

# Effect of rural transport infrastructure on the intensification of purchased input use for major food crop production: the case of smallholder farmers in Horro Guduru Wollega Zone, Western Ethiopia

Sileshi Tamene\*, Tebarek Lika Megento

Department of Geography and Environmental Studies, Addis Ababa University, Ethiopia

\* Corresponding author: sileshitamene@gmail.com

## ABSTRACT

This paper examines the effect of rural transport on smallholder farmers' purchased input use. A random sample of 500 respondents was selected and relevant data was collected. Descriptive, correlation, and regression statistics were used to analyze the data. The multiple linear regression analysis revealed that farmers' purchased input use was found to be significantly and negatively related to distance to major market, distance to all weather road, distance to farm plot, transport cost, and size of land holding. In contrast, farmers' purchased input use was found to be significantly and positively related to family size, off farm income, membership in a cooperative, being in Horro district, having animal cart, and access to good road. Further, the results of hierarchical multiple regression showed that approximately 82% of the total variation in purchased input use can be explained by the linear combination of all independent variables. Furthermore, the result showed that rural transport infrastructure-related variables, as a set, contributed 13.3% to the prediction of farmers' purchased input use over and above the remaining predictors. The results suggest that improving the rural road infrastructure and access to rural transportation services is vital in encouraging farmers' purchased input use.

## KEYWORDS

hierarchical regression; Horro Guduru; intensification; purchased input use; rural transport

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## 1. Introduction

The achievement of major food crop intensification remains the greatest challenge facing smallholder farmers in developing countries. The poor state of the rural transportation network and inefficient logistics continue to hinder agricultural intensifications in Africa (Delaney et al. 2017). The key rural transport infrastructure challenges are inadequate and poor conditions of the rural road network and limited availability of vehicles, which has led to an increase in the cost of transportation further affecting agricultural input prices (Salami et al. 2010). The very poor condition of transport infrastructure, the effect of geographic isolation, high transport costs, and time lost to roadblocks, can completely undermine the returns to investments in crop intensification practices (Delaney et al. 2017).

Like in many other sub-Saharan African countries, small-scale agriculture is the most important sector for achieving sustainable household food security in Ethiopia. It accounts for 80% of the working population, 86% of the total foreign exchange earnings, and 48% of gross domestic product (GDP) (Worku 2011). An increasing use of modern agricultural inputs such as chemical fertilizers and improved seeds remains one of the best hopes for greater agricultural production and productivity of rural Ethiopia, where more than 80% of the population lives (Minten et al. 2013). However, lack of enhanced supply and promotion of improved seeds, organic and inorganic fertilizers, and low level of an irrigation system are major obstacles to sustain the agricultural production in the country (Elias et al. 2006).

As a landlocked country with largely non-navigable rivers, road transport plays a significant role in the performance of the Ethiopian economy. In Ethiopia immature rural transport and other key physical infrastructure have led to high transport costs for agricultural products to the market as well as of farm inputs, reducing farmers' competitiveness (Fufa and Hassan 2006; Lulit 2012). This could be a disincentive to the use of productivity-enhancing agricultural inputs and therefore could discourage smallholder farmer's major food crop intensification.

Most of the literature on small-scale agriculture market participation concerns only the output side of marketing production (Arethun and Bhatta 2012; Bekele et al. 2010; Gebremedhin and Hoekstra 2008). However, the sustainable marketing of smallholders also requires integration into the input markets (Pingali and Rosegrant 1995). To bridge the gap in the literature on the marketing participation of rural household on the input side, we analyze the rural transport determinants of purchased modern agricultural inputs use. In Ethiopia, there is relatively large literature dealing with the role of technological innovation and diffusion in increasing agricultural productivity and intensification (Elias et al. 2013; Katungi et al.

2011; Weir and Knight 2004). Past agricultural research in the country also focused on the impact of improved agricultural technologies on smallholder farm income and its implication for poverty reduction strategies (Hailu 2014; Katungi et al. 2011; Salami et al. 2010).

Although these past studies provided useful information on the trends, patterns, and determinants of agricultural input adoption, rigorous assessments of rural transport constraints on the use of purchased (variable) inputs for major food crop production, as a measure of household commercialization from the input side have rarely been studied in Ethiopia. A better understanding of rural transport constraints that hinders smallholder farmers' participation in agricultural input markets as a buyer is therefore important for designing promising pro-poor agricultural and transport policies that could stimulate the use of modern agricultural inputs and increase small-scale agricultural production. This study aims to fill this knowledge gap and provide quantitative information to empirically address the relationship between smallholder farmers' food crop intensification and rural transport infrastructure. The findings of this research are supposed to be used by different stakeholders involved in rural transport policy, agricultural land use planning, and sustainable food crop production strategies.

The overall objective of this study was to investigate rural transport constraints of major food crop intensification strategies by small-scale farmers in Ethiopia. The specific objectives of this study were to: (1) examine relationship between proximity to all-weather roads and total values of purchased input use among smallholder farmers; (2) determine the extent to which a combination of rural transport infrastructure, institutional factors, resource endowment, and physical factors predict smallholder farmers' purchased agricultural input use; (3) identify the extent to which rural transport infrastructure (distance to major market, distance to all-weather road, distance to farm plot, transport cost, mode of transport and road conditions) predicts smallholder farmers' purchased agricultural input use, controlling for the effects of demographic, institutional, resource endowment, and physical factors.

## 2. Theoretical underpinnings of the study

This study aims to look at the nature and extent of rural transport infrastructure and its effect on modern agricultural input use among smallholder farmers of Horro Guduru Wollega Zone, Western Ethiopia. There are several theories that attempted to explain how rural transport infrastructure investment can bring about economic growth and development (Banerjee et al. 2012; Didenko et al. 2017; Jelilov and Kachallah 2017; Margarian 2011; Roland-holst 2009).

Of these multiple theories, “the theory of induced technical and institutional change” was used as relevant theoretical perspective to design the research questions that this study is based on. In addition, this theoretical perspective was used for organizing and interpreting the findings of this study. The theory of induced technical and institutional change provides the structure to define how this particular research will philosophically, epistemologically, methodologically and analytically approached.

Economic historians are increasingly drawing on the theory of induced technical change in attempting to interpret differential patterns of productivity growth among countries and over time (Ruttan 2008; Ruttan and Hayami 1984). Agricultural economists like Hayami and Ruttan (1993, p. 6) argue by saying that in agriculture, changes in the ‘relative resource endowments’, especially land and labor, induce a derived demand for technological innovations to facilitate the replacement of relatively less scarce and cheap factors for more scarce and expensive ones. For example, when labor is in short supply, there is a tendency for capital in the form of labor-saving machinery to be substituted for human labor. Whereas, in a land-scarce economy, yield-increasing and land enhancing inputs such as fertilizers and improved seeds are substituted for land which in turn depends on the agricultural input market conditions (Hayami and Ruttan 1985, 1993; Ruttan 2008). Moreover, roughly 22 years ago, Ruttan (1996, p. 54) in one of his seminal papers addressed that induced technical change acts to make the ‘scare factor more abundant’.

Induced technical and institutional change theory offers a theoretical understanding appropriate to examine the complex and dynamic relations between rural transport access and smallholder farmers’ purchased input use. When we examine the appropriateness of this theory for understanding the nature of rural transport and purchased input use in the study area, two related realities emerge: first, the effort of promoting the rural agricultural economy and bringing maximum benefits to smallholder farmers needs technical change and innovations to transform the most common and tedious traditional rural transport mechanisms-human portage (head, shoulder, and back-loading) to improved rural transport means-pack animals and animal drawn carts. Such rural transport improvements brought about by rural transport innovations can enhance the use of purchased input use among smallholder farmers. Second, this theory also acknowledges that improved production technologies (fertilizer and improved seed) as well as improved farm management practices (credit and extension institutions) can play in replacing relatively scarce resources like land and labor.

### 3. Data and Methods

#### 3.1 Selection and description of study site

The study was conducted in Horro Guduru Wollega Zone, western Ethiopia. This Zone lies between Latitude 9°10′ N and 9°50′ N and Longitude 36°00′ E and 36°50′ E (Figure 1). It has a total land area of 8,097 km<sup>2</sup> (CSA 2011; Tamene and Megento 2017). Shambu is the capital town of the zone and found 314 km West of Addis Ababa. According to the report of CSA (2011), this zone had a total population of 641,575 of which 50.09% are male and 49.91% are female. According to the same source, about 89% of the population lives in the rural areas driving their livelihoods from agriculture.

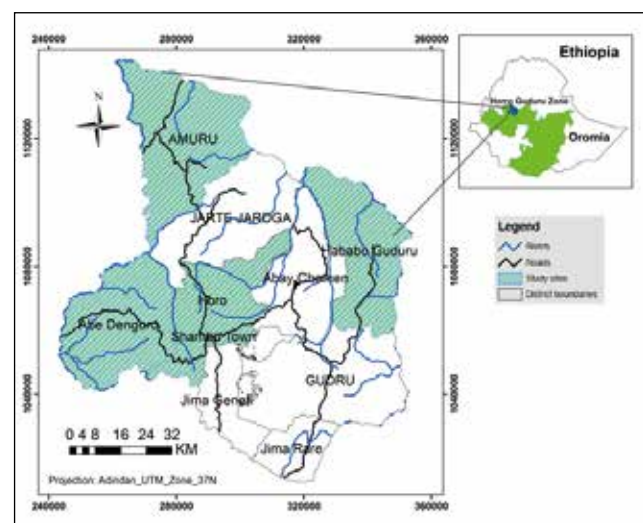


Fig. 1 Location map of Horro Guduru Wollega Zone.

Source: Adapted Finance and Economic Development Bureau of Oromia, 2016.

The average annual temperature in the study area is 22.1 °C, with an average minimum of 13 °C and an average maximum of 30 °C (Beyene et al. 2015). The average altitude of Horro Guduru Wollega Zone ranges from 860 to 2657 meters above sea level (Beyene et al. 2015). Mixed crop-livestock agriculture is the mainstay in the study area with notable food crops including wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), teff (*Eragrostis tef*), maize (*Zea mays*), pulses (*Vicia faba*, *Pisum sativum*) and cash crops like sesame (*Sesamum orientale*), niger (*Guizotia abyssinica*), and linseed (*Linum usitatissimum*) (CSA 2014).

Even though few independent variables used in our previously published article (Tamene and Megento 2017) are also used in current manuscript, a greater number of independent variables are newly introduced to the current manuscript to emphasize on the originality of this paper. Furthermore, due the following reasons each manuscript has a distinct focus and purpose. First, each manuscript addressed different

research questions. Second, each manuscript studies the data from completely different angles. Third, each manuscript used different relevant literature. Fourth, they both differ in their analytic methods, interpretations, and conclusions. Lastly, the dependent variables in both manuscripts are conceptually different and empirically not related. Therefore, the manuscripts should be considered independently.

### 3.2 Study Design, Sampling, Data Collection, and Analysis

The study utilized a smallholder household based cross-sectional quantitative survey design using a structured questionnaire with face to face interview. Descriptive and analytical cross-sectional micro-level data have been used to estimate the effect of rural transport infrastructure on smallholder farmers' purchased input use. Horro Guduru Wollega Zone was identified as one of the potential cereal crop producing corridors of Ethiopia. On the contrary, the existing rural road transport infrastructure in the zone is not satisfactory to support smallholder agricultural production system including the purchases of necessary inputs (Tamene and Megento 2017). Therefore, Horro Guduru Wollega Zone was purposively selected.

A multistage simple random sampling technique was sequentially employed to select four districts from Horro Guduru Wollega Zone, four rural kebeles (RKs) from each district, and rural farm households from each rural kebele-Kebele is the smallest administrative unit in Ethiopia. The first stage involves a random selection of four districts from the nine districts of Horro Guduru Wollega Zone. As a result, four districts (Hababo Guduru, Horro, Amuru and Abe Dondoro) were selected (Figure 1). The second stage involves the random selection of four RKs from each of the four districts making a total of 16 RKs.

The third and final stage was the random selection of farm households with farmland size of 0.25 ha and above from each RK. The list of farm households in each RK was compiled with the assistance of the extension agents and RK managers. According to Gray et al. (2007) suggestion, the researcher used a 95% confidence level to determine the sample size for this specific study. It is usual that RKs may vary considerably in the number of smallholder farmers they contain and hence to avoid bias, probability proportional to size (PPS) was employed. Thus, 500 smallholder farmers from the four districts were sampled for the study.

The household survey was conducted from February to June 2016, which followed shortly after the main season (Meher) harvest. Interviews were conducted in places convenient to farmers either at home or in the field.

Statistical analysis such as descriptive statistics, correlation, and multiple regression with a hierarchical model specification was performed using the Statistical Package for Social Sciences (IBM SPSS

software program version 20. To determine whether rural transport infrastructure added significantly to the prediction of smallholder farmers' purchased input use, over and above the variance predicted by demographic, household resource endowment, institutional infrastructure, and location specific variables, the independent variables were entered in to two separate blocks of the regression analysis (hierarchical method). In the first block, all independent variables except rural transport infrastructure related variables (variables of interest) were included into the regression analysis. At the second step, the new independent variables (rural transport infrastructure related variables) were added, and all of the independent variables (those entered at first block) remain in the independent set to see the unique contribution of rural transport infrastructure related variables in the intensification of purchased agricultural input use.

### 3.3 Description of Variables

Our variables of interest (both dependent and independent) used in this study and their levels of measurement are shown in table 1. These variables are supposed to capture the influence of the potential independent variables on the purchased input use as a dependent variable.

#### 3.3.1 Rural transport infrastructure

It is assumed that a well-functioning rural transportation infrastructure is significant determinants of the form and pace of food crop intensification of smallholder farmers. Smallholder level purchased input use for major food crop production ( $Y$ ) is therefore modeled as a function of smallholder farmers' access to rural transport infrastructures and services. Access to rural transport infrastructures and services, captured as an average distance to major market, average distance to farm plot, average distance to all weather-road, are expected to be negatively correlated to the total values of purchased input use (Bekele et al. 2010). Availability of good quality rural access road is considered crucial to improving access to agricultural input markets, resulting in greater use of productivity-enhancing modern agricultural inputs (Jayne et al. 2003). Ownership of Intermediate Means of Transportation for local-level transport services in rural areas is also expected to promote increased use of purchased modern inputs. Hence, household level purchased input use is modeled as a function of distance to major market, distance to farm plot, distance to all weather-road, transport cost, ownership of Intermediate Means of Transportation and road quality.

#### 3.3.2 Demographic factors

To capture the effects of demographic factors on smallholder farmers' purchased input use, we used the age of household head and family size. It was assumed that older households tend to be more

**Tab. 1** Summary of variables used and their measurements.

Variable name and type	Description	Measurement	Expected sign
Purchased input use	A dependent variable indicating the total amount of birr spent for purchasing agricultural inputs for major food crops	Ethiopian Birr*	
Age of household head (continuous)	Age of household head	Number of years	-
Family size (continuous)	Total family size of the household head	Number	+
Size of land holding (continuous)	Area of farm land owned by the household	Hectare	+
Livestock ownership (continuous)	Total livestock ownership of the household	Total livestock unit (TLU)	-/+
Off farm income (continuous)	Income earned from non-agricultural activities	Ethiopian Birr*	+
Membership in a cooperative (Dummy)	Being a member of an agricultural cooperatives	1 = Yes; 0 = No	+
Extension visit monthly (Dummy)	Frequency of extension visit	1 = Monthly visit; 0 = Twice in a year	+
Level of annual rainfall (continuous)	Amount of annual precipitation	Millimeter (mm)	-/+
Distance to major market (continuous)	Distance travelled by the household to reach the nearest major market	Kilometer	-
Distance to farm plot (continuous)	Average farm plot distance from the homestead	Kilometer	-
Distance to all weather road (continuous)	Distance travelled by the household to reach the nearest all weather road	Kilometer	-
Transport cost (continuous)	Transport cost incurred to move 100 kg of agricultural input over 1 km	Birr per 100 kg per km	-
Animal cart (Dummy)	Transport mode used	1 = Animal cart; 0 = Headloading	+
Good road (Dummy)	Road quality	1 = Good road; 0 = Bad road	+
High land (Dummy)	Agro-ecology type	1 = Highland; 0 = Otherwise	-/+
Horro (Dummy)	District type	1 = Horro district; 0 = Otherwise	-

Source: Own construction.

\* During data collection 1 USD equals 23.73 Ethiopian birr.

market-oriented and have higher agricultural input market participation. The number of members in the household is also assumed to be very important in the use of purchased input use since the use of such productivity-enhancing inputs are said to be more labor-intensive than conventional subsistence farming.

### 3.3.3 Household resource endowment

Off-farm income, livestock ownership and size of landholding increase the welfare of farmers because they help farmers in getting the required input needed for agricultural production (Abdullah et al. 2017). Purchased agricultural inputs are mainly financed through cash from off-farm activities and livestock sales (Christiaensen 2017). Therefore, household resource endowment (size of land holding, livestock ownership, and off farm income) are hypothesized to increasingly recognized as a resource that can significantly influence the quantity of purchased input use among smallholder farmers.

### 3.3.4 Institutional infrastructure variables

Apart from household resource endowment and demographic factors several other factors such as the institutional frameworks affect the demand for and consumption of purchased farm inputs such chemical fertilizers (DAP and urea), improved seeds (maize and wheat) and pesticides. Therefore, the third important set factors affecting purchased input use among smallholder farmers in rural areas include the institutional infrastructure variables such as membership in a cooperative (Hellin et al. 2009; Markelova et al. 2009) and contact with agricultural extension agents (Belay 2015).

### 3.3.5 Physical and location specific factors

Several environmental variables were hypothesized to encourage/discourage farmers to invest in purchased agricultural input use for major food crop production. These include the amount of annual rainfall received and agro-ecology. The total values of purchased input use and physical factors (amount

of annual rainfall received and agro-ecology where a household belongs) are related. It is expected that, on average, smallholder farmers in midland agro-ecology and with sufficient rainfall tend to use more purchased inputs. To capture the differences in purchased input use among study districts, district dummy was considered.

### 3.3.6 Rural transport infrastructure

It is assumed that a well-functioning rural transportation infrastructure is significant determinants of the form and pace of food crop intensification of smallholder farmers. Smallholder level purchased input use for major food crop production is therefore modeled as a function of smallholder farmers' access to rural transport infrastructures and services. Access to rural transport infrastructures and services, captured as an average distance to major market, average distance to farm plot, average distance to all weather-road, are expected to be negatively correlated to the total values of purchased input use (Bekele et al. 2010). Availability of good quality rural access road is also considered crucial to improving access to agricultural input markets, resulting in greater use of productivity-enhancing modern agricultural inputs (Jayne et al. 2003). Ownership of Intermediate Means of Transportation for local-level transport services in rural areas is also expected to promote increased use of purchased modern inputs.

The above described independent variables were entered in to into a hierarchical linear regression analysis through sequential block-enter approach so as to predict smallholder farmers' purchased input use. The choice of how to include independent variables was determined by researchers based the overall purpose of the analysis. In the first block of hierarchical linear regression analysis, demographic variables, household resource endowment variables, institutional infrastructure variables, and physical and location specific variables were entered as the first block of independent variables.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{10} X_{10} + \varepsilon \quad (1)$$

Since we are also interested in examining the effect of rural transport infrastructure variables on smallholder farmers' purchased input use after demographic variables, household resource endowment variables, institutional infrastructure variables, and physical and location specific variables have been controlled for, we entered rural transport infrastructure variables (variables of interest) in the subsequent blocks of independent variables in the hierarchical linear regression analysis (block 2). Therefore, to see if the rural transport infrastructure variables predict smallholder farmers' purchased input use above and beyond the effect of the controls and to test if successive model fit better than previous one the following model was developed.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{16} X_{16} + \varepsilon \quad (2)$$

Here in the case of both models:

$Y$  is the financial cost or monetary value of variable inputs (Ethiopian birr),

$\beta_0$  is the constant term or the intercept,

$\beta_{1-16}$  are the regression coefficients associated with respective independent variables

$X_1$  is age of household head (years),

$X_2$  is family size (number),

$X_3$  is size of land holding (hectare),

$X_4$  is livestock ownership (TLU),

$X_5$  is off farm income (Ethiopian birr),

$X_6$  is membership in a cooperative (dummy),

$X_7$  is extension visit monthly (dummy),

$X_8$  is level of annual rainfall,

$X_9$  is high land (dummy),

$X_{10}$  is Horro (district dummy),

$X_{11}$  is distance to major market (km),

$X_{12}$  is distance to all weather road (km),

$X_{13}$  is distance to farm plot (km),

$X_{14}$  is transport cost (Ethiopian birr),

$X_{15}$  is animal cart (Dummy),

$X_{16}$  is good road (Dummy),

$\varepsilon$  is the random error component reflecting the difference between the observed and fitted linear relationship.

After fitting a hierarchical linear regression model and computing the parameter estimates some predictor variables are omitted since they are much less important or most likely affect the explanatory power of the model if included.

## 4. Results

### 4.1 Preliminary analyses

There are a number of assumptions that must be met for multiple linear regression model to be reliable (Osborne and Waters 2002). Preliminary analysis to ensure the non-violation of the assumptions of normality (Kim 2015; Miot 2017; Yap and Sim 2011), linearity (Osborne and Waters 2002), homoscedasticity and multicollinearity (Daoud 2017; Friday and Emenonye 2012; Imdadullah et al. 2016) were completed prior to the analysis. The preliminary analysis revealed that these assumptions were not seriously violated.

### 4.2 Descriptive statistics

Descriptive statistics were used to summarize data. Table 2 shows a descriptive analysis of continuous variables by presenting numerical facts about the quantitative dataset. The total number of observations ( $n$ ) was 500 smallholder farmers in four districts of Horro Guduru Wollega Zone, Western Ethiopia. The mean score for household size was 6.48, with a standard deviation of approximately 3.31 points,

**Tab. 2** Descriptive statistics for continuous variables ( $n = 500$ ).

Variable	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
Age of household head	17	64	34.29	13.02	.56	-.77
Family size	2	12	6.48	3.31	.19	-1.29
Size of land holding	.4	6.0	2.41	1.18	.45	-.48
Livestock ownership (TLU)	.55	11.51	3.26	1.64	.95	1.59
Off farm income	0	9100	2416.30	2730	.89	-.68
Distance to major market	5	35	20.18	7.87	-.15	-1.16
Distance to farm plot	.4	13.0	6.41	3.38	-.08	-1.07
Distance to all weather road	0	27	12.97	6.76	-.16	-.79
Transport cost	.50	3.20	2.18	.78	-.53	-.74
Purchased input use	717.50	37644.43	10096.92	9357	1.44	1.09

Source: Compiled from field data, 2016.

figures which are above the national average of 4.6 persons (CSA 2017).

The average distance to the nearest major market is about 20.18 km, indicating poor market access of smallholders in the study area, while the average distance to all-weather roads is 12.97 km. The values for skewness and the kurtosis indices are very small and fall within the acceptable range which indicates that the variables most likely do not include influential cases or outliers (see Table 2).

The average purchased input (chemical fertilizer, improved seed, and herbicides) value used for major food crop production (maize, wheat, and teff) is ETB 10096.92. The result also indicates that on average smallholder farmers get about ETB 2416.30 income from off-farm employment. A household on average operates about 2.41 ha ( $SD = 1.18$ ), a result which is two times greater than the national average of 1.14 ha (CSA 2015; Tamene and Megento 2017). Finally, on average, households incur a 2.18 ETB to transport one kg of farm input for 100 km from input market center to home.

### 4.3 Correlation analysis

The strongest negative significant Pearson product-moment correlation coefficient for the total values of purchased input use was with the proximity to all-weather roads:  $r(498) = -.772, p < .001$ . Whereas the strongest positive Pearson product-moment correlation coefficient for the total values of purchased input use was with off-farm income:  $r(498) = .654, p < .001$  (Table 3). The simple coefficient of determination ( $r^2 = 0.596$ ) indicated that distance to all weather road explains 59.6% of the variation in total values of purchased input use by smallholder farmers. Approximately, the other 40% of the total variance between distance to all weather road and purchased input use remains unexplained. This value of simple coefficient of determination shows the binary linear relationship between distance to all weather road and purchased input use in the absence of other independent variables. Thus distance to all weather road seems to explain a significant amount of variation in purchased input use.

**Tab. 3** Pearson correlations of purchased input use (dependent variable) and independent variables.

Independent Variables	Correlation coefficient (r)	P value
Age of household head (years)	-.419**	.000
Family size (no.)	.571**	.000
Size of land holding (ha)	-.416**	.000
Livestock ownership (TLU)	.263**	.000
Off farm income (ETB)	.654**	.000
Distance to major market (km)	-.745**	.000
Distance to farm plot (km)	-.467**	.000
Distance to all weather road (km)	-.772**	.000
Transport cost (km)	-.727**	.000
Level of annual rainfall (mm)	.114*	.011

$n = 500$ , \*\*  $P < .001$  (2-tailed), \*  $P < .05$  (2-tailed)

Source: Compiled from field data, 2016.

#### 4.4 Hierarchical multiple regression

A multiple regression analysis was conducted to examine whether rural transport infrastructure, institutional factors, resource endowment, and physical factors could significantly predict smallholder farmer's purchased input use. The results of multiple regression analysis using all sixteen independent variables are summarized in table 4 of model 2. A strong relationship between purchased input use and the independent variables was observed and the model was a significant predictor of purchased input use ( $R^2 = .822$ ,  $F(16, 483) = 138.95$ ,  $p < .001$ ).

The multiple coefficient of determination ( $R^2$ ) value of 0.822, indicates that approximately 82.2% of the total variation in purchased input use can be accounted for by the linear combination of explanatory variables. But the remaining 17.8% of the variance has been attributed to other variables not included in the

model and disturbance term. The adjusted  $R^2$  value is 0.816, which is very close to the multiple  $R^2$ , indicating that we shouldn't worry too much about whether we are using too many variables in the model.

##### 4.4.1 Rural transport infrastructure

The estimated unstandardized regression coefficients displayed in table 4 showed the relative importance of each predictor in the model. Among rural transport infrastructure variables, transport cost was the strongest negative predictor as indicated by its estimated unstandardized regression coefficient, ( $\beta = -3707.88$ ,  $p < .001$ ) followed by good road dummy ( $\beta = 1832.57$ ,  $p < .001$ ) and animal cart dummy ( $\beta = 1090.49$ ,  $p < .05$ ). The unstandardized regression coefficients for the association between distance to major market, distance to all weather road and distance to farm plot on one hand and smallholder

Tab. 4 Hierarchical regression for variables predicting purchased input use ( $n = 500$ ).

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	
	B	Std. Error	Beta			
1	(Constant)	22750.229	11824.431		1.924	.055
	Age of household head	-98.328	23.189	-.137	-4.240	.000
	Family size	651.186	102.507	.230	6.353	.000
	Size of land holding	-2572.812	288.302	-.325	-8.924	.000
	Livestock ownership (TLU)	577.724	205.493	.101	2.811	.005
	Off farm income	1.240	.113	.362	10.989	.000
	Membership in a cooperative	2801.652	602.726	.145	4.648	.000
	Extension visit monthly_Dummy	571.666	542.847	.027	1.053	.293
	Level of annual rainfall (mm)	-8.864	7.432	-.038	-1.193	.234
	High land_Dummy	2078.012	725.521	.100	2.864	.004
	Horro_Dummy	1046.011	611.352	.044	1.711	.088
2	(Constant)	22594.157	10233.971		2.208	.028
	Age of household head	-7.988	18.552	-.011	-.431	.667
	Family size	189.180	82.571	.067	2.291	.022
	Size of land holding	-1070.479	246.050	-.135	-4.351	.000
	Livestock ownership (TLU)	38.776	168.814	.007	.230	.818
	Off farm income	.812	.092	.237	8.848	.000
	Membership in a cooperative	1457.595	467.319	.076	3.119	.002
	Extension visit monthly_Dummy	722.301	424.473	.035	1.702	.089
	Level of annual rainfall (mm)	1.000	6.519	.004	.153	.878
	High land_Dummy	-269.070	574.761	-.013	-.468	.640
	Horro_Dummy	3379.733	492.646	.142	6.860	.000
	Distance to major market	-160.575	46.674	-.135	-3.440	.001
	Distance to all weather road	-316.427	50.336	-.229	-6.286	.000
	Distance to farm plot	-215.478	61.132	-.078	-3.525	.000
	Transport cost	-3707.879	380.257	-.310	-9.751	.000
Animal cart_Dummy	1090.493	548.139	.044	1.989	.047	
Good road_Dummy	1832.569	457.855	.096	4.003	.000	

a. Dependent Variable: Purchased input use

Note:  $R^2 = .689$  for model 1,  $R^2 = .822$  for model 2 and  $\Delta R^2 = .133$ .

Source: Compiled from field data, 2016.



farmers' purchased input use on the other hand are -160.57, -316.43 and -215.48 respectively; the associated standard errors for these regression coefficients are 46.67, 50.34 and 61.13 respectively.

#### 4.4.2 Household demographics

The results of the regression model showed that family size is an important factor identified to influence purchased input use ( $\beta = 189.18$ ,  $t(485) = 2.29$ ,  $p = .02$ ).

#### 4.4.3 Household resource endowment

Size of land holding significantly predicted purchased input use,  $\beta = -1070.48$ ,  $t(485) = -4.35$ ,  $p < .001$ . Off-farm income is positively associated with total values of purchased input use such that, holding everything else constant, for each additional ETB off-farm income, the total values of purchased input use is predicted to increase by .81 ETB, and this association is statistically significant ( $p < .001$ ).

#### 4.4.4 Institutional infrastructure variables

As can be seen in table 4, membership in a cooperative had a significant positive regression coefficient, indicating smallholder farmers who are members of cooperative associations were expected to invest ETB 1457.59 more than the nonmembers, after controlling for the other variables in the model, and this result is statistically significant ( $p = .002$ ).

#### 4.4.5 Location specific factors/district dummy

The value associated with being a farmer living in Horro district is ETB 3379.73 (adjusting for the other variables in the model), and the coefficient on this dummy variable is both positive and statistically significant ( $p < .001$ ).

#### 4.4.6 The unique contribution of rural transport infrastructure related variables to purchased input use

The percent of the variability in the purchased input use that can be accounted for by all the predictors together is 82.2%. This is a significant contribution and hence is an excellent model. The change in variance accounted for ( $\Delta R^2$ ) was equal to .689 - .822 = .133, which was significantly different from zero  $F(6, 483) = 59.76$ ,  $p < .001$ . In this case, the percentage of variability in purchased input use accounted for went up from 68.9% to 82.2%. The F change associated with  $R^2$  change of .133 is statistically significant showing that adding rural transport infrastructure variables to the model increases the model's predictive capacity. This is to mean that rural transport infrastructure explained additional 13.3% of the variance in purchased input use, after controlling for the possible effects of potential confounding variables [ $\Delta R^2 = 0.133$ ,  $\Delta F(6, 483) = 59.764$ ,  $p < 0.001$ ]. The unstandardized regression coefficients ( $\beta$ ), intercept, and the standardized regression coefficients ( $Beta$ ), for the full model are reported in table 5.

## 5. Discussion

### 5.1 Family size and purchased input use

The results of hierarchical multiple regression revealed a positive relationship between family size and purchased input use indicating that large families spend more on purchased input use as compared to small families. There are many prior research findings that explain how the number of family members' influences purchased input use decisions of smallholder farmers. For example, Nambiro (2008) found a significant positive effect of family size on the proportion of farm allocated to the cultivation of improved hybrid maize seed. Another study by Kamara (2004) and Perz (2003) found availability of family labor as a precondition for greater use of chemical fertilizers, pesticides, and improved seeds. Therefore, labor-augmenting technologies are important to encourage small families so that they can take part in input market participation. As a result, this finding supports induced technical innovation theory that agricultural equipment designed for use in small farm plots make it feasible for farmers to shift from labor-intensive practices to higher-yielding mechanized practices (Hayami and Ruttan 1993).

### 5.2 Household-level asset variables and purchased input use

#### 5.2.1 Landholding

This study found a negative and statistically significant relationship between farm size and smallholder farmer's purchased input use. Past studies have found a mixed result. For instance, the largest share of households renting mechanization is more likely related to large farming size (Diao et al. 2016; Ma et al. 2018). In addition, Ma et al. (2018) investigated the determinant role of increased farmland values on the level of supplementary feed used for dairy production. Kiplimo and Ngeno (2016) and Hung et al. (2007) also found a negative relationship between a continuous reduction in farm size (farm fragmentation) and farm household level input use. In contrary to these findings, FAO (2015) found the use of seed and fertilizer technologies to be scale-neutral, which is their use intensity does not depend on farm size. FAO further underlined that, since fertilizer is 'a land augmenting input', smallholders use it intensively, probably to substitute for land (p. 10). Our finding goes in line with FAO's finding supporting the theory of induced technical innovation which advocates the need to substitute the relatively less scarce and cheap factors of production (fertilizer) for more scarce and expensive ones (land) (Hayami and Ruttan 1985; Hayami and Ruttan 1993).

#### 5.2.2 Off-farm income

The study revealed that income from off-farm sources positively influenced the application of complementary inputs such as fertilizer, pesticides, and high

yielding seed varieties. This is because off-farm income was an important source for smallholder farmers to increase their market access to agricultural inputs to intensify production. Findings of this study are in line with those of Dahal et al. (2007), who concluded that off-farm income earning opportunities drive smallholders towards agricultural intensification. Kamara (2004) also found that farmers' access to adequate and sustainable off-farm income has a significant effect on their use of modern agricultural inputs. Moreover, in their seminal work, Lim-Applegate et al. (2002) pointed out the significance of off-farm employment as a source of income for Australian farm families.

### 5.3 Cooperative membership and purchased input use

Membership in agricultural cooperatives is among the variables that determine the propensity of smallholder farmer's participation in the agricultural input market. In this research, it was expected to have a positive influence. Accordingly, membership in farmer cooperatives was found to significantly influence the level of participation in agricultural input marketing. There are several points that help us to maintain this view. Firstly, agricultural cooperatives play a pivotal role in subsidizing fertilizer and seed distribution. Secondly, participating in farmer organizations has the potential to secure better prices for produce. And thirdly, they also play a key role in improving farmer's access to technical advice. The results thus obtained are compatible with previous studies. For instance, in their research findings, Birachi et al. (2011) indicated that membership to cooperative society was the significant driver of agricultural commercialization among food crop farmers in Burundi. Furthermore, Carrer et al. (2018) found significant and positive relationship between participation in pools (cooperatives) and the adoption of forward contracts among citrus growers in the State of Sao Paulo, Brazil.

### 5.4 Rural transport infrastructure and purchased input use

#### 5.4.1 Distance to major market

Access to agricultural input markets is expected to be negatively correlated with the total values of purchased input use. It is, therefore, hypothesized that reduced distance to major market will positively affect smallholder farmers' purchased input use. As expected, there was a negative and significant association between distance to the nearest major market and total values of purchased input use. The current results confirmed the hypothesis that farmers with reduced physical distance to input markets have a higher probability of using modern agricultural inputs than those who are remote (Hailu and Fana 2017). This is partly because the costs of obtaining agricultural inputs such increase more quickly with increased distance to input supply centers.

This finding also corroborates the ideas of Nin-Pratt (2016) and Katungi et al. (2011), who suggested that greater access to urban markets increases the intensity of input use and productivity in the rural sector.

#### 5.4.2 Distance to farm plot

As expected, the regression result showed that plot distance from the homestead has a negative and significant relationship with total values of purchased input use. It may be the case therefore that the more remote the farm plot from farmer's residence, the lesser would be the probability of purchased agricultural input utilization. This result is in line with the findings of a great deal of the previous work in this field. For instance Hailu et al. (2014) found a statistically significant negative relationship between plot distance from the homestead and probability of chemical fertilizer adoption decision. By using a dataset from Ghana, Kotu et al. (2017) also found that plots located adjacent to the homestead are more likely to adopt sustainable agricultural intensification practices than the more distant ones.

#### 5.4.3 Distance to all weather road

The current study found a negative and statistically significant association between distance to all weather road and total values of purchased input use. It is evident that the cost of transport is determined by taking account of road roughness and seasonality. All weather road was reported from earlier studies to be an important variable which explains variations in purchased input use. For example, in Madagascar, Ninnin (1997) reported that dry season fares were less costly than wet season fares. By using data drawn from longitudinal Ethiopian Rural Household Surveys, Wondemu and Weiss (2012) also reported that improving the class of rural roads to a degree that allows all-weather road access sharply increases average household income. They further established that with the equal level of farmland ownership, having paved road access allows a smallholder farmer to generate 82% higher income than would be the case with poor access road. Using cross-sectional data, Beshir (2014) also examined the factors that affect the probability of improved forage seeds adoption in two districts of South Wollo zone, Ethiopia. He found a negative and statistically significant relationship between distance to all weather road and the probability of adoption and intensity of use of improved forage seeds.

#### 5.4.4 Transport cost

The coefficient of transport cost incurred had the expected negative sign and significant effect on the total values of purchased input use (see Table 4). This is because, on the whole, it has been established that there is a strong correlation between transport cost incurred and the ability of smallholder farmers to purchase and use modern agricultural inputs. This finding is consistent with previous studies of Kotu

et al. (2017), who reported that because of inefficient input markets characterized by high transaction and transport costs, in Ghana, farmers mostly pay higher than official prices for nitrogen, phosphorus and potassium (NPK) fertilizer. In another study in Australia, Freebairn (2003), reported that Australians who live in remote rural areas will incur additional transport costs to get access to some services offered in large urban areas. Similarly, according to Wondemu and Weiss (2012), high input prices due to lack of infrastructure, such as underdeveloped rural road networks have led to high transport costs for farm inputs, thus holding back farmers' demand for purchased input use.

#### 5.4.5 Mode of transport

The survey showed a marked variation in the purchased input use among smallholder farmers by type of transport mode owned and used. This research found that an improvement in the mode of rural transport use from head-loading to animal cart will result in an additional 1090.493 birr investment in purchased input use by smallholder farmers. The supply of agricultural inputs was expected to increase substantially with the increased probability of modal shift. The overall efficiency of the transport mode used can seriously affect access to farm inputs. As a result, with respect to transport mode owned and used, modern input use was expected to be higher for smallholder farmers who owned animal cart as compared to those who use the various methods of human portage (head, shoulder, and back-loading). Our finding reveals that ownership of pack animals is the most deriving factor for input market participation where the difference in purchased input use was seen among those who own and not.

Past empirical findings suggested that limited access to an improved mode of transport that helps to move farm inputs from input delivery center to homestead and from homestead to farm remains a major challenge for smallholder farmers (Hine 2004). According to Zewdie (2015), those households who face binding transport constraints may be unsuccessful to afford the maximum desired levels of input use. The traditional mode of transport like human portage negatively affected the level of input use for agricultural production in Nigeria (Akramov 2009; Orakwue et al. 2015). Yet, the use of improved inputs, such as fertilizer and improved seeds is very low among those smallholders who do not own transport animals as compared to those who own the same. In Ethiopia too, transport mode choice is said to be an increasingly important area in getting access to agricultural inputs for smallholder farmers (Kassa 2014).

#### 5.4.6 Road Condition

Linking smallholder farmers with a good road network was found to be positive and significant in access to and utilization of purchased farm inputs. If all other

variables are controlled, a good road condition, as opposed to bad road condition, will result in an additional ETB 1832.569 investment in purchased input use by smallholder farmers. This current study further showed that a good road system from input market to the farms would allow easy and timely access to purchased inputs. This might also partly explain why good-quality roads (paved roads) provide a good stimulus to farm profitability and productivity of the rural economy.

A study by Quan (2009) showed that good physical connections to input markets are a fundamental enabler for smallholder farmer's purchased input use. He further showed that good road access being paramount for farm input commercialization through new technologies that increased the yield of basic food crops. Another recent study in Kenya and Tanzania by Bradbury et al. (2017) explicitly revealed the poor accessibility challenges that smallholder farmers experience in getting agricultural inputs from the market to the farms. In their examination of the transport costs and access constraints for well connected and remote rural farmers of Kenya and Tanzania, they found that smallholders who are linked by a network of unclassified, earth access tracks that are poorly maintained and mostly impassable during the rainy seasons are less likely to use of purchased inputs than those who are connected to good road networks linking farming areas to major markets.

## 6. Conclusion and policy implications

It is incontestable that rural road connectivity and rural transport services are among the key components for rural development, as it promotes access to economic and social services, stimulating the demand and consumption of purchased agricultural inputs that in turn enhance production and productivity of the farmers. To this end, this study revealed that size of land holding, distance to major market, distance to all-weather road, distance to farm plot, transport cost have a significant negative relationship with purchased input use. Whereas family size, off-farm income, and membership in a cooperative are found to be significant and positively related to smallholder farmers' purchased input use.

Two important policy implications emerged from the study: First, to free smallholder farmers from a vicious cycle of subsistence production, policy reforms in the area of rural infrastructure, access to input markets and to credit facilities must be the central government and local government's rural development top priority. Second, input use intensification need a close policy follow-up so as to enhance production and productivity of farmers. Hence, a policy-mix that can increase smallholder farmers' off-farm income is desirable as income is a critical predictor of improved seed and fertilizer use.

## 7. Limitations and future research directions

First and foremost, the most obvious limitation of this study is its cross-sectional design. This limitation calls upon future research to adopt a longitudinal (time series) study approach to robustly capture the impact of public infrastructure investment towards determining the exact role of rural transport infrastructure in purchased input use. Second, the environmental costs of modern agricultural input use were overlooked by this study; therefore, future research concerns should consider a more in-depth analysis of the impact of modern agricultural input use on environmental quality. To measure smallholder farmers' purchased input use intensity, the total financial cost (monetary value) of variable inputs was used. Purchased input use in this study is therefore refers to the quantity of money that smallholder farmers spent on major food crop variable inputs (chemical fertilizer, improved seed, and pesticides) in 2015/16 crop production season. Indeed, in order to estimate the extent of purchased input use we used information on quantity of variable inputs used and the prices at which they are purchased. Since the effect of agricultural input use on farmers' productivity is not the concern of this paper, it can be another potential area for future study.

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