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The Impact of Agricultural Extension Service on the Uptake of Various Agricultural Technologies in Ethiopia[1]

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Abstract

Many governments provide a free agricultural extension service that aims to link farmers to scientific knowledge and yield-enhancing technologies. However, the impact of this service in achieving its aim has been unclear. This study focuses on Ethiopia to explore the impact of the agricultural extension service on farmers' utilisation of various agricultural technologies. Using a large and representative data set, the study applies an instrumental variable method, along with other robustness checks, and finds that the impact of the extension service is heterogeneous to the type of farm technologies. The study finds that the agricultural extension service has a positive impact on chemical fertiliser and crop rotation use, but a negative impact on organic fertiliser use, and no impact on pesticide, herbicide and fungicide use. Based on these results, policy-makers interested in promoting the utilisation of organic fertiliser need to retrain the extension agents and redirect their efforts towards recommending organic fertilisers as much as they do chemical fertilisers and crop rotation.

Keywords: agricultural extension, impact, agricultural inputs, instrumental variable, Ethiopia

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Résumé

Beaucoup de gouvernements fournissent un service de vulgarisation agricole gratuit qui vise à mettre les agriculteurs en contact avec les connaissances scientifiques et les technologies permettant d'améliorer le rendement. Cependant, l'impact de ce service sur la réalisation de son objectif n'est pas clair. Cette étude met l'accent sur l'Ethiopie pour explorer l'impact du service de vulgarisation agricole sur l'utilisation par les agriculteurs de diverses technologies agricoles. En utilisant un ensemble de données important et représentatif, l'étude applique une méthode de variable instrumentale, ainsi que d'autres contrôles de robustesse, et constate que l'impact du service de vulgarisation est hétérogène selon le type de technologies agricoles. L'étude constate que le service de vulgarisation agricole a un impact positif sur l'utilisation des engrais chimiques et de la rotation des cultures, mais un impact négatif sur l'utilisation des engrais organiques, et aucun impact sur l'utilisation des pesticides, herbicides et fongicides. Sur la base de ces résultats, les décideurs politiques intéressés par la promotion de l'utilisation des engrais organiques doivent recycler les agents de vulgarisation et réorienter leurs efforts pour recommander les engrais organiques autant que les engrais chimiques et la rotation des cultures.

Mots-clés : vulgarisation agricole, impact, intrants agricoles, variable instrumentale, Ethiopie

Introduction

Agricultural technology uptake among African smallholder farmers has been growing much slower than in other parts of the developing world. For example, in 2014, the average application of chemical fertilisers in sub-Saharan Africa increased by only 1.5 per cent for nitrogen and 1.9 per cent for phosphate, in comparison to 19.8 and 18.4 per cent in South Asia and by 39.5 and 38.4 per cent in East Asia, respectively (FAO 2015). In Ethiopia, the average chemical fertiliser use in 2016 was 14.4 kilograms per hectare of land, which was lower still than the sub-Saharan Africa average of 16.2 kilograms per hectare for that year (World Bank 2020).

Studies to understand the factors behind the low uptake of agricultural technologies have found that the main barriers are liquidity constraints and lack of access to credit, lack of information and knowledge about new technologies, and risk and uncertainty around trying new methods (Mishra 2018; Carter, Cheng and Sarris 2016; Tadesse 2014; Foster and Rosenzweig 2010; Minot and Benson 2009; Anderson and Feder 2004). In order to address these factors, various efforts have been made by national governments and non-governmental organisations (NGOs).

These include giving access to credit, subsidising inputs, providing free access to agricultural information and, recently, experimenting with various index-based insurance products (Belissa et al. 2019; Kondylis, Mueller and Zhu 2017; BenYishay and Mobarak 2019). Nevertheless, the successes in achieving widespread adoption of improved technologies remain limited.

This article zooms in on one of the most important policy efforts – the agricultural extension service (AES) – and uses instrumental variable, random effects probit models to study its impact on the uptake of various agricultural technologies among Ethiopian farmers. The agricultural extension service links farmers to scientific knowledge and information with the help of extension agents, also known as Development Agents (DAs). Given the low level of literacy and income of most Ethiopian farmers, the extension service is fully financed and provided by the state to make it accessible to all smallholder farmers. The agents are trained in various disciplines, such as plant science, animal science, environmental science and agricultural extension, and are deployed to farming villages (MOA 2017). According to MOA's 2017 statistics, on average there were twenty-one DAs for every 10,000 farmers – the highest ratio in Africa. This number is larger in high-potential areas. There are also 12,500 farmer training centres (FTCs) established all over the country, where model farmers and DAs provide various extension services and market information for other farmers (MOA 2017). Despite the enormous investment in the extension service, few empirical studies have evaluated its impact on agricultural technology adoption.

The only study we are aware of that used a rigorous method to study the impact of the Ethiopian extension service is Dercon et al. (2009). They looked at the impact of the extension service on poverty reduction, and found that the extension service significantly reduced poverty and increased consumption among Ethiopian farmers. A few studies have been conducted in other settings. For example, Wossen et al. (2017) researched the impact of the Nigerian extension service and found that the extension service led to higher technology adoption and lower poverty. Another study, by Pan, Smith and Sulaiman (2018), examined the impact of the Ugandan extension service and found that the extension service had minimal impact in driving the adoption of some technologies, such as improved seeds, but a higher impact on relatively low-cost technologies, such as improved cultivation techniques. A study on the Argentinian extension service found no effect on productivity and the quality of grapes except for those farmers with low initial productivity (Cerdán-Infantes, Maffioli and Ubfal 2008). A review of the extension service evaluation literature by Birkhaeuser, Evenson and Feder (1991) also showed that the effectiveness of the extension service across many countries is mixed.

Against this backdrop, this study used large and representative data that covers two time periods and employed panel data and instrumental variable methods to investigate the impact of the Ethiopian agricultural extension service on the adoption of various agricultural technologies. The theory is that the AES serves as farmers' source of knowledge and information about various agricultural technologies, and that it would drive farmers to adopt the technologies they believed to be profitable. Therefore, the assumption in this paper is that farmers who have access to the extension service would be better placed to acquire information and knowledge about the available best-bet technologies compared to farmers without access to the service. The paper further assumes that farmers who have acquired information and knowledge about best-bet technologies would be more likely to adopt them than those farmers who have no information or knowledge about these technologies.

The results show that the impact of the extension service is heterogeneous across technologies: it has a positive result on chemical fertiliser and crop rotation use, a negative result on manure use, and no impact on other farm chemicals, such as pesticides, herbicides and fungicides. This study also indicates that the impact of the extension service on the uptake of these technologies varies by household head's age and gender as well as household's farm size.

The remainder of the article is organised as follows: the next section presents a brief review of the literature; the third section discusses the research methodology, providing detailed information on the context and data and outlines the empirical strategies; the fourth section presents and discusses the econometric results, and the last section concludes.

Background and Literature

Evenson (2001) provides a brief and comprehensive description of the purpose of agricultural extension services, as follows:

> Extension programs seek two general objectives. The first is to provide technical education services to farmers through demonstrations, lectures, contact farmers, and other media. The second is to function in an interactive fashion with the suppliers of new technology by providing demand feedback to technology suppliers and technical information to farmers to enable them to better evaluate potentially useful new technology and ultimately to adopt (and adapt) new technology in their production systems (2001: 577).

The agricultural extension service originated from the land grant agricultural colleges in the United States that were set up around the mid-eighteenth century to educate farmers about the scientific advances at college laboratories. Back then, agricultural education involved professors giving public lectures to farmers and facilitating the establishment of agricultural societies that organised such lectures and meetings in order to share more information and knowledge with the farmers as well as among the farmers themselves (True 1928). Today, however, instead of college professors or researchers directly addressing the farmers – the main consumers of their product (knowledge), so to speak – the service mainly involves extension personnel as a channel to transfer information and knowledge from the scientific world to the farmers. This is certainly the case in Ethiopia, where extension agents are trained in various agricultural disciplines, and are then deployed to villages where they communicate this knowledge to farmers.

The model was adopted by the Ethiopian government in 1931, by establishing the Imperial Ethiopian College of Agriculture and Mechanical Arts (IECAMA, now Haramaya University), which mirrored the land grant colleges of the United States. Since then, different regimes have provided the service in various forms (Davis et al. 2010). Even so, farmers continue to use traditional methods of knowledge production, which they exchange among themselves, in addition to the more scientific agricultural extension service that complements such knowledge, as evidenced by the 'model' farmer extension approach (Ragasa 2019).

During the Imperial regime, the extension approach (known as the comprehensive package project) was funded mainly by the Swedish International Development Authority (SIDA). This purpose of the project was the overall socioeconomic development of smallholder farmers, by providing improved technologies, mechanisation and demonstrations, and teaching planning and marketing skills along with price stabilisation policies. However, since land rights during that period were reserved for landlords, the project failed to improve the livelihood of most of the poor farmers, who were tenants on the land. Besides, this programme was very expensive. It was replaced by the Minimum Package Project (MPP-I), which focused on reaching out to as many farmers as possible with the 'minimum' essential agricultural services. Unfortunately, this project also failed because of the landlord-tenant land tenure system in place during that period (Kassa 2003).

After the military regime took power in 1974, the extension service was named MPP-II, but the ambitious plan to cover a larger geographic area with fewer resources (human and physical), coupled with additional responsibilities assigned to the extension agents (such as tax collection), meant that once again the project did not achieve its goal. Following the change in government in 1991, a participatory demonstration and training extension programme was launched as a pilot project by an NGO known as Sasakawa Global 2000 (SG-2000), on 160 extension management demonstration plots. The mission of SG-2000 was to stimulate the adoption of agricultural technologies by smallholder farmers and thereby enhance their productivity. The results of these demonstrations were encouraging. For instance, the yield on the demonstration fields increased by about threefold. This success led to the current government (since 1991) adopting the participatory demonstration and training extension system (PADETES) as the national extension policy (Davis et al. 2010; Kassa 2003). Currently, Ethiopia has one of the largest and fastest-growing agricultural extension services (AES) in Africa, with an agent-to-farmer ratio of 21 to 10,000 (MOA 2017).

In 1994, only 5.5 per cent of farmers used the extension service (Kassa 2003); by 2015, about 35 per cent of farmers were using it. Unfortunately, although the number of farmers that use the extension service has increased over the decades, this is a long way from every farmer having access to the service.

Methodology

This section presents a brief description of the study area (Ethiopia), and details the data and the empirical strategy.

Study area

Ethiopia is the second most populous African country, with more than 100 million inhabitants. It is located in the Horn of Africa and covers a total area of 1.1 million square kilometres. The country is known for its diverse agroecology and topography, consisting of three major climatic zones: the cool zone of the high plateaus; the temperate zone, covering areas between 1,500 metres and 2,400 metres above sea level; and the hot lowlands, covering areas below 1,500 metres. Rainfall and temperature widely vary across these climatic zones. The average temperature ranges from 7 ^{0}C in the cool climate zone to 25 ^{0}C in the hot lowlands. The average rainfall ranges from 100 millimetres in the dry lowlands to 2,000 millimetres in the wetlands (CIA 2021).

The Ethiopian economy is heavily dependent on agriculture: agriculture employs 83 per cent of the population, and constitutes more than 40 per cent of the GDP and 85 per cent of export earnings. Coffee is the largest export commodity. Other main exports include oilseeds, cereals, sugarcane, spices, cotton, natural gum, khat and cut flowers. Rain-fed small-scale agriculture dominates Ethiopian agriculture – the average landholding is less than one hectare (CSA 2015).

The Ethiopian government, cognisant of the role of agriculture as an engine of economic growth, has placed agriculture at the heart of its policy and allocates more than 10 per cent of its budget to the development of the sector. The government's Agricultural Development Led Industrialisation (ADLI) strategy aims to reduce poverty and ensure food security by enhancing agricultural productivity, and thus grow the Ethiopian economy. Agricultural technologies (fertilisers, improved seeds, improved agronomic practices, etc.) are the key ingredients for enhanced agricultural productivity. However, the development of agricultural technologies does not guarantee their widespread adoption by smallholder farmers. Farmers need to have access to information on available technologies and how to use them, and access to market information, in order to inform their choice of agricultural technologies to adopt and thereby increase their agricultural productivity (FDRE 2010).

In its effort to inform smallholder farmers, the government has been training an army of extension agents in various agricultural sciences, including animal science, plant science, natural sciences and animal health (veterinary science). They have also been trained in the organisational management of co-operatives and marketing, to mention some of the most common programmes. By 2018, 157,693 extension agents had graduated from these programmes. Figure 1 shows the trend of graduates from 2004 to 2018, which reached its peak in 2007 and declined rapidly after that, reaching a minimum in 2018.

Data and Descriptive Statistics

This study uses data from two sets of the Living Standard Measurement Study-Integrated Survey on Agriculture (LSMS-ISA), 2013/14 and 2015/16. The LSMS-ISA is collected by the Central Statistical Agency (CSA) of Ethiopia in collaboration with the World Bank. The sample consisted of 5,262 households, of which 3,776 are rural. A two-stage probability sampling technique was used to select the respondents. In the first stage, enumeration areas (EAs) were randomly selected from a set of EAs proportional to their sizes. This resulted in 290 rural EAs, 43 EAs from small towns, and 100 urban EAs, totalling 433 EAs. In the second stage, ten households were randomly selected from each EA. A further two households were randomly selected from non-agricultural households to enhance representativity. The attrition rate was reported to be below 5 per cent (CSA 2017). Figure 2 depicts the enumeration areas.

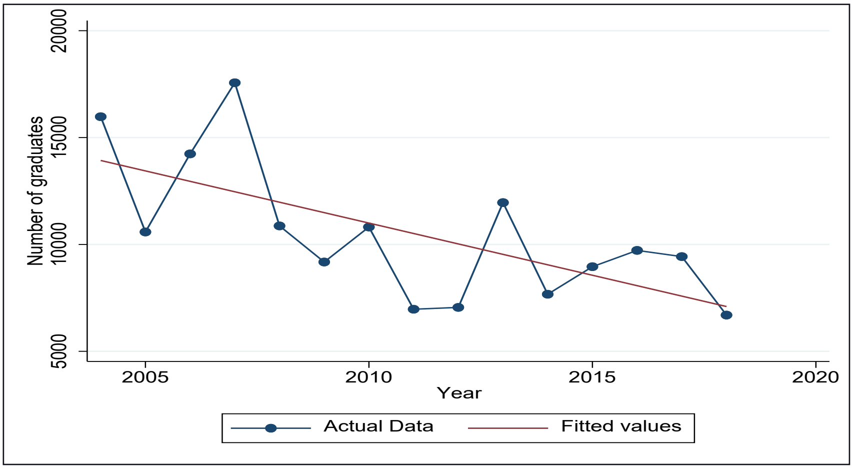

Figure 1: Trend showing the total number of graduates trained in various agriculture disciplines in Ethiopia

Source: Authors' drawing based on data obtained from the Ministry of Agriculture

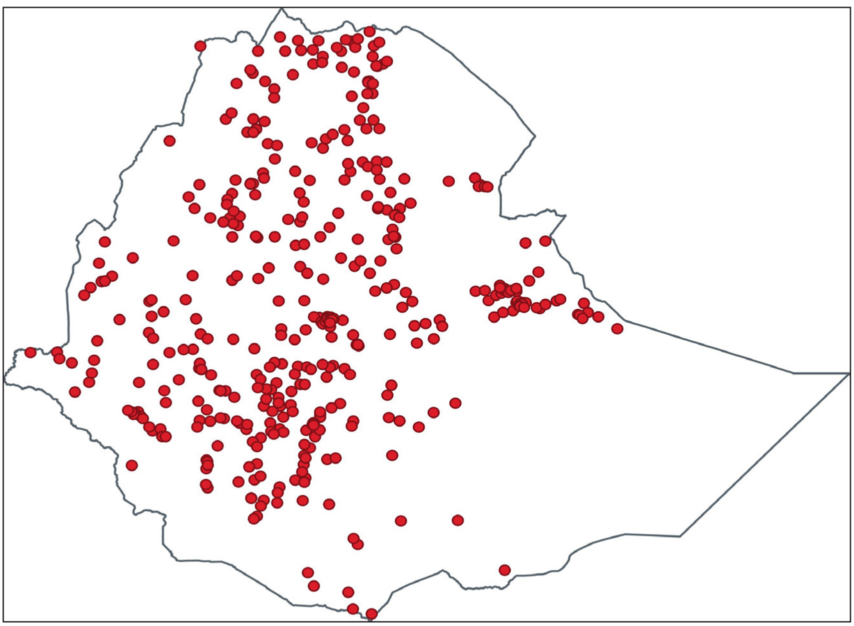

Figure 2: Enumeration areas of the LSMS data in Ethiopia

Note: The dots indicate the locations of the enumeration areas covered by the LSMS dataset

Table 1 presents the descriptive statistics of the data. The sample farm household heads were forty-seven years old on average, the median family size was about 5.2 and the average farm size 0.15 hectares. About 76 per cent of farm household heads were male, 33 per cent of the farm household heads were literate, about 52 per cent had a land certificate, and 52 per cent and 63 per cent, respectively, had good and fair perceived soil quality on their farm land.

In our sample, only about 35 per cent of farmers reported using the extension service. On average, about 43 per cent of farmers used chemical fertilisers (urea, DAP or both), 65 per cent practised crop rotation, about 87 per cent applied manure and 73 per cent used other chemical inputs (herbicide, pesticide, fungicide or any other combination of these).

Notice that only 35 per cent of farmers reported using the extension service despite its widespread coverage of rural areas. Therefore, this study starts by investigating the factors that hinder the utilisation of the agricultural extension service. Then, it proceeds to explore the impact of extension services on the adoption of various inputs.

Table 1: Descriptive Statistics

VARIABLES	MEAN	STD. DEV.	MIN.	MAX.	N
Panel A: Outcome variables					
Fertiliser use	0.427	0.495	0	1	6885
Crop rotation Use	0.65	0.477	0	1	6835
Manure application	0.865	0.342	0	1	6956
Chemical application	0.729	0.445	0	1	6956
Extension service use	0.346	0.476	0	1	6917
Panel B: Explanatory variables					
Extension service use	0.346	0.476	0	1	6917
Sex of head 1 if male	0.757	0.429	0	1	6579
Age of head in years	47.279	15.104	18	99	6577
Age squared	7.61	0.643	5.781	9.19	6577
Family size	5.146	2.326	1	16	6624
Education of head in school years	0.33	0.47	0	1	6576
Farm size in ha	0.149	0.48	0	16.512	6956
Land certificate	0.518	0.5	0	1	6956
Access to credit	0.172	0.377	0	1	6950
Good soil quality	0.515	0.5	0	1	6956
Fair soil quality	0.634	0.482	0	1	6956

Source: Authors' computation based on LSMS data

Estimation Strategy

This section first presents the estimation strategy used to identify the determinants of extension service use and later discusses the strategy for identifying the impact of the extension service on the uptake of various agricultural technologies.

Random Effects Probit Model

In order to identify the factors that determined the use of the extension service, this study uses the random effects probit model, represented in equation 1 and 2. The model is specified as follows:

$$I_{it} = \beta X_{it} + \alpha_i + \varepsilon_{it} \qquad (1)$$

where I_{it} is a latent continuous variable that measures the difference in utility between what a farmer i derives from using the extension service and not using it in time t; $X_{it}s$ is a set of covariates, including the sex of the household head, age of the household head, family size, education of the household head, farm size, land certificate (proxy for land tenure security), access to credit, soil quality indicators and region (geographic location); β is the coefficients of interest; α_i is the random effect associated with individual i; and ε_{it} is the stochastic error term with zero mean and constant variance. A farmer uses extension service ($Extension_{it}$) if the utility (s)he gains from using it outweighs not using it. Mathematically, this can be expressed as follows:

$$\text{Extension}_{it} = \begin{cases} 1 \; if & I_{it} > 0 \\ 0 & Otherwise \end{cases} \qquad (2)$$

We also use the random effects probit model to investigate the impact of the extension service on the uptake of various technologies, as specified in equation 3 and 4. This model serves as a robustness check of the estimates from the instrumental variables method, which is outlined in the next section.

$$z_{hit} = \beta Extension_{hit} + \gamma X_{hit} + \alpha_i + \varepsilon_{hit} \qquad (3)$$

where z_{hit} is a latent utility continuous variable for technology h (chemical fertiliser, crop rotation, organic fertiliser, or other chemical input); X_{hit} is a set of covariates, including the sex of the household head, age of the household head, family size, education of the household head, farm size, land certificate (proxy for land tenure security), access to credit, soil quality indicators and region (geographic location); $Extension_{it}$ is a dummy variable, which indicates whether the farmer uses the extension service; α_i is the random effect; and ε_{hit} is the stochastic error term with zero mean and constant variance. A farmer adopts technology h ($Technology_{hit}$) if the utility (s)he gains from adopting it outweighs not adopting it, and this can be expressed mathematically as:

$$Technology_{hit} = \begin{cases} 1 \text{ if } z_{hit} > 0 \\ 0 \text{ Otherwise} \end{cases} \tag{4}$$

Instrumental Variable Approach

The aim of this article is to identify the impact of the agricultural extension service on the adoption of various agricultural technologies. Identifying this impact using observational data where assignment to the extension service is non-random could be challenging due to endogeneity problems. In our case, for example, an endogeneity bias may arise if farmers of high ability or who are better motivated self-select themselves for access to the extension service; we have no data on such characteristics. Even though the presence of panel data permits us to account for the time-invariant unobserved characteristics, it does not allow us to control for all sources of bias, such as time-varying unobserved factors (for example, the farmer's motivation might change over time) or simultaneity bias – a farmer who adopts new technologies may seek the extension service to learn how to best use the technologies. Therefore, in order to account for such potential sources of endogeneity biases, this study employs an instrumental variable approach (IV) – a widely adopted approach in development economics (see, for example, Acemoglu, Johnson and Robinson 2001; Knack and Keefer 1997).

As mentioned, it might not be possible to account for all the factors that lead to the extension service being used, especially those factors that are unobserved and time-varying but that could influence both the farmers' utilisation of the technologies (the outcomes of interest) and their utilisation of the extension service (the treatment variable). In such cases, one might over- or underestimate the impact of the extension service. To account for such factors, this study relies on the instrumental variable method. This method requires the use of an instrumental variable that is correlated with the endogenous regressor (treatment) but uncorrelated with the error term.

We include data on whether an extension agent lives in the community, as an instrument for extension service utilisation by farmers. The government assigns the extension agents to their respective villages where they serve, but the government does not force the extension agents to live in these villages. However, the odds of a farmer using an extension service are likely to be high if the extension agent does live in the same village. On the other hand, the extension agent's choice of where to reside per se does not affect the uptake of technologies. We thus argue that if an extension agent lives in the community this could serve as a valid instrument to analyse its effect on technology adoption. Additionally, the statistical test confirms this argument, as reflected in the positive and statistically significant correlation the study finds between where the extension agent resides and the farmers' use of the extension service. The instrument also passes the validity test, since this study finds an F-statistic of 48.9, which is much larger than the rule that requires the F-statistic to be greater than 10 (see Table 2). Tesfaye and Tirivayi (2018) also use whether an extension agent resides in a village as an instrument to measure the adoption of improved storage technology in their investigation on the impact of improved storage on food security and farmers' welfare in Ethiopia.

To estimate the impact of the agricultural extension service (a potentially endogenous variable) on the uptake of various technologies using an instrumental variable method, the following equations are specified:

$$Technology_{hi} = \mu + \alpha Extension_{hi} + \gamma X_{hi} + \varepsilon_{hi} \quad (5)$$

$$Extension_{hi} = \delta + \beta EAP_{i} + \tau X_{hi} + v_{hi} \quad (6)$$

where EAP_{hi} is whether an extension agent lives in the same community as the farmer i; ε_{hi} and v_{hi} are the stochastic error terms. The study estimates equations 5 and 6 jointly using the two-stage least squares estimation technique.

Table 2: Correlation between the instrumental variable and the endogenous explanatory variable

VARIABLES	(1)	(2)
	Extension service use	
(mean) EA present	0.215***	0.146***
	(0.0223)	(0.0209)
Constant	0.160***	-0.487*
	(0.0214)	(0.296)
Observations	6,359	6,308
R-squared	0.014	0.168
F-statistic		48.9
Controls	NO	YES
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Results and Discussion

This section presents the empirical results and discussion. It starts by discussing the drivers of agricultural extension service uptake and then presents the impact of the agricultural extension service on chemical fertiliser, crop rotation, organic fertiliser, pesticide, herbicide and fungicide use.

Drivers of Agricultural Extension Service Use

In this part we present the factors that affected the farmers' utilisation of the agricultural extension service. The results of the random effects probit model show that the sex and age of the household head, family size, land certificate, credit access and perceived soil quality were important. These results persisted after controlling for regional fixed effects. As can be seen from Table 3, male household heads were about 45 per cent more likely to use the agricultural extension service compared to female household heads. These findings are consistent with those of a number of previous studies (Ragasa et al. 2013; Manfre et al. 2013; Emmanuel et al. 2016).

Age also affected use of the extension service. The results show that an older age was negatively correlated with extension service utilisation: a one-year increase in age was associated with a 3 per cent reduction in the likelihood of using the agricultural extension service. Family size positively affected extension service utilisation by about 6 per cent. Interestingly, the results also show that land certification had a positive effect on the use of the service. Farmers who had a land certificate were 50 per cent more likely to use the service than those without the certificate. This might indicate that tenure security is an important driver of extension service use. Similarly, farmers with credit access were about 85 per cent more likely to use the service compared to farmers without credit access. Moreover, farmers with good and fair perceived soil quality were about 13 per cent and 30 per cent more likely to use the service compared to farmers with poor perceived soil quality, respectively. Compared to the base category, the Gambella region, only the Somali region had a lower uptake of the extension service. The remaining regions, except the Afar region, had higher likelihoods of extension service utilisation.

The Impact of the Agricultural Extension Service

The impact of the agricultural extension on chemical fertiliser use

The results from both the random effects probit and the instrumental variable regression show that farmers who accessed the agricultural extension service were more likely to use chemical fertilisers. As can be seen from Table 4, the results are robust to the inclusion of demographic and socioeconomic factors as well as regional and year fixed effects. However, the magnitude of the estimates from the random effects probit model tends to be much larger than that of the instrumental variable regression. Given that the random effects probit model may overestimate the impact of the service due to unaccounted factors, this study prefers to discuss the estimates from the instrumental variable regression.

Table 3: Determinants of Agricultural Extension Service Utilisation using Random Effects Probit Model

VARIABLES	EXTENSION USE	
Sex of head 1 if male	0.447***	0.488***
	(0.0776)	(0.0781)
Age of head	-0.0254**	-0.0296**
	(0.0115)	(0.0115)
Log of age squared	0.456*	0.559**
	(0.270)	(0.271)
Family size	0.0417***	0.0607***
	(0.0140)	(0.0144)
Education of head	-0.0949	-0.113*
	(0.0624)	(0.0640)
Farm size	-0.0431	-0.0797
	(0.0562)	(0.0596)
Land certificate	0.823***	0.505***
	(0.0576)	(0.0593)
Access to credit	1.013***	0.846***
	(0.0663)	(0.0658)
Good soil quality	0.176***	0.129**
	(0.0530)	(0.0538)
Fair soil quality	0.491***	0.300***
	(0.0564)	(0.0580)
Tigrai		2.181***
		(0.191)
Afar		-0.650*
		(0.335)
Amhara		1.587***
		(0.176)
Somalia		-0.865***

		(0.292)
Gumuz		0.686***
		(0.229)
SNNP		1.274***
		(0.169)
Harari		2.058***
		(0.220)
Oromia		1.519***
		(0.174)
Constant	-4.434***	-6.105***
	(1.514)	(1.534)
Observations	6,533	6,533

Standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' computation based on LSMS data

The instrumental variable regression shows that farmers who used the agricultural extension service were 79 per cent more likely to apply chemical fertiliser than farmers who did not use the service. Soil quality also affected chemical fertiliser utilisation: farmers who perceived their soil as fair (rather than good) tended to be 6 per cent more likely to use fertiliser compared with farmers who perceived their soil quality as poor. On the other hand, farmers who perceived their soil quality as good showed no significant difference in chemical fertiliser use compared to farmers with poor soil quality. This means that farmers tended to use less fertiliser if their land was reasonably fertile or of poor quality. Other studies have indicated the importance of soil quality in the effectiveness of fertilisers. For example, Marenya and Barrett (2009) show that the effect of chemical fertiliser on crop productivity was marginal on farm soil with a low carbon content.

Yet another important factor in chemical fertiliser use was the age of the farmer. The results show a U-shaped relationship between farmer age and chemical fertiliser adoption, which suggests that younger farmers were less likely to use fertiliser than older farmers. This is in line with studies such as that by Ryan and Gross (1943), where they found a U-shaped relationship between farmer age and the adoption of high-yielding corn varieties in the US. However, the results contradict prior studies that looked at the determinants of agricultural technology adoption in Ethiopia, where they found a negative relationship between farmer age and technology adoption (see, for example, Fufa and Hassan 2006).

In addition, this study indicates a positive relationship between land certification and chemical fertiliser adoption: farmers with a certificate were 5 per cent more likely to use chemical fertiliser compared to their counterparts with no land certificate. Consistent with previous findings, access to credit also had a positive relationship with chemical fertiliser use (Abate et al. 2016; Liverpool and Winter-Nelson 2010). Furthermore, the study indicates that farmers with credit access were 10 per cent more likely to use chemical fertilisers than those without credit access. Lastly, our results show that compared to the Gambella region, our base category, all the other regions, except the Tigray region, showed a higher uptake of chemical utilisation.

The Impact of the Agricultural Extension on Crop Rotation

Our study results show that exposure to the agricultural extension service led to a higher utilisation of crop rotation. The importance of crop rotation in managing weeds and pests, and improving soil fertility, is stated in the agronomy literature (West and Post 2002; Liebman and Dyck 1993; Lazarus and Swanson 1983). Based on the instrumental variable regression, Table 5 shows that farmers who used the agricultural extension service were 34 per cent more likely to practise crop rotation compared to farmers who did not use the extension service. This study also finds a positive relationship between perceived soil quality and crop rotation: farmers with fair and good soil quality were 4 per cent and 9 per cent, respectively, more likely to practise crop rotation than farmers with poor perceived soil quality. As in the case of chemical fertiliser use, the study also found a U-shaped relationship between farmer age and crop rotation uptake. Another demographic factor that affected crop rotation was the sex of the household head: male-headed households were about 6 per cent more likely to use crop rotation than female-headed households. On the other hand, the results do not show a significant relationship between gender and fertiliser adoption. Previous studies have shown mixed results on the role of gender in the adoption of agricultural technologies (see, for example, Obisesan 2014; Ndiritu, Kassie and Shiferaw 2014; Doss and Morris 2000).

Additionally, family size positively and significantly affected crop rotation use, albeit to a small degree. An increase in family size by one person led to only a 1 per cent increase in the likelihood of using crop rotation. Interestingly, this study shows a negative and significant relationship between education and crop rotation: literate farmers were about 6 per cent less likely to practise crop rotation than illiterate farmers. With respect to regional fixed effects, compared to the base category, the Gambella region, all other regions, except Afar and Somalia, were more likely to practise crop rotation.

Table 4: Agricultural Extension Service and Chemical Fertiliser Adoption

VARIABLES	RE probit		IV	
	Fertiliser Use			
Extension service use	2.876***	2.715***	0.836***	0.789***
	(0.112)	(0.109)	(0.0993)	(0.134)
Sex of head 1 if male	0.0952	0.166*	-0.00774	0.00611
	(0.0889)	(0.0895)	(0.0139)	(0.0163)
Age of head	-0.0284**	-0.0369***	-0.00332*	-0.00509***
	(0.0134)	(0.0134)	(0.00186)	(0.00194)
Log of age squared	0.621**	0.826***	0.0769*	0.117***
	(0.316)	(0.315)	(0.0426)	(0.0437)
Family size	0.0396**	0.0359**	0.00307	0.00118
	(0.0166)	(0.0171)	(0.00230)	(0.00269)
Education of head	0.168**	-0.0181	0.0384***	0.00385
	(0.0751)	(0.0768)	(0.0109)	(0.0110)
Land certificate	0.667***	0.459***	0.0723***	0.0601***
	(0.0687)	(0.0705)	(0.0230)	(0.0202)
Access to credit	0.968***	0.913***	0.0949***	0.111***
	(0.0908)	(0.0896)	(0.0330)	(0.0368)
Farm size	-0.0391	-0.0395	0.00120	0.00264
	(0.0542)	(0.0535)	(0.0159)	(0.0141)
Good soil quality	0.207***	0.177***	0.0106	0.0122
	(0.0656)	(0.0665)	(0.0118)	(0.0120)
Fair soil quality	0.605***	0.492***	0.0660***	0.0562***
	(0.0705)	(0.0721)	(0.0161)	(0.0144)
Period			-0.0206*	-0.0165
			(0.0106)	(0.0113)
Constant	-5.958***	-9.063***	-0.398*	-0.733***
	(1.771)	(1.811)	(0.237)	(0.250)
Observations	6,499	6,499	6,276	6,276
Region FE	NO	YES	NO	YES

Standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' computation based on LSMS data

Table 5: Agricultural Extension Service and Crop Rotation Adoption

VARIABLES	RE probit		IV	
	Crop rotation			
Extension service use	1.149***	0.900***	1.051***	0.138
	(0.0794)	(0.0755)	(0.173)	(0.162)
Sex of head 1 if male	0.362***	0.465***	-0.00730	0.0801***
	(0.0865)	(0.0795)	(0.0224)	(0.0191)
Age of head	-0.0262**	-0.0354***	-0.000713	-0.00682***
	(0.0128)	(0.0117)	(0.00293)	(0.00217)
Log of age squared	0.518*	0.753***	0.0104	0.138***
	(0.300)	(0.275)	(0.0679)	(0.0491)
Family size	0.0174	0.0640***	-0.00578	0.00960***
	(0.0160)	(0.0154)	(0.00372)	(0.00295)
Education of head	-0.177**	-0.351***	-0.0150	-0.0589***
	(0.0748)	(0.0715)	(0.0171)	(0.0114)
Land certificate	0.939***	0.325***	0.0491	0.0703***
	(0.0675)	(0.0646)	(0.0380)	(0.0231)
Access to credit	0.920***	0.644***	-0.112**	0.0887**
	(0.102)	(0.0962)	(0.0551)	(0.0422)
Farm size	0.185**	0.177**	0.0284**	0.0197*
	(0.0726)	(0.0709)	(0.0129)	(0.0114)
Good soil quality	0.372***	0.357***	0.00478	0.0534***
	(0.0637)	(0.0626)	(0.0196)	(0.0132)
Fair soil quality	0.726***	0.541***	0.0634**	0.105***
	(0.0652)	(0.0639)	(0.0266)	(0.0159)
Period			-0.0616***	-0.00721
			(0.0167)	(0.0124)
Constant	-3.813**	-6.903***	0.267	-0.783***
	(1.675)	(1.561)	(0.379)	(0.283)
Observations	6,452	6,452	6,230	6,230
Region FE	NO	YES	NO	YES

Standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors computation based on LSMS data

The impact of the agricultural extension on manure use

Another important input this study analyses is the uptake of organic fertiliser (manure) among farmers who used the agricultural extension service *vis-à-vis* those who did not use the agricultural extension service. The benefits of organic fertiliser in maintaining as well as enhancing soil fertility have been documented in the agronomy literature (see, for example, Kirchmann and Ryan 2004; Oikeh and Asiegbu 1993). Interestingly, the results reported in Table 6 show that farmers who used the agricultural extension service were about 32 per cent less likely to use organic fertiliser than those who did not use the service. The results of our focus group discussions reveal that the extension agents had been intensively promoting the uptake of chemical fertilisers, which may explain why those who used the extension service tended to use organic fertiliser less. Furthermore, based on interviews with extension agents, this study uncovers that organic fertiliser had gained growing attention from the extension system. During our fieldwork, most extension agents were organising training sessions to teach farmers the importance and utilisation of organic fertiliser. Hence, future research may investigate whether the relationship between extension service use and uptake of organic fertilisers changes in a positive direction.

Again, this study finds a positive and significant relationship between family size and organic fertiliser use: an increase in family size by one person led to a 1 per cent increase in the likelihood of organic fertiliser use. This is not surprising given the labour-intensive nature of organic fertiliser utilisation: it is bulky in comparison to chemical fertilisers, and requires a large amount of work, from its preparation to its transportation and application. The participants in our focus group discussions were consistently urging the government to provide them with tractors with trailers so that they could easily transport the manure from their homes to their fields.

Additionally, this study finds that land certification had a positive relationship with organic fertiliser use: farmers with a land certificate were about 3 per cent more likely to use organic fertiliser than farmers with no land certificate. Previous studies (such as Adgo et al. 2014; Deininger, Ali and Alemu 2011) have documented the positive effect of land certification on land conservation practices, as a result of tenure security.

However, the results reveal that perceived soil quality had no significant effect on manure utilisation. Lastly, this study found that two regions, Oromia and Gumuz, had low utilisation of organic fertiliser compared to the base category of the Gambella region.

The impact of the agricultural extension service on herbicide, pesticide and fungicide use

Lastly, our analysis shows no statistically significant impact of the agricultural extension service on three other chemical inputs, namely herbicides, pesticides and fungicides (where the household was categorised as a chemical user if it adopted either one of these chemicals; 0 otherwise).[2] The results reported in Table 7 show negative signs, but they are not statistically distinguishable from zero. On the other hand, the utilisation of chemicals correlates with perceived soil quality: there was a lower likelihood (by about 6.5 per cent) of chemical use in lands with good soil quality and fair quality (lower by about 8 per cent) than the base category, which was poor quality soil. Interestingly, the results also show that male-headed households used chemicals less (by about 6 per cent) than female-headed households. This could be because female-headed households, which are pressed for time, may have to depend on chemicals since they are less labour-intensive than hand weeding is. Furthermore, this study finds a negative relationship between family size and chemical use. An increase in family size by one person led to a less than 1 per cent likelihood reduction in chemical utilisation. This could also be attributed to the fact that bigger families tend to have more labour available for activities such as weeding, hence they rely less on chemicals.

Table 6: Agricultural Extension Service and Manure Utilisation

VARIABLES	RE probit		IV	
	Manure			
Extension service use	-0.864***	-0.763***	-0.379***	-0.378***
	(0.0635)	(0.0629)	(0.0850)	(0.118)
Sex of head 1 if male	-0.138*	-0.173**	-0.000192	-0.00263
	(0.0775)	(0.0775)	(0.0127)	(0.0148)
Age of head	0.00407	0.00854	-0.000899	-0.000240
	(0.0117)	(0.0117)	(0.00174)	(0.00182)
Log of age squared	0.0963	-0.00220	0.0404	0.0264
	(0.273)	(0.272)	(0.0409)	(0.0419)
Family size	0.0626***	0.0590***	0.0117***	0.0121***
	(0.0148)	(0.0151)	(0.00219)	(0.00252)

Education of head	-0.00626	0.0707	-0.00954	0.00159
	(0.0646)	(0.0658)	(0.0105)	(0.0110)
Land certificate	-0.125**	0.0204	0.0344*	0.0398**
	(0.0597)	(0.0615)	(0.0195)	(0.0180)
Access to credit	-0.164**	-0.136**	0.0404	0.0365
	(0.0667)	(0.0663)	(0.0292)	(0.0333)
Farm size	-0.141***	-0.124***	-0.0501***	-0.0464***
	(0.0462)	(0.0460)	(0.0123)	(0.0124)
Good soil quality	-0.115**	-0.121**	0.00385	-0.000792
	(0.0570)	(0.0572)	(0.0113)	(0.0118)
Fair soil quality	-0.132**	-0.0185	0.00666	0.0124
	(0.0611)	(0.0621)	(0.0141)	(0.0131)
Period			0.0225**	0.0213**
			(0.00967)	(0.0105)
Constant	0.994	2.407	0.645***	0.743***
	(1.517)	(1.537)	(0.229)	(0.239)
Observations	6,533	6,533	6,308	6,308
Region FE	NO	YES	NO	YES

Standard errors in parentheses. Significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: Authors' computation based on LSMS data

Another interesting result in this study is the negative relationship between land certification and chemical utilisation. A potential explanation for this may be that farmers with secured tenure may tend to use sustainable agronomic practices, such as crop rotation, to fight weeds and diseases (the results in Table 5 support this explanation). In addition, this study finds a negative relationship between credit access and chemical use. Further investigation is required to understand why farmers without credit access are more likely to use chemicals than those with access.

Table 7: Agricultural Extension Service and Chemical Utilisation

VARIABLES	RE Probit		IV	
	Chemicals			
Extension service use	-0.917***	-0.869***	-0.0111	0.0464
	(0.0600)	(0.0597)	(0.132)	(0.185)
Good soil quality	-0.278***	-0.271***	-0.0648***	-0.0671***
	(0.0549)	(0.0547)	(0.0145)	(0.0153)
Fair soil quality	-0.412***	-0.337***	-0.107***	-0.0867***
	(0.0588)	(0.0593)	(0.0197)	(0.0180)
Sex of head 1 if male	-0.204***	-0.240***	-0.0451***	-0.0590***
	(0.0788)	(0.0771)	(0.0166)	(0.0207)
Age of head	0.00362	0.00854	7.52e-05	0.00197
	(0.0118)	(0.0116)	(0.00214)	(0.00230)
Log of age squared	-0.0586	-0.155	0.0175	-0.0226
	(0.277)	(0.272)	(0.0497)	(0.0519)
Family size	-0.0300**	-0.0265*	-0.00738***	-0.00706**
	(0.0142)	(0.0141)	(0.00282)	(0.00344)
Education of head	-0.174***	-0.0392	-0.0412***	-0.00947
	(0.0633)	(0.0635)	(0.0133)	(0.0138)
Land certificate	-0.366***	-0.287***	-0.114***	-0.0924***
	(0.0582)	(0.0600)	(0.0289)	(0.0262)
Access to credit	-0.330***	-0.346***	-0.139***	-0.156***
	(0.0652)	(0.0646)	(0.0425)	(0.0496)
Farm size	-0.259***	-0.268***	-0.0559***	-0.0530***
	(0.0574)	(0.0571)	(0.0146)	(0.0160)
Period			-0.0436***	-0.0483***
			(0.0127)	(0.0142)
Constant	2.668*	3.223**	0.890***	1.161***
	(1.551)	(1.533)	(0.277)	(0.300)
Observations	6,533	6,533	6,308	6,308
Region FE	NO	YES	NO	YES

Standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' computation based on LSMS data

Heterogeneous Impact

This section investigates whether the impact of the extension service on the uptake of the four types of agricultural technologies is heterogeneous by age, sex, farm size and education. Recall that, in the preceding analyses, the study estimated the average impact of the agricultural extension service on technology adoption for all farmers. However, in reality, the impact could vary among farmers. For this reason, this study employs the random effects probit model and uses interaction terms between these groups of characteristics and the extension service variable. The results are presented in Table 8.

The results show that the extension service had a negative impact on the uptake of chemical fertiliser by older farmers. Contrarily, it had a positive impact on the uptake of organic fertiliser among older farmers. This result is puzzling, as the average impact of the extension service is positive for chemical fertiliser and negative for organic fertiliser uptake. Further research is required to pinpoint the reasons behind it.

Another interesting heterogeneity is observed between the sex of the household head and uptake of organic fertilisers and chemicals. Contrary to the negative average impact of the extension service on the uptake of organic fertiliser and chemicals, its impact on male-headed farmers is positive and highly significant. Male-headed farmers who used the extension service were more likely to use organic fertiliser and chemicals (by 40 per cent and 70 per cent, respectively) than female farmers who also used the extension service.

Moreover, the extension service had varying impacts depending on farm size. This study finds that the impact of the extension service on chemical fertiliser and other chemical inputs was negative and statistically significant for farmers with large farm sizes. This is yet another puzzling result that future research could investigate.

Table 8: Heterogeneous Impact using RE probit

VARIABLES	RE probit			
	Fertiliser	Rotation	Manure	Chemicals
Extension service use	4.212***	1.876***	-1.957***	-1.618***
	(0.350)	(0.367)	(0.249)	(0.247)
Age of head	0.00582**	0.00165	0.000311	-0.00329
	(0.00290)	(0.00302)	(0.00278)	(0.00261)
Sex of head 1 if male	0.349***	0.615***	-0.229**	-0.571***
	(0.100)	(0.102)	(0.0967)	(0.0940)
Farm size	0.102	0.228***	-0.100*	-0.186***
	(0.0672)	(0.0809)	(0.0528)	(0.0590)
Education of head	0.303***	-0.0351	-0.0146	-0.201**
	(0.0923)	(0.0957)	(0.0920)	(0.0829)
Age x extension	-0.0115**	0.000514	0.0155***	0.00383
	(0.00532)	(0.00604)	(0.00405)	(0.00394)
Sex x extension	-0.257	-0.318	0.405***	0.699***
	(0.196)	(0.212)	(0.142)	(0.145)
Farm size x extension	-0.360***	0.993	-0.142	-1.748***
	(0.133)	(0.626)	(0.101)	(0.326)
Education x extension	-0.257	-0.248	0.0448	0.0191
	(0.166)	(0.179)	(0.126)	(0.121)
Constant	-2.062***	-0.182	2.073***	2.073***
	(0.187)	(0.179)	(0.178)	(0.169)
Observations	6,501	6,453	6,536	6,536

Standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' computation based on LSMS data

Conclusion and Recommendations

This study evaluated the impact of the Ethiopian agricultural extension services on the uptake of various agricultural inputs. It employed an instrumental variable regression approach to account for potential endogeneity problems that may over- or underestimate the true impact. The results show that the extension service had a heterogeneous impact on the uptake of different inputs. Specifically, the study found a positive impact on chemical fertiliser and crop rotation uptake. Contrarily, the study found a negative impact on organic fertiliser utilisation. Lastly, the study found no impact on the uptake of other agricultural chemicals, such as herbicides, insecticides and fungicides.

Based on these results, the study provided some policy recommendations. One of these is that the extensive focus of the agricultural extension service on promoting chemical fertilisers, though understandable given the urgent need to increase agricultural productivity, could be neglecting other important inputs, such as organic fertilisers, which could play a key role in promoting sustainable agricultural productivity. Therefore, the extension service needs to take cognisance of this and adjust its approach such that it gives equal attention to other agricultural inputs and management practices.

Notes

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2. Initially, we ran regressions separately for each chemical and jointly, as presented in Table 6. The results remain qualitatively the same and hence we report the results on only the latter, for the sake of brevity.

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