author's computation from data in CSA (2016).

The significant sources of TI in faba bean production are farms with Cambisols and access to credit with marginal contribution of 8.4 and 2.5 percent, respectively. The effect of credit access on TI is positive and unexpected possibly because of inappropriate credit utilization. Many farmers in Ethiopia used to divert credit to purposes not intended in their credit proposals and requests.

Agricultural Innovations

Agricultural innovation is the process whereby individuals or organizations bring existing or new products, processes and forms of organization into social and economic use to increase effectiveness, competitiveness, resilience to shocks, thereby contributing to achieve food and nutrition security, economic development and sustainable natural resource management (World

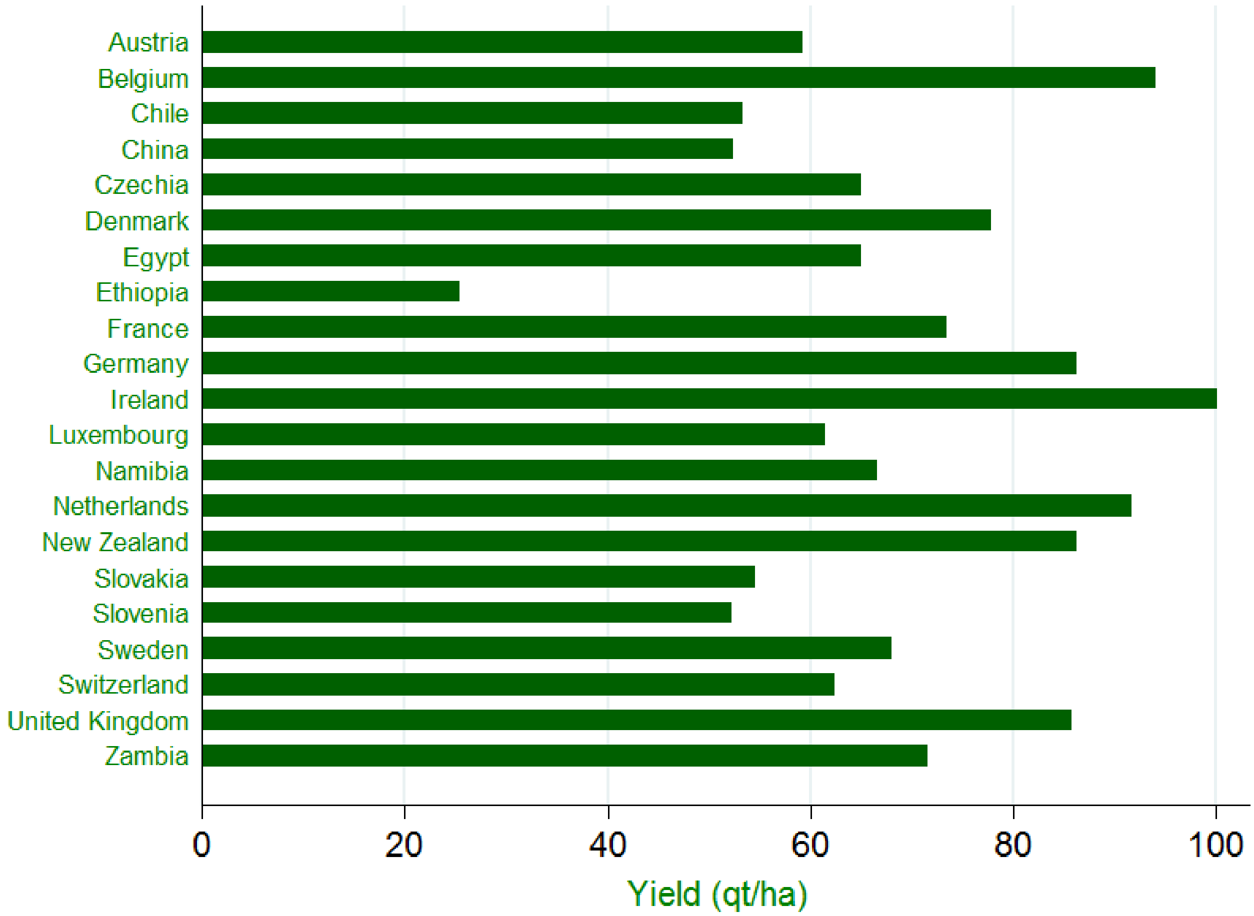
Bank, 2006, 2012). Agricultural innovation covers technological, social, economic, organizational and institutional dimensions of change.

Major agricultural innovations of crop research in Ethiopia are development of new high-yielding varieties, diseases resistant varieties, technical change, value chain and institutional innovations. Ethiopia has undertaken a number of agricultural research projects and breeding programs in the last five decades. These research efforts have resulted in development and release of new high-yielding varieties for production. By the end of 2016, 366 varieties of cereals (of which 74 and 34 are bread wheat and durum wheat varieties); 199 pulse crops (of which 31 are faba bean varieties) 97 oil crops; 207 tubers, roots and vegetables crops; 40 condiments and medicinal plants; 41 fruit cr0ps; 33 forage and pasture; 30 fiber crops; and 36 stimulus crops; a total of 1049 crop varieties have been released for production in Ethiopia (MoANR, 2016).

High-yielding Wheat Cultivars

Yield improvement is probably the best option of boosting production with available resources. Globally, wheat has undergone substantial yield improvements since the beginning of Green Revolution in the 1920s due to innovations on high-yielding varieties. Yield improvement in Ethiopia is, however, a recent phenomenon clearly observed since the 1990s. Wheat yield level for Ethiopia in 2014 is illustrated in comparison with top 20 countries of the world with high yield performance (Figure 8). Ireland, Belgium, and Netherlands are the top three countries of the world in wheat yield.

Altitude affects the distribution of wheat production through its influence on rainfall, temperature, and presence of diseases. Arsi, Bale and Shewa areas with favorable soil, moisture and disease conditions within the range of 1900-2300 m altitude zone comprise 25 percent of the total wheat production area in the country (MoANR, 2016). The remaining 75 percent of wheat production area falls in the 2300-2700 m altitude zone. Soil types used for wheat production range from well-drained fertile soils to waterlogged heavy Vertisols. In 2014/15 cropping season, about 1.7 million hectares of land was covered by wheat from which 42.3 million quintals were produced.



Source: Author's plot from data in FAOSTAT (2016).

Figure 8: Comparison of wheat yield in Ethiopia with top 20 countries (2014)

The multiple production constraints interfering with the yield performance of new varieties is one of the major challenges of agricultural research in Ethiopia. Due to various production constraints including agroecology, climatic and soil factors, there is considerably high variation of yield performance of varieties between research station and farmers' fields. In response to this, in the last five decades, 74 new varieties of bread wheat and 34 new varieties of durum wheat have been released for production in Ethiopia (MoA, 2016). However, compared to China where more than 1850 wheat varieties have been released in the past 10 decades (1920 to 2014) (Qin et al., 2015), the number of new varieties developed and released for production in Ethiopia are apparently very few, given the diverse agroecologies and soils with multiple production constraints.

Bread wheat varieties

Actual yield on research station reflects the current state of soils and climate, average skills of the farmers, and their average use of technology. Because of production challenges, yield stability has been the major research objective of many crop breeding programs in Ethiopia. The yield performance of 33 recently released (since 2007) bread wheat varieties and their yield gap between potential (or attainable) and actual (minimum) on research station are summarized in Table 24.

The maximum potential yield (qt/ha) recorded so far on station is 71 for *Shorima* bread wheat variety released for production in 2011. But the maximum actual yield on research station is 60 qt/ha recorded for *Hidase* bread wheat variety released in 2012. The average yield gap of varieties between attainable and actual is about 12.2 qt/ha, which is 35.7 percent of actual yield.

This yield gap estimated for Ethiopia is higher, compared to findings of other studies on rainfed wheat production systems in other countries. Chapagain and Good (2015) found significant management gaps between attainable and actual yields of rainfed wheat (24%) in Alberta. Genetic gaps (i.e., gaps due to genetic selection) in wheat was 18 percent. Genetic selection with optimal crop management could increase yields of wheat significantly with high yield gains. According to Lobell et al. (2009), yields in irrigated wheat appear to be at or near 80 percent of potential yield. But in rainfed wheat systems, the fundamental constraint is uncertainty in growing season weather. Average yields in such rainfed systems are commonly low, suggesting ample room for improvement, but with more errors in estimation of yield gaps.

The yield gap verifies the huge difference in genetic performance, technical feasibility and production environments between attainable and actual yield. It might indicate the level of adoption risk involved and depletes the confidence of farmers to adopt new and high-yielding varieties possibly because yield performance of such new varieties would be unpredictable. This problem remains to be the major source of adoption risk for smallholder wheat producers in Ethiopia. Innovations in crop research should focus on ways of reducing yield gap between potential and actual yields both on station and farmer's fields through controlling for the various constraints accountable to this yield variability.

Table 24: Yield gap in bread wheat varieties in Ethiopia (qt/ha)

Variety	Year of release	Attainable yield	Actual yield	Yield gap	
				Quantity	%
Liben	2015	65	55	10	18.2
Bulluq	2015	65	60	5	8.3
Fentale	2015	57	45	12	26.7
Amibera	2015	51	45	6	13.3
Dambal	2015	63.7	56.3	7.4	13.1
Obora	2015	63.1	46.8	16.3	34.8
Kingbird	2015	45	40	5	12.5
Sanate	2014	67	34	33	97.1
Mandoyu	2014	59.6	49.5	10.1	20.4
Adel-6	2013	40	35	5	14.3
Nejmah-14	2013	40	35	5	14.3
Sekota-1	2013	30	30	0	0.0
Sorra	2013	41.9	41.9	0	0.0
Mekelle-03	2012	45	40	5	12.5
Hidase	2012	70	44	26	59.1
Ogolcho	2012	40	28	12	42.9
Tsehay	2011	38	38	0	0.0
Mekele-01	2011	35	30	5	16.7
Mekele-02	2011	35	30	5	16.7
Hoggana	2011	68.9	43.29	25.61	59.1
Gambo	2011	57	35	22	62.9
Shorima	2011	71	28.9	42.1	145.4
Galil	2010	52	35	17	48.6
Danda'a	2010	55	35	20	57.1
Kakaba	2010	52	33	19	57.6
Inseno-1	2009	30	25	5	20.0
Bolo	2009	35	28	7	25.0
Gasay	2007	50	44	6	13.6
Dinknesh	2007	29	29	0	0.0
Alidoro	2007	52.5	26.8	25.7	95.9
Menze	2007	33	19	14	73.7
Sulla	2007	60	30	30	100.0
Millennium	2007	44.24	44.24	0	0.0
Minimum		***29***	***19***	***0***	***0.0***
Maximum		***71***	***60***	***42.1***	***145.4***
Average		***49.7***	***37.6***	***12.2***	***35.7***

Note: Recently released three bread wheat varieties called *Biqa* (2014), *Honqolo* (2014), and *Jefferson* (2012) are not included in this analysis due to incomplete information on their yield performance.

Source: Author's computation from data in MoA, MoARD, and MoANR (2007-2016).

Durum wheat varieties

The performance and stability of durum wheat yield for 10 recently released (since 2007) high-yielding varieties was analyzed for their variability between station and field and among varieties (Table 25). As shown from the table, the maximum attainable yield (qt/ha) recorded on station is 70 for *Toltu* durum wheat variety released for production in 2010. However, the maximum actual yield is 48.0 qt/ha recorded for *Dire* durum wheat variety released for production in 2012. The average yield gap between attainable and actual is 12.0 qt/ha (26.8%). Yield gap is as high as 26.0 qt/ha (59.1%) for *Toltu* durum wheat variety.

The results verify that productivity of durum wheat varieties released for production are characterized by high yield gap between actual and potential, leading to high and unpredictable production risks faced by adopters of such technical innovations. Innovati0ns designed to reduce yield gap between actual and potential are more likely adopted by smallholder farmers in Ethiopia.

Table 25: Yield gap in durum wheat varieties in Ethiopia (qt/ha)

Variety	Year of release	Attainable yield	Actual yield	Yield gap	
				Quantity	%
Utuba	2015	45	40	5	12.5
Mukiye	2012	56	40	16	40.0
Mangudo	2012	50	43	7	16.3
Dire	2012	51.6	48	3.6	7.5
Hulluka	2012	60	44	16	36.4
Toltu	2010	70	44	26	59.1
Werer	2009	45	40	5	12.5
Hitosa	2009	60	40	20	50.0
Denbi	2009	56	40	16	40.0
Tate	2009	59	42	17	40.5
Flakit	2007	21.5	21.5	0	0.0
Yield gap between varieties:					
Minimum		**21.5**	**21.5**	**0.0**	**0.0**
Maximum		**70**	**48**	**26.0**	**59.1**
Average		**52.2**	**40.2**	**12.0**	**28.6**

Note: Durum wheat variety called *Obse* released in 2007 is not included in this analysis due to incomplete information on yield performance.

Source: Author's computation from data in MoA, MoARD, and MoANR (2007-2016).

High-yielding Faba Bean Cultivars

By 2016, 31 faba bean varieties have been released for production in Ethiopia. However, as is in other crops, yield instability of new faba bean varieties has been a challenge faced by producers. Though Ethiopia is the second largest producer of faba bean in the world, yield performance of varieties released for production is very low. In Ethiopia, faba production covers about 15 percent of the total area allocated globally. It is the first pulse crop in terms of both area coverage and volume of production (Biruk, 2009).

The level of faba bean yield for Ethiopia and the top 20 countries of the world is indicated in Figure 9. The top three countries with high yield performance are Ireland (100.1 qt/ha), Bulgaria (100.0 qt/ha) and Belgium (94.1 qt/ha). Though Ethiopia ranks second in total production, it surprisingly ranks 118th with an average yield of 18.9 qt/ha. In Africa, Egypt has attained the highest yield improvement ranking 14th in the world with average yield of 65.1 qt/ha.

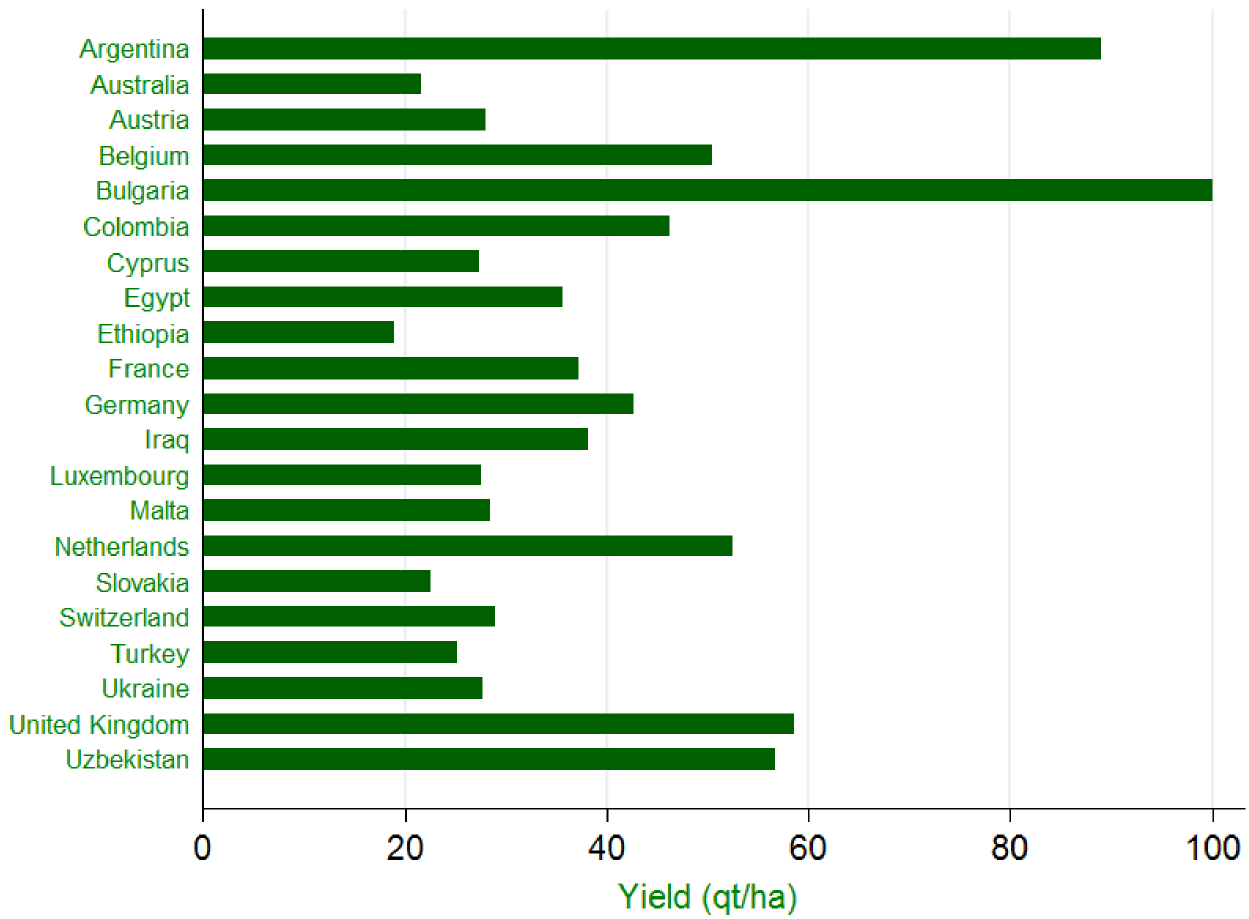


Figure 9: Comparison of faba bean yield in Ethiopia with top 20 countries (2014)

Yield gap between research station and farmers' fields were analyzed by the observed yield gap between actual and potential yield (Table 26).

Table 26: Yield gap in faba bean varieties in Ethiopia (qt/ha)

Variety	Year of release	Attainable yield	Actual yield	Yield gap	
				Quantity	%
Ashebeka	2015	54	30	24	80.0
Dide'a	2014	50	23	27	117.4
Mosisaa	2013	48	40	8	20.0
EK01001-5-1	2013	43	37	35	16.2
EH00099-1	2013	44.1	44.1	0	0.0
Gora	2013	57	22	35	159.1
Bule-04	2012	43	37	6	16.2
Hachalu	2010	45	32	13	40.6
Tumsa	2010	69	25	44	176.0
Angacha-1	2009	40	30	10	33.3
Dosha	2009	62	28	34	121.4
Gachena	2008	30	17	13	76.5
Walki	2008	52	24	28	116.7
Minimum		**30**	**17**	**0**	**0**
Maximum		**69.0**	**44.1**	**44.0**	**176.0**
Average		**49.0**	**29.9**	**19.1**	**74.9**

Note: Faba bean variety called *Hashenge* released in 2015 is not included in this analysis due to incomplete information on yield performance.
Source: Author's computation from data in MoA, MoARD, and MoANR (2007-2016).

The yield performance of 13 recently released faba bean varieties and their yield gap shows that the maximum attainable yield (qt/ha) recorded on station was 69 for *Tumsa* faba bean variety released in 2010. However, the maximum actual yield was 44.0 qt/ha (176.0%) recorded for EH00099-1 variety released for production in 2013. The average yield gap between potential and actual is 19.1 qt/ha (74.9%), with substantial variation, as high as 44.0 qt/ha (176.0%.
As evidenced, the yield gap observed in faba bean varieties is considerably large. The results verify that productivity of faba beans released for production are characterized by high yield gap both on station and on farmers' fields, leading to high and unpredictable production risks faced by adopters of these varieties. Research need to take into account the various constraints of faba bean production assumed to be sources of yield gap and adoption risk.

Resistance to Disease

Research on development and release of disease resistant crop varieties has been the major effort of researchers of agricultural innovations in Ethiopia. Because diseases are the major production constraints interfering with productivity and efficiency, developing and releasing disease-resistant varieties is the very attractive attribute of crop varieties. For new varieties to be released and adopted by farmers in Ethiopia, they need to fulfil not only resistance to diseases but also above average yield performance and other attributes (e.g. morphological, nutritional).

Disease-resistant wheat varieties

To control and minimize the adverse effects of diseases on wheat output, a number of studies have been conducted in Ethiopia. A few of the latest studies on disease-resistant wheat cultivars include Wubshet et al. (2016), Alemayehu et al. (2015), Haile et al. (2013), Tamene and Tadese (2013), and Tesfaye et al. (2007). Regardless of such efforts, wheat diseases are still the major production constraints in Ethiopia.

The major wheat diseases in Ethiopia are stem rust, leaf rust, yellow rust, and septoria. Most of the varieties released are susceptible or moderately resistant to the major wheat diseases. Twenty-one wheat varieties are evaluated for their good resistance to these disease (Table 27). The analysis of resistance of 21 wheat varieties to the five major wheat diseases (including Ug99) shows that 14 (67%) of the recently released varieties are resistance to stem rust, followed by 10 and nine varieties resistant to yellow rust (48%) and leaf rust (43%). The best diseases tolerant variety is *Shorima,* which is resistant to four major diseases followed by other varieties (i.e. *Liben*, *Bulluq*, *Ogolcho*, *Hoggana*, *Qulgullu*, *Utuba*, and *Hulluka)* resistant to three major disease. Currently, there are very few varieties resistant to Septoria and UG99. Many new varieties recently released for production are susceptible or only moderately resistant to the major wheat diseases. Accordingly, these diseases remain to be the major sources of crop damage in Ethiopia. Overall, the resistance of these varieties to the five major disease is only 39 percent, suggesting the need for more innovation efforts of generating new disease-resistant varieties of wheat.

Table 27: Disease-resistant wheat varieties in Ethiopia

Variety	Year of release	Stem rust	Leaf rust	Yellow rust	Septoria	Ug99	Total points (5)	Index
Bread wheat								
Liben	2015	Yes	Yes	Yes			3	0.6
Bulluq	2015	Yes	Yes	Yes			3	0.6
Dambal	2015	Yes					1	0.2
Obora	2015	Yes					1	0.2
Ogolcho	2012	Yes	Yes	Yes			3	0.6
Tsehay	2011			Yes			1	0.2
Mekele-01	2011	Yes					1	0.2
Hoggana	2011	Yes		Yes	Yes		3	0.6
Gambo	2011					Yes	1	0.2
Shorima	2011	Yes	Yes	Yes	Yes		4	0.8
Galil	2010		Yes		Yes		2	0.4
Kakaba	2010					Yes	1	0.2
Danda’a	2010					Yes	1	0.2
Qulqullu	2009	Yes	Yes	Yes			3	0.6
Dinknesh	2007	Yes					1	0.2
Menze	2007	Yes					1	0.2
Durum wheat								
Utuba	2015	Yes	Yes	Yes			3	0.6
Hulluka	2012	Yes	Yes	Yes			3	0.6
Hitosa	2009				Yes		1	0.2
Denbi	2009				Yes		1	0.2
Flakit	2007	Yes	Yes	Yes			1	0.6
Total points (21)		*14*	*9*	*10*	*5*	*3*	*41/105*	*0.39*
Index		**0.67**	**0.43**	**0.48**	**0.24**	**0.14**	**0.39**	

Note: Wheat varieties susceptible or moderately resistant to diseases are not included in this analysis.

Source: Author’s computation from data in MoA, MoARD, and MoANR (2007-2016).

Diseases-resistant faba bean varieties

The major faba bean disease in Ethiopia are chocolate spot, rust, and ascochyta blight or faba bean gall. Various studies on development of faba bean varieties resistant to these major diseases have been conducted in Ethiopia. Recent studies in this case include Alemayehu et al. (2015), Tamene et al. (2015), Tewodros et al. (2015), and Ermias and Addisu (2013).

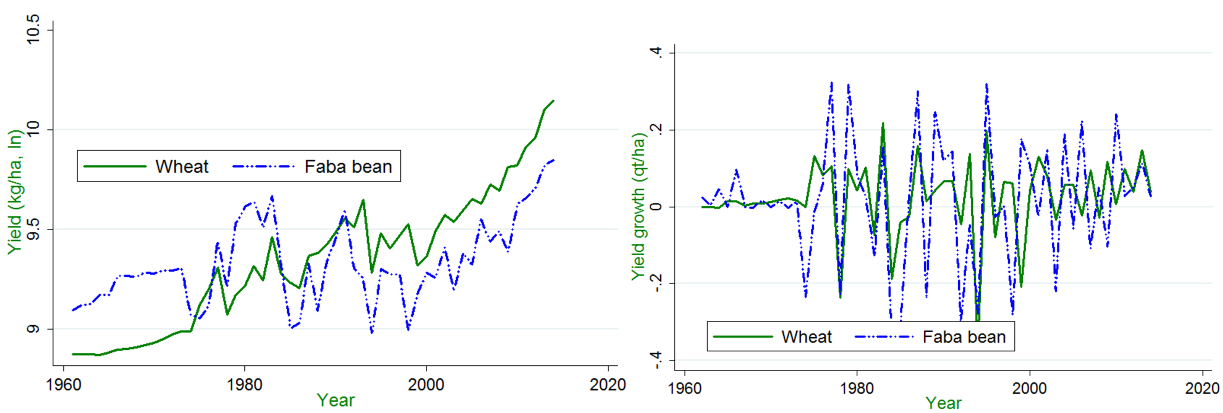
The analysis of resistance of four faba bean varieties to the four major diseases shows that they all are resistant to chocolate spot and three of them resistant to rusts (Table 28). The highest diseases tolerant variety is *Mosisaa*. Currently, there are very few varieties resistant to the major faba bean diseases. Many of them are susceptible or moderately resistant to the major wheat diseases. Generally, the resistance of recently released faba bean varieties to the four major diseases is 25 percent. There is still a huge research gap of generating disease-resistant faba bean varieties adaptable to areas with multiple environments.

Table 28: Disease-resistant faba bean varieties in Ethiopia

Variety	Year of release	Chocolate spot	Rust	Ascochyta blight	Total points (4)	*Index*
Mosisaa	2013	Yes	Yes	Yes	3	*1.00*
EK01001-5-1	2013	Yes	Yes		2	*0.67*
EH00099-1	2013	Yes			1	*0.33*
Bule-04	2012	Yes	Yes		2	*0.67*
Total points (4)		4	3	1	8/12	*0.67*
Index		***1.00***	***0.75***	***0.25***	*0.67*	

Note: Faba bean varieties susceptible or moderately resistant to diseases are not included in this analysis.
Source: Author's computation from data in MoA, MoARd, and MoANR (2007-2016).

Technical Change
The pattern of yield, as a proxy for total factor productivity (TFP), in the last five and half decades was assessed in this study (Figure 10. As illustrated, wheat and faba bean yields were trendless until the mid-1970s, following the downfall of the Imperial regime. After 1975, there has been seemingly increasing trend with significant fluctuations around the longrun pattern.



Source: Author's plot from data in FAOSTAT (2016).
Figure 10: Patterns of productivity growth of wheat and faba bean (1961-2014)

These patterns were categorized into the three regimes as summarized in Table 29. In the past 54 years, the yield change is only 8.3 qt/ha for wheat and 2.2 qt/ha for faba bean, annual increase of 0.15 qt/ha and 0.04 qt/ha, respectively, compared to the base year (1961). The annual yield growth rate appears to be very small, only 2.2 and 0.4 percentage points for wheat and faba bean. These rates of yield growth in the past 54 years are considered as negligible, compared to the performance of other countries (see details in pervious sections). This is mainly the result of yield instability caused by production constraints prevalent in the country. The figures verify the least effectiveness of technological innovations in crop research to control for such constraints.

Table 29: Wheat and faba bean productivity patterns over policy regimes (1961-2014)

Policy regime	Wheat yield (mean)	Faba bean yield (mean)
Imperial regime (1961-1974)	7.5	10.1
Derge regime (1975-1991)	11.1	11.7
1992-2014 (current regime)	15.8	12.3
1961-2014 (all regimes)	12.1	11.5
Change in 54 years (qt/ha)	8.3	2.2
Change in 54 years (%)	110.7	21.8
Yearly yield growth (qt/ha)	0.15	0.04
Yearly yield growth (%)	2.1	0.4

Source: Author's computation from data in FAOSTAT (2016).

Technical change is a change in the methods of production over time. Technological progress shifts isoquants inward by allowing the firm to achieve more output from a given combination of inputs (or the same output with fewer inputs). It is an upward shift in the production frontier, or equivalently to an inward shift in the isoquant map. Following the development of superior production techniques, the same level of output can be produced with fewer input changes over time.

Before estimation of the yield growth time trend model, the timeseries data of wheat and faba bean yield were tested for nonstationary. The yield timeseries were funding to be stationary at their first differences, following difference-stationary stochastic processes (Table 30).

Table 30: Unit root test results of wheat and faba bean yield series (1975-2014)

Variable	Wheat		Fab bean	
	With constant	With constant and trend	With constant	With constant and trend
Yield level (T=35):				
Lag length	4	4	4	4
ADF statistic	0.91	-0.52	-1.76	-1.99
Yield growth rate (T=38)				
Lag length	0	0	0	0
ADF statistic	-10.06***	-10.23***	-8.42***	-8.33

Note: ***, ** and *, respectively, denote 1%, 5% and 10% significance level.
Source: Author's computation from data in FAOSTAT (2016).

The generalized least squares (GLS) parameter in the technical change time trend model was estimated by using Prais-Winsten and Cochrane-Orcutt regression, where autocorrelation problems can be controlled for (Table 31).

The model ouptuts show that wheat yield increased by about 2.8 percent pe year due to technical progress related to wheat. Technical progress in this case is expected to come either from improvement in the quality of physical capital (e.g. input factors) or human capital (e.g. investment in research and training). The effectiveness of physical capital in the production process tends to be positively influenced by infrastructure. The quality of human capital (such as labor and managerial input) can also stimulate productivity growth through creating new technologies. The rate of technical progress is the rate of output increase that cannot be explained by the change in inputs over time. It implicitly treats technical progress as a residual measure. Accordingly, technical progress (regress) is explained by a positive (negative) rate of technical change.

Using non-parametric analysis of wheat yield trends in China since the 1920s to 2014, Qin et al. (2015) found that average grain yield of wheat has increased annually by 1.3 percent for north winter wheat, 1.5 percent for south winter wheat, and 0.5 percent for spring wheat in China. Empirical evidence verifies that the annual yield growth rate in Ethiopia is higher compared to that of China and the world's average (below 1%). However, the time period this growth covers is relatively short in Ethiopia, with a cumulative growth of 112 percent in 40 years. The pattern of yield growth rate in Ethiopia before 22 years was trendless.

Table 31: GLS estimates of productivity time trend model (1975-2014)

Parameters	Wheat		Faba bean	
	Parameter estimate	Standard error	Parameter estimate	Standard error
Growth rate				
Lag 1	-0.221*	0.135	-0.052	0.136
Lag 2	-0.020	0.135	0.130	0.136
Technical change (time)				
Time (year)	0.028***	0.005	0.022***	0.008
Regime time dummy	-0.141	0.101	-0.3511**	0.164
Constant	6.690***	0.096	6.834***	0.149
Rho	0.651		0.624	
Sample size	37		37	
Adjusted R2 (original)	0.95		0.89	
Adjusted D-statistic (original)	1.20		1.25	
Adjusted D-statistic (transformed)	1.95		1.91	

Note: ***, ** and *, respectively, denote 1%, 5% and 10% significance level.
Source: Author's computation from data in FAOSTAT (2016).

Productivty of faba bean in Ethiopia, in the last four decades, increased by 2.2 percent per year due to technical prgoress. However, there is technical regress in faba bean yield during the current regime (in the past 22 years). Compared to the *Derge* regime, faba bean yield decreased by about 35.1 percent (1.6% per year) due to technical regress revealing the net technical progress attained in the current regime (1992-2014) to be 0.5 percent only. This requires clear policy focus to faba bean research and innovation for enhancing production and productivity of the crop.

Other Innovations

Institutional innovations

Institutional innovation may be defined as novel, useful and legitimate change that disrupts the cognitive, normative, or regulative mainstays of an organizational field (Raffaelli and Glynn, 2103). Institutional innovation, like all innovation, is both novel and useful, but differs in that it is also legitimate, credible and appropriate. Institutional innovation allows organizations to re-architect themselves to scale learning and generate richer innovations at other levels, including products, business models, and management systems. It is meant to include the formal and informal rules as well as beliefs, values and frameworks for understanding that create stability and order of the system referred to as the enabling environment.

The major breakthrough in agricultural commodity marketing system in Ethiopia is the Ethiopia Commodity Exchange (ECX) established in 2007 as per the proclamation no. 550 and 551 in 2007 (FDRE, 2007a; 2007b). The ECX has been operational since 2008 and currently trades on five major commodities (coffee, sesame, haricot bean, maize and wheat) with multiple grades widely produced, traded, and consumed (ECX, 2016). Quality of wheat is graded into there as hard, soft and mixed (ECX, 2016).

The ECX is a new initiative for Ethiopia and the first of its kind in Africa. It is envisioned to revolutionize Ethiopia's tradition agriculture through creating a new marketplace that serves all market actors in the agricultural value chains (including farmers and consumers). It is a unique partnership of value chain actors working for bringing integrity, security, and efficiency to the commodity market in Ethiopia. It was established to benefit and modernize the way Ethiopia was trading its agricultural commodities. Before the establishment of ECX, agricultural markets in Ethiopia had been characterized by high costs and high risks of transacting, with one third of output reaching the market (ECX, 2016). It provides market integrity of the product itself, the transaction, and the market actors. Some of the risks managed within the ECX are: (1) operational risks, (2) credit risks, (3) market risks, (4) liquidity risks, and (5) reputation and image risks.

An innovation which creating *novel*, *useful*, and *legitimate* changes is said to be an institutional innovation (Raffaelli and Glynn, 2103). Accordingly, the ECX is an institutional innovation in the agricultural marketing system in Ethiopia addressing the multiple challenges facing actors in the value chain.

Management innovations

Management innovation may be defined as the invention and implementation of a management practice, process, structure, or technique that is new to the state of the art and is intended to further organizational goals (Michelman, 2007). Management innovation is anything that substantially alters the way in which the work of management is carried out, or significantly modifies customary organizational forms, and, by so doing, advances organizational goals. It shapes the four processes of model of management innovation (motivation, invention, implementation, and theorization and labeling).

Key expects of wheat and faba bean research in Ethiopia were asked to identify the major technical, intuitional, and management innovation related to wheat and faba bean in Ethiopia. They have identified various innovations and their adoptions by different actors in the value chain. They have also listed adoption of crop management practices considered new to most of the smallholder farmers in Ethiopia, including (1) treatment of acidic and black soils; (2) use of seed and fertilizer recommendation rates: (3) row plating; (4) establishment and strengthening of marketing cooperatives; (5) creation of market linkages between smallholder producers and other market actors (6) establishment of fertilizer blending centers; and (7) wheat self-sufficiency program.

These management innovations have been adopted so far by actors in the agricultural value china. Adoption of these innovations in Ethiopia is an opportunity to enhance food production and productivity in Ethiopia.

Conclusion

Agriculture, as the mainstay of the Ethiopian economy contributing to 79 percent of employment, 42 percent of GDP (FAO, 2106) would play a vital role in bringing the entire economic progress. However, crop production in Ethiopia is constrained by crop diseases, environmental, agroecological, technological, institutional, infrastructural, marketing, policy, and other socio-economic factors. One of the major challenges in transforming the traditional smallholder agriculture is lack of agricultural innovations and their dissemination among smallholder producers.

The production and supply of food crops is influenced by multiple factors. To feed the growing population in Ethiopia, increasing production and productivity appears to be a well-defined goal of stakeholders in agricultural production. This study was intended to assess (1) crop production constraints and their incidence, prevalence and intensity of crop damage; (2) production, intensity of input use, adoption of improved inputs, supply and participation in wheat and faba bean markets; (3) productivity, efficiency, and sources of inefficiency; and (4) agricultural innovations, yield gaps, and technical change in wheat and faba bean production.

To allow for empirical support to the review findings in this study, both cross-sectional and dataset are used to address the intended objectives of the study. The LSMS data of the CSA, data on technical and institutional innovations related to wheat and faba bean production collected from the MoANR, the time series data from FAOSTA are used in this study.

In addition to the systematic review of existing studies, six empirical methods of data analysis are employed in this study: (1) seemingly unrelated bivariate probit model to identify the likelihood of adoption and the factors influencing adoption of improved inputs for crop production; (2) sample-selection models to analyze the market participation, intensity of participation and factors determining smallholder farmers'' participation and market supply; (3) SPF models to estimate the productivity of production inputs, to compute TE scores characterized by a set of covariates, and two-limit Tobit models to identify the sources of TI in wheat and faba bean production; (4) yield gap analysis of new varieties on research stations to investigate the production and adoption risks arising from production shocks; and (5) time trend growth model of yield to estimate the technical change observed in the past 40 years in the production of wheat and faba bean.

Considerably consistent and policy-relevant empirical findings explaining substantial variation across regional states, agroecologies, soli type, plot slope, and other farm and household characteristics are well-characterized, stylized, and documented with policy implications particularly discussed. The results of this study specifically lead to the following implications:

1. Given the current state of agricultural research and innovation in Ethiopia, there is an overriding need to develop and release more new crop varieties which are high-yielding, diseases-resistant, and/or adapted to the diverse environments in Ethiopia.
2. The major deterrent to smallholder farmers in Ethiopia has still remained to be inadequate supply, less productive and ineffective production inputs. Adequate supply of improved production inputs enabling smallholder farmers to enhance productivity growth and to control for the multiple production constraints is one of the options to boost crop production and supply. The adoption and use of improved inputs by smallholder farmers is very low suggesting the need to enhance promotion, production and distribution of improved inputs and improving the common factors enhancing adoption of crop production inputs.
3. There appears to be an urgent need to implement policy interventions which can increase the productivity of major inputs (e.g. land and labor). The use of family labor to multiple on- and off- farm activities; and supply of adequate, appropriate, and effective inputs like improved seeds, fertilizers, pesticides, and fungicides would likely improve productivity. This, however, requires a well-established and competitive system of input production, supply, distribution, and utilization where all actors play their role for productivity growth in Ethiopia.
4. Adoption of existing agricultural innovations including mechanization services and crop management practices are also commendable to improve production efficiency and to control for production constraints. Accelerating the recent attempts to develop and release irrigated wheat and other crop varieties adapted to Ethiopian lowlands, where land input is relatively abundant, may also substantially improve output and to reduce the gap between potential and actual yield.
5. The major sources of inefficiency differentials among wheat and faba bean producers in Ethiopia are plot characteristics, access to marketing infrastructure, water availability, and financial constraints. Policy makers need to strongly focus on improving soil fertility, water and credit availability, access to market infrastructure, and supply of improved inputs. This may be enhanced through scaling up of good experiences in regions with better technical efficiency like Tigray.
6. Unfortunately, agricultural market performance has still persisted to be topic of long controversy in Ethiopia. Improving the performance of both input and output markets in the value chain, where crop producers can benefit more in the process of making value chains suitable to pro-poor growth and development, is the other policy imperative. This is

particularly related to improving the performance markets through new innovations (e.g. ECX) and adopting existing innovations, thereby significantly reducing the multiple market risks and skewed benefit shares observed in the agricultural value chains.

7. Policy interventions related to smallholder commercialization and value chain development are more likely options to improve the commercial behavior of smallholder wheat and faba bean producers to make market-oriented production decisions for increased supply and marketability of their crop outputs.
8. In addition to the strategic and policy focus given to major corps like wheat, it could be a policy imperative to prioritize crops like faba bean, as well, for the fact that Ethiopia is the first and the second largest producer of faba bean in Africa and globally, where a great deal of comparative advantage can be exploited nationally and internationally. Nationally, faba bean is more likely to address the food security threats in Ethiopia. Ethiopia will also have more comparative advantages in the international markets of pulse corps.

This study mainly used review of existing studies and analysis of cross-sectional data on the four major regional states in Ethiopia. The parameter estimates obtained from such cross-sectional data analysis have shortrun interpretations and implications. It is more important to assess longrun implications by estimating the dynamics of input use and adoption, production and market supply, agricultural innovations, efficiency and productivity, and technical change in the major crops produced, traded and consumed in Ethiopia. Further studies need to particularly employ panel data estimators using latest datasets covering major crops in all crop producing regions of the country.

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