Extension Services in Ethiopia: first adoption of chemical fertilisers in rural villages.

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Abstract

In this paper we evaluate the efficiency of extension programmes in the adoption of chemical fertilisers in Ethiopia between 1994 and 2004 using matching techniques in a quasi-experimental setting. Additionally to common factors, measures of culture, proxied by ethnicity and religion, aim to control for potential tensions between extension agents and peasants. We find a considerable impact of extension service on the first fertiliser adoption. Although, there are several exercise of evaluation of extension services policies, this paper manages to disentangle the policy treatment from other confounding effects for two reasons. First we focus on the first adoption decision to isolate the effect of new information provided by the extension service. Secondly, we restrict the sample to villages characterized by late adoption, id est villages where adoption had not occurred before and its appearance can be associated with the policy action with more certitude.

Keywords: Adoption, Extension Service, Culture, Matching Frontier, Ethiopia

1 Introduction

The main channel to promote fertiliser usage in rural areas are extension service programmes (Byerlee et al., 2007). These programmes aim to support the application of modern inputs like fertiliser or improved seeds and also teach new agricultural practices or serve as a source of credit for agricultural equipment. However, their efficiency is questioned by the literature as application rates remain low (Byerlee et al., 2007; Kassie et al., 2009; Spielman et al.,

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2011), resulting, in large stocks due to an excess of their supply (Abrar et al., 2004; Rashid et al., 2013).

This work aims to contribute to the discussion about the effectiveness of extension service programmes. Recent literature by Krishnan and Patnam (2014) and Nisrane et al. (2011) found large positive impacts of extension service on fertiliser adoption and agricultural output between 1994 and 2004 but rarely any impact after 2004. Unlike previous works on the topic, we use the pure definition of adoption and focus only on households without prior knowledge of fertiliser usage. The underlying justification lies in the recurrent necessity of fertiliser usage. Since the decision to use fertiliser occurs repeatedly, previous personal experience of households influences the repeated decision after the initial adoption. Hence, the observed diminishing impact of extension service as source of information on fertiliser usage after 2004 may be attributed to its redundancy as the vast majority of households has already applied fertiliser at least once and does not require further extensions service but, instead, relies on close neighbours for knowledge exchange and for a discussion regarding continued usage Krishnan and Patnam (2014). Our analysis identifies the effect of extension service on first adopters and provides evidence for the importance of the programme in areas where fertiliser had not previously been used. Thus, we measure the pure effect of extension service and investigate whether extension agents fulfill their intended function of raising awareness about the technology and spurring diffusion. In addition, the study highlights potential obstacles to the performance of development agents from a cultural vantage point.

The remainder of the paper is organized as follows: Section 2 reviews the history of extension programmes in Ethiopia and the discussion about the efficiency of such programmes. Section 3 presents the data selected from the Ethiopia Rural Household Survey (ERHS) and investigates the determinants of late adopters. Section 4 describes the matching technique applied to analyse the impact of extension services on fertiliser adoption. Section 5 presents and discusses the results.

2 Extension service in Ethiopia

Soil degeneration, erosion and deforestation are common problems in Ethiopia In addition, current farming practices and technologies are outdated and agricultural productivity is low (Diao et al., 2007; AGRA, 2014). A potential solution to foster agricultural productivity is the promotion of extension service programmes since they might provide information and awareness about modern technologies. Positive examples of functioning extension services can be found worldwide, e.g., Pakistan (Ali and Rahut, 2013), Uruguay (Maffioli et al., 2013), Kenya (N. Kingiri, 2020), Ghana (Avane et al., 2021) or Nigeria (Fabiyi, 2015; Kolade et al., 2014).

In Ethiopia, agricultural extension service programmes first occurred in the 1950th (Kassa, 2003). Since then, programmes with different design and scope like the Minimum Package Project I & II (from 1971 to 1974 and 1981 to 1985) or the Peasant Agriculture Development Extension Programme (PADEP, launched in 1985) have been in place (Kassa, 2003; Kassa and Abebaw, 2004). These programmes have been generally inefficient due to their top-down approach and the non participatory nature (Kassa, 2003; Mossie and Meseret, 2015). More recent approaches like Sakawa Global 2000 (SG2000, 1993) or the participatory demonstration and training extension system (PADETES, 1995) aimed to resolve these shortcomings. However, evaluation results are mixed. While Bonger et al. (2004) or Spielman et al. (2011) find hardly any positive impacts for income and production, Dercon et al. (2009) attributes a decrease of 9.8 percentage points in poverty to the work of the extension agents. With respect to the use of new technologies, Kassie et al. (2009) discovers a positive influence of extension agents on the adoption decision. Also Nisrane et al. (2011), Ragasa et al. (2013) and Krishnan and Patnam (2014) reveal positive and large effects on fertiliser usage for the time since the launch of the PADETES programme until 2004 but barely any impact afterwards (Nisrane et al., 2011; Krishnan and Patnam, 2014).

Common problems relating to fertiliser diffusion are seen in the fluctuation of prices as well as uncertainties in production and consumption (Kassie et al., 2009; Dercon and

Christiaensen, 2011). However, Abrar et al. (2004) show that prices are not the major obstacle to fertiliser diffusion. Instead, they suspect that it is the lack of the access to fertiliser and credits that hinder diffusion (Abrar et al., 2004). The potential shortcomings in access to fertiliser and credit have been counterbalanced by an massive increase in the quantity of extension workers, who are responsible for the provision of credit and fertiliser, besides agricultural training and other governmental tasks (Davis et al., 2010).

In general, the main problem is not seen in the efficiency of extension programmes but in the low and gender biased participation (Davis et al., 2010; Ragasa et al., 2013). Low participation levels may also explain the high importance of neighbours Krishnan and Patnam (2014) as the propensity to adopt does not depend solely on the contact with the agent but on the perceived usefulness of their advices (Ragasa et al., 2013). Even though, Kassa (2003) and Davis et al. (2010) pinpoint low quality recommendations and missing consideration of indigenous knowledge as as weak points of extension service, farmers perception may be biased also due to the cultural background of the responsible advisor: Abebe et al. (2016) De Weerdt (2002), and Munshi (2014) discuss farmers preference to collaborate with ethnic or religious adherents. On the one hand, norms and values that are shared by cultural allies, allow the establishment of trust and provide a common sense of belonging which can facilitate cooperation (Platteau, 1994; Fafchamps, 2006; Karlan et al., 2009; Aggey et al., 2015). On the other hand, common norms in rural societies can oblige individuals to act against their own interests (Fehr et al., 1997; Platteau, 2009), like the cultural constraint of using microcredits in certain parts of Ethiopia (Davis et al., 2010). Hence, the participation in and the perceived usefulness of the extension programme may be subject to a cultural bias if the ethnic or religious background of the agent does not fit the prevailing norms of the rural society. In the case presented in this paper, a cultural mismatch is not unlikely as Ethiopia is home to more than 80 ethnic groups (Census, 2007), and intermixing across ethnic territories occurs frequently (Bekele and Drake, 2003; Beretta et al., 2018; Jordan and Guerzoni, 2016).

The presented literature does not distinguish between the first adoption and repeated adoptions. Hence, the performance of extension agents is measured independently from farmers' prior knowledge and experiences about fertiliser usage. Yet, prior experiences influence personal attitudes towards available technology and the perceived value of extension agent recommendations. Even the best advice may fail if unpredictable environmental circumstances prevent fertiliser to augment yields and impairs the reputation of the development agent. Thus, the mixed results and vanishing importance of extension service for fertiliser adoption may be partially attributed to a confounding definition of adoption. Therefore, the following sections will investigate the performance of extension service programmes among first adopters. Moreover, we restrict the sample to villages characterized by late adoption, id est villages where adoption had not occurred before and its appearance can be associated with the policy action with more certitude. Thus, the next section will also show how a group of 7 villages experienced a delay in the initial diffusion of fertilisers of 26 years, making them a good test bed for this policy evaluation exercise.

3 Data

3.1 Data selection

The paper uses a sub-sample of seven Peasant Association (PA)[1] and 643 households from the Ethiopia Rural Household Survey (ERHS) which originally covers 1477 rural households in 15 Peasant Association between 1994 and 2009[2]. The selection reflects the necessity to consider prevalent diffusion levels[3] in order to properly analyse the effect of extension services. The first column in Table 1 reveals substantial differences within the total sample of 15 villages in diffusion levels for the survey baseline year 1994. While the villages in the

[1]Namely the Peasant Associations Adado, Dinki, Doma, Geblen, Haresaw, Imdibir and Shumsheha.

[2]The questionnaire of the 2009 round of the survey lacks the specific questions about extension service participation between 2004 and 2009 and the information is not identifiable in the raw data. Hence, the last survey round is excluded from the analysis.

[3]Hereby, the diffusion of fertiliser presents the share of households within a society, that have applied fertilisers at least once. The author is aware that the initial adoption of fertiliser does not imply a persistent usage and that the decision to apply fertiliser occurs repeatedly over time which results in a fluctuation of fertiliser application rates between years.

lower section of Table 1 barely show a proper initialization of the diffusion process, fertiliser was used at least once by more than 60% of households in villages in the upper section of Table 1. In addition, the villages have large disparities in the timing of the very first adoption.

Table 1: *Fertiliser Diffusion across Peasant Associations*

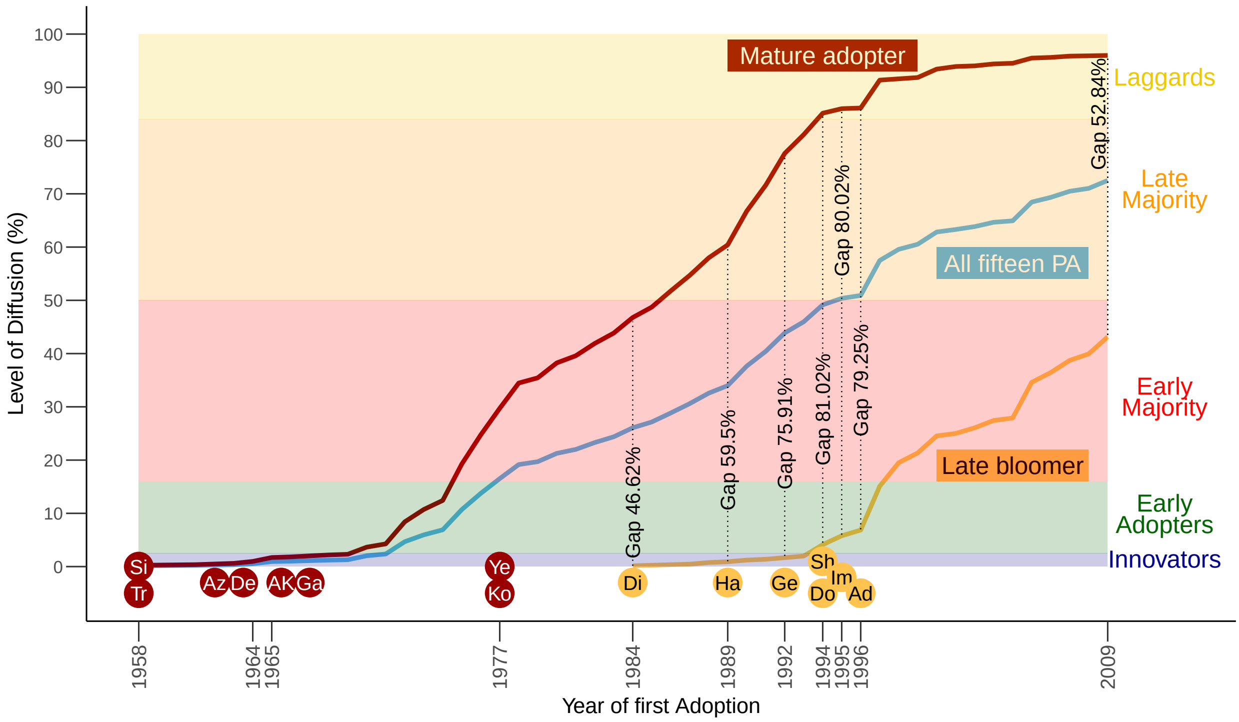
	Pesant Association	Diffusion Level in 1994	First Adoption (Year)	Diffusion Level by 2009
Mature Adopter	Aze Deboa	98.67	1964	100
	Trirufe Ketchema	94.12	1958	99.01
	Gara Godo	91.97	1965	98.95
	Sirba na Goditi	89.69	1958	92.78
	Debre Berhan	89.13	1964	97.28
	Yetmen	86.88	1977	91.80
	Koro Degaga	70.64	1977	96.33
	Adele Keke	61.85	1965	89.69
Late Bloomers	Dinki	12.64	1984	60.91
	Haresaw	9.52	1989	80.95
	Doma	5.4	1994	67.56
	Geblen	4.54	1992	40.90
	Shumsheha	0.67	1994	28.37
	Imdibir	0	1995	35.82
	Adado	0	1996	14.61

Source: Author's calculations based on ERHS.
Note: The diffusion levels express the percentual share of fertiliser adopters per village. Columns 2 & 4 include adoptions occurred in 1994 & 2009. Column 3 presents the year of first fertiliser adoption in each PA.

These profound differences in initial conditions impede an analysis of the performance of extension service among all 15 PAs. Secondly, the lack of precise information about extension service participation before 1994 makes it impossible to link the first adoption of fertiliser to the presence of extension service in the years prior the launch of the survey. Third, fertiliser usage after 1994 in villages with high diffusion levels may not be solely attributed to the extension service but also to the prevalent knowledge and experience about fertiliser usage in the local environment (Krishnan and Patnam, 2014). Thus, the paper will on first adopters in the 15 villages where first adoptions occurred after 1994. In this way, we minimize the probability that an households had access to prior knowledge about fertiliser in the local environment and we have a full battery of controls from the survey data.

However, understanding the vast differences in diffusion levels in 1994 and the time gaps of fertiliser start off is still useful as these outcomes may be based on a systematic dissimilarity of some key factors. Figure 1 depicts PAs splitted in two groups, namely mature adopters and late bloomers Rogers (2003). Notably, a huge chronological gap appears between the first overall adoption in 1958 and the take up in fertiliser usage among the late bloomers. For late bloomers, the first adoption occurred when the diffusion among mature adopters reached already more than 46% and their vast majority of adoptions takes even place when mature adopters already passed the theoretical tipping point of the diffusion curve.

Figure 1: *Year of First Adoption by PA and Diffusion of fertiliser*



Source: Author's calculations based on ERHS and applied on the adopter categorization by Rogers (2003). *Note:* The x-axis depicts years when fertiliser usage started in each PA (See also Table 1). The blue curve illustrates the total fertiliser diffusion of all PA, the dark red curve considers only PAs that start adoption prior 1984 and the dark yellow curve depicts diffusion for PAs with adoption initialization in 1984.

Interestingly, the speed of diffusion is remarkably similar between groups. Late bloomers start the process of diffusion 26 years after mature adopters and reach a diffusion level of 47.02% 24.5 years after mature adopters. In other words, late bloomers did not substantially catch-up or benefit from their late fertiliser uptake.

The comparison of selected household specific variables, widely considered as influential factors for agricultural technology diffusion (Feder et al., 1985), in Table 2 does not present any unexpected fact.

Table 2: *Comparison of adoption determinants by Adopter Categories*

	Mature Adopter	Late Bloomer	Late Bloomer						
			Adado	Dinki	Doma	Geblen	Haresaw	Imdibir	Shumsheha
Plot Size (ha)	1.53	0.76	0.39	1.17	1.14	0.22	0.47	0.11	1.47
Soil Quality	1.7	1.85	1.59	1.87	1.11	2.83	2.44	1.78	1.87
Crop Variety	2.57	2.01	1.55	1.79	1.57	1.12	1.3	2.98	3.09
Distance (km)	8.12	10.29	7	11	3	18	16	5	12

Source: Author's calculations based on ERHS
Note: The comparison presents mean values of adoption determinants in the baseline year 1994. Soil Quality ranges from to one to three with value 1 as indicator for good soil and value 3 for poor soil. Crop variety refers to the average number of different crops on household plots and the distance is measured between village and market.

Mature adopters have on average larger plots with better soil quality while farming a larger variety of crops and facing shorter distance to markets[4]. However, considering the political and environmental circumstances in Ethiopia, two additional explanations should be highlighted. After the fall of the monarchy in 1974 and the establishment of a military dictatorship, the Derg treated northern Ethiopian areas as enemies. According to the supplementary village studies of the ERHS, Geblen and Haresaw were facing a civil war under the Derg regime (1974-1991) that: "[...] heavily devastated the area economically and ecologically, and socially compounded the natural calamities." (Bevan and Pankhurst, 1996b). Beside the social insecurity, the notorious famine of 1984 caused the resettlement of households in many areas and the PA of Doma just emerged due to the migration of households from the drought-affected Gamo highlands in 1985 (Bevan and Pankhurst, 1996a). Thus, households of these three PAs were prevented from using fertiliser due to civil war or the harsh living conditions that caused resettlement[5]. In turn, the historical political and envi-

[4]Since values in Table 2 correspond to 1994 as reference year, all indicators, apart from distance to market, may be erroneous due to fertiliser uptake before 1994.

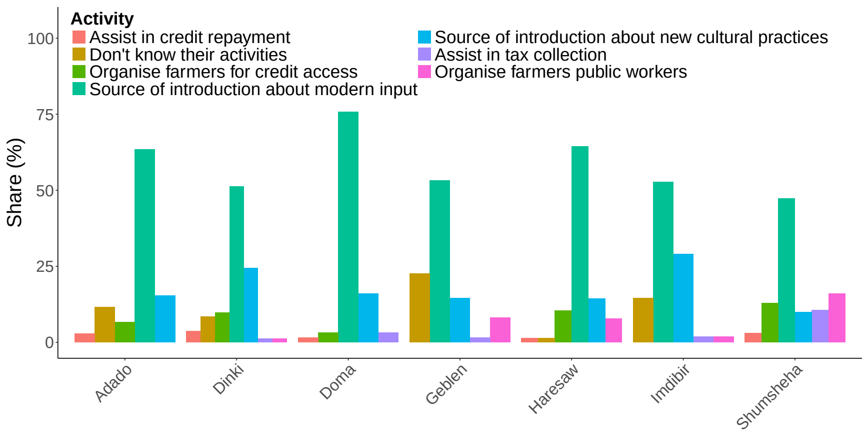
[5]In order to avoid bias from migration, we correct for migration history and do not consider fertiliser adoption prior to land ownership.

ronmental conditions fail to fully explain the low diffusion levels in Dinki and Shumsheha or the total absence of fertiliser usage in Adado and Imdibir in 1994[6].

3.2 Extension service among late bloomers

For the purpose of counteracting soil degeneration and promoting food stability in rural societies, extension service programmes aim to introduce modern inputs such as fertiliser and new agricultural practices. Extension service agents are present in each of the late blooming PAs. The data allows us to track extension service participation between 1994 and 2004 for the SG2000 and PADETES programmes. During that period, 166 out of 643 households adopted fertiliser and almost 50 % of adopters had had previous contact with the extension service program. Considering that only 18 % of households have had contact with the extension service, 71.55 % of these farmers started using fertiliser in the same year. Figure 4 presents the extension service correspondence and subsequent adoption. While correspondence varies, impact appears to be quite positive for the majority of villages. Only households in Imdibir do not respond to the incentives given by extension agents.

Figure 2: *Most important activities of Extension Workers between 1994 - 1999*



Source: Author's calculations, based on data from the ERHS.

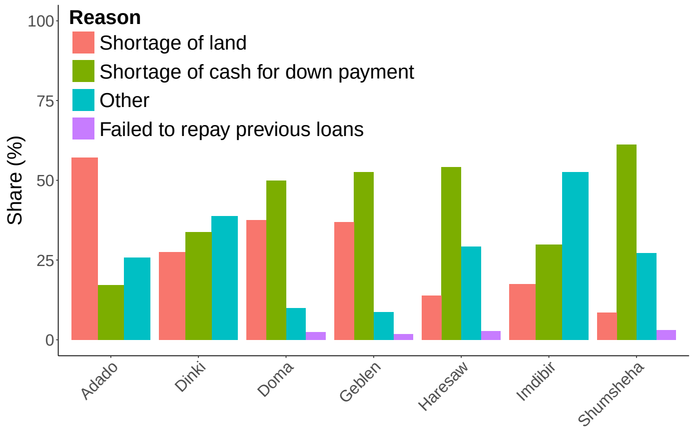
The analysis of supplementary data from the ERHS does not reveal systematic differences between PAs in terms of their understanding and acknowledgement of the extension work.

[6]Droughts and other weather shocks were severe in any of the 15 PA's of the ERHS and all suffered to various degrees from the Derg regime. However, fertiliser application took place in most locations and only Doma, Geblen and Haresaw seem to be thwarted by the political situation in this particular context.

In all villages, the vast majority perceives the extension service as source of modern inputs and new cultural practices. Nonetheless, Figure 2 also shows a reasonable share of missing awareness about the activities of extension agents for peasants in Adado, Geblen and Imdibir. The lack of awareness might explain the low participation shares seen in Figure 4.

Further reasons to not participate may originate from the design of the programmes which require a down payment and sufficient land size. Most farmers indicate one of both as the main barrier to participate (see Figure 3).

Figure 3: *Reason to not participate Extension Service between 1994 - 1999*

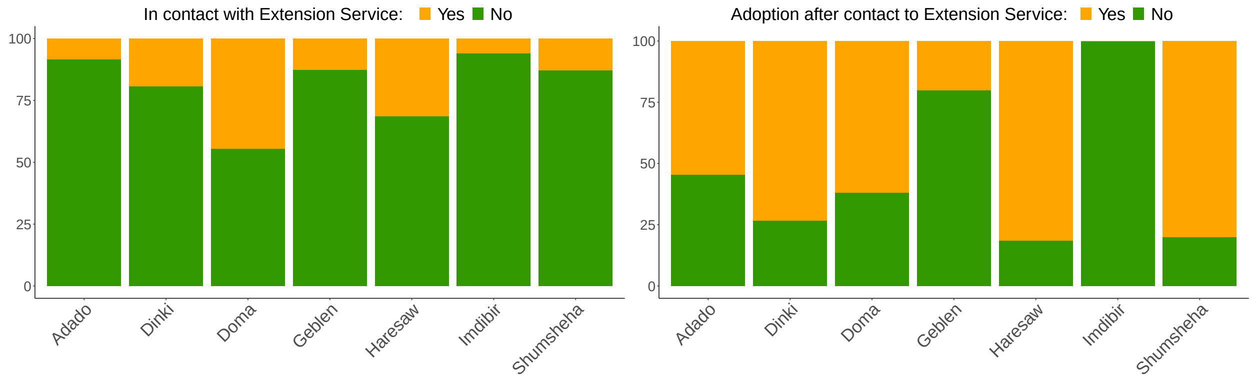


Source: Author's calculations, based on data from the ERHS.

Surprisingly, peasants in Imdibir neither perceive their small plot sizes nor the down payment as a main obstacle to joining the program. Instead they do not specify the main reason.

In what follows, we will consider these aspects to properly estimate the impact of the extension service on fertiliser adoption among the selected villages.

Figure 4: *Contact with extension service and fertiliser adoption conditional on contact*



Source: Author's calculations based on ERHS.
Note: Share of households by village that have been in contact with the extension service between 1994 and 2004 (left) and share of fertiliser adoptions in same time period conditional on the contact to extension agents (right).

4 Methodology

4.1 Estimation strategy

Participation in an extension service programme or the seeking of advice from the extension agent suffers from self-selection bias, if more farmers in terms of wealth, education and skills have higher odds of getting into contact with the development agent (Dercon et al., 2009). The probability of selection-bias is relatively high for the present data as extension agents are required to achieve a minimum adoption. Therefore, they might cherry-pick farmers with an a-priori alleged probability to adopt (Kassa, 2003). Thus, since treated and non-treated farmers are likely to behave differently even in the absence of the treatment, the estimation of extension service as a treatment for fertiliser adoption requires a sound statistical approach. In an optimal scenario, we would like to measure the average treatment effect on the treated group:

$$ATT = E\left[\, Y^T - Y^C \mid T \,\right] \tag{1}$$

with Y^T as adoption of fertiliser (outcome variable) if treated and Y^C if not treated, under the condition that all farmers belong to treatment group T. Clearly, it is impossible to observe $E[Y^C \mid T]$. The problem is known as the unobservable counterfactual (Holland, 1986). The most common approach to deal with unobservable counterfactual consists in applying matching techniques. The basic idea is to create an artificial counterfactual by selecting farmers from the observed non-treated group which share the largest common overlap with treated farmers with respect to known determinants of both the outcome variable and the probability to be assigned to the treatment. Ideally, the artificial counterfactual group is (almost) identical in observable variables to the treated farmers. This case would eliminate the selection bias as treated and control units coincide in their pre-treatment attributes and allows the estimation of the ATT defined as follows:

$$ATT = E[Y^T \mid T, X] - E[Y^C \mid C, X] \tag{2}$$

where X is the vector of covariates known to influence the outcome variable or the assignment to treatment.

4.2 Matching Frontier

The common technique for estimating ATT by using a matching procedure is propensity score matching which is widely applied across various fields of research (Guerzoni and Raiteri, 2015). However, propensity score matching, like other matching techniques, suffers from the trade-off to optimize either the imbalance between treated and control group to reduce model dependence and bias on the one hand or keeping a sufficiently large sample size to restrain the variance of the estimate on the other hand. So far, joint optimization of sample size and balance has occurred manually as present matching techniques could only optimize one or the other. The recent approach of matching frontier by King et al. (2016) disentangles the trade-off between imbalance and variance by the automatic and simultaneous optimization of sample size and balance (King et al., 2016).

To achieve the simultaneous optimization, matching frontier uses a greedy algorithm to encounter the high computational complexity. Their greedy algorithm is an iterative process that stepwise prunes observations with the maximum distance from the overlap area while considering an updated distance calculation at each iteration. The outcome is the matching frontier presenting all optimal matched sample subsets along the imbalance-variance trade-off, i.e. each matched subset provides the minimal imbalance given the number of pruned observations[7]. The precise algorithm for achieving the matching frontier depends, inter alia, on the choice of the imbalance metric. We will apply two different imbalance metrics in combination with two different sets for pruning to investigate the consistency of the ATT.

The first parameter set to construct the matching frontier uses the discrete L_1 imbalance metric. The L_1 processes differences between treated and control units as bins of a multivariate histogram (King et al., 2016). The L_1 is defined as follows:

$$L_1(H) = \frac{1}{2} \sum_{(v_1 ... v_k) \in H} |t_{v_1 ... v_k} - c_{v_1 ... v_k}| \tag{3}$$

with $v_1 ... v_k$ as the range of covariates of the multivariate histogram and with the relative proportions[8] of treated ($t_{v_1 ... v_k}$) and control ($c_{v_1 ... v_k}$) units by covariate. In combination with the L_1 metric no treated units will be pruned. Thus, the reduction in imbalance may appear more challenging if treated units turn out to be very distinct from the controls and finding suitable matches could become cumbersome. The optimal algorithm will iteratively prune observations with the largest proportional distance between treated and control units unless the imbalance metric is larger than in the previous repetition (King et al., 2016).

Contrary to the first set of parameters, the Average Mahalanobis Imbalance (AMI) metric and pruning of treated observations defines the second specification. The AMI measures the average of shortest distances between all units i of a sample and their nearest unit in the opposite group by

[7] King et al. (2016) proof the optimality of their algorithm as pruning does not affect the nearest matched unit(s). See King et al. (2016) for the full proof.

[8] The proportions refer to the frequency of treated (control) units per stratum in relation to the entire frequency of treated (control) units in the strata (King et al., 2016).

$$D = mean_i \left[D(X_i, X_{j(i)}) \right] \tag{4}$$

with $X_{j(i)}$ as defined as

$$X_{j(i)} = \arg \min_{X_j | j \in \{1-T_i\}} \left[\sqrt{(X_i - X_j)S^{-1}(X_i - X_j)} \right] \tag{5}$$

$\sqrt{(X_i - X_j)S^{-1}(X_i - X_j)}$ presents the distance between the multi-dimensional vectors X_i and X_j with S as covariance matrix (King et al., 2016).

Since the second specification allows pruning of unfeasible treated units, the estimation will not present the ATT of the sample but the treatment effect on feasible observations and it is crucial to interpret the estimate under consideration of matched sample characteristics, i.e. one should take into account which kind of observations have been pruned and which remain. The greedy matching algorithm would, starting from the full sample, match each control observation to the nearest treatment observation and provide the shortest distance for each match. Subsequently, the AMI calculates the average distance of all matches and units with the largest minimum distance to their matched counterpart are removed. The outcome is a reduced subset of the original data. If the reduced subset contains more than two observations and an AMI greater than zero, the procedure repeats but starting from the reduced subset until only two observations remain or the AMI becomes zero. The greedy algorithm produces optimal results since re-matching would not decrease distance (King et al., 2016).

After defining the estimation strategy and the matching frontier to estimate the ATT, the following subsection will briefly describe the construction of the sample and provides insights into the performance of the chosen matching techniques on the sample selection.

4.3 Sample selection

In order to estimate the impact of the extension service on fertiliser adoption, the sample is split into treated and control groups according to household participation in the extension service programme. Since the treatment status can be observed over the time period spanning from 1994 to 2004, the sample splits treatment and control groups for each year. The control group contains all households that never had contact with an extension agent throughout this period. These households appear in the control group each year as long they do not migrate or adopt fertiliser[9]. Additionally, households that receive treatment join the control group in all years prior to the year of treatment, i.e. households with treatment in 1997 can be part of the control group in 1994, 1995, 1996. The treatment group comprises only households that obtain an extension service in the same year. Once a household has been treated, it cannot serve as control in successive rounds.

Moreover, to avoid spurious results, treated units are removed from the sample in the years following their first treatment. In that way, households receiving repeated treatment over time or adopting at a later date are just present in the year(s) before obtaining treatment and in the year of treatment. The reasoning behind this procedure is to avoid measurement error as households being treated are systematically different from the control units due to the treatment and their decision to adopt at a later stage may still be influenced by the treatment received in a prior round. Equally, households receiving multiple treatments cannot be matched properly after their first treatment as the repeated assignment to the treatment group is not independent from the previous event in the sample. Hence, the impact estimation is limited to measuring the immediate response of households to the extension service, i.e. decision about fertiliser adoption of a household within the same year of receiving the treatment.

The matching occurs taking into consideration variables that are known - in the literature - to affect the adoption and/or the selection into the treatment group (Feder et al., 1985; Sunding and Zilberman, 2001; Croppenstedt et al., 2003; Asfaw and Admassie, 2004; Dadi et al., 2004; Weir and Knight, 2004; Yesuf et al., 2005; Knowler and Bradshaw, 2007; Duflo et al., 2011; Dercon and Christiaensen, 2011; Krishnan and Patnam, 2014), in order to achieve

[9]Fertiliser adopters do not appear in the sample after the adoption took place as the concern of the work is to evaluate determinants of the very first adoption and not to address the repeated confirmation of the adoption decision.

a balanced sample with respect to the baseline characteristics of treatment and control group. Since matching requires complete information, pruning observations with missing values from original data reduce the number of observations to 643 unique households whereof 109 did receive treatment at a certain point in time between 1994 and 2004. With these households we build two samples and exploit the available observations to circumvent information gaps of time variant variables during non survey rounds.

The first sample is a full pooling sample of 4728 unmatched observations and covers each year from 1994 to 2004. The full pooling sample contains non-survey years in order to include all 109 treated households. However, the inclusion of non-survey years in the full pooling sample restricts matching on time invariant variables[10]. In order to exploit also time variant variables a second sample of 1907 observations is built from the 1994, 1997, 1999 and 2004 survey rounds. This partial pooling sample allows to better match on potentially decisive factors but cuts half the number of observed treated units from 109 to 54.

Table 3 presents the balance tests for the full pooling sample and the partial pooling sample. Balance is achieved for matched subsets of 282 and 104 observations with the L_1 and AMI in the full pooling sample. The partial pooling sample presents balance for subsets of 108 observations with both matching algorithms. A closer look on the unmatched full pooling samples reveals significant differences between treated and control units for household specific characteristics. Treated households have larger farm sizes, are mainly male headed and have higher levels of literacy. Surprisingly, households experiencing a worse environmental shock are more present in the treatment group. This observation is in line with the analysis of Marmai (2016), showing the influence of extreme weather shocks on innovative behaviour. However, both, the L_1 and AMI, reduce the imbalance between treated and control units to non-significant levels for the sub-samples drawn from the full data[11]. The partial pooling contains a larger set of variables but limits the sample to the 1994, 1997,

[10] Farm size, literacy and sex are relatively time consistent but we account for potential changes. If it was impossible to determine the status of a variable with certainty for the point in time, the observation was excluded from the sample.

[11] The L_1 suffers from keeping all treated households and is not able to completely remove the significant differences in farm size.

1999 and 2004 survey rounds. The additional variables are missing in the full pooling sample due to their unobservable specification during non-survey rounds. Besides being male and facing an environmental shock, treated units are younger and own an oxen which is also a crucial determinant of fertiliser adoption in Ethiopia (Dadi et al., 2004). Moreover, we do not observe significant differences in access to treatment between members belonging to the local religious or ethnic majority. The reason for including the membership indicator is twofold. First, Bekele and Drake (2003) describes the insecurity in land tenure and the resulting shorter planning horizons of farmers belonging to the local ethnic minority in Ethiopia. They expect a positive correlation between the application of new conservation methods and the membership in the ethnic majority group. Against their hypothesis, members of the ethnic majority do have a positive and significant correlation with the non application of conservation techniques. The results of Bekele and Drake (2003) show that different ethnic groups in the same area respond differently to new agricultural practices. Second, the characteristics of extension agents are unobserved and we cannot account if agents cultural background fits the local ethnic and religious environment. However, we assume agents to belong to the ethnic majority of the area as the distribution of governmental extension agents outside their home area could be counterproductive due to language barriers. Hence, matching on the majority status should account for cultural differences between extension agents and farmers. As hypothesized by Bekele and Drake (2003), the membership status should also account for land security and access to information, which besides farm size, includes off farm income and Equb membership[12], are important determinants of adoption in Ethiopia (Bewket, 2007; Kassie et al., 2009; Abebaw and Haile, 2013).

Matching occurs also for village characteristics in order to check for potential differences in supply and demand constraints. Distance to market measures the remoteness of a village and hence the dependence on the extension agent to access fertiliser. The fractionalization index for ethnicity and religion expresses the probability that two randomly drawn individuals do not have the same religion or ethnicity (Alesina et al., 2003; Alesina and Ferrara, 2005;

[12]Equb or iqub, are local types of rotating savings and credit associations.

Jordan and Guerzoni, 2016). It is a measure for the diversity of the rural society and is taken into account as fragmented societies are under suspicion of thwarting economic development due to lower provision of public goods, conflict, coordination troubles and ethnic favourism (Horowitz, 1985; Easterly and Levine, 1997; La Porta et al., 1999; Alesina and Ferrara, 2000; Alesina et al., 2003; Franck and Rainer, 2012). However, the combination of distance to market and both fractionalization indices makes it possible to correctly identify the village and therefore to consider the socio-environmental conditions for the matching process.

Table 3: *Balancing tests for matched samples*

	Variable	full pooling n = 4728									partial pooling n = 1907								
		Unmatched sample			L_1			AMI			Unmatched sample			L_1			AMI		
		C	T	Diff *p.value*	C	T	Diff *p.value*	C	T	Diff *p.value*	C	T	Diff *p.value*	C	T	Diff *p.value*	C	T	Diff *p.value*
Household characteristics	Farm Size	0.99	1.27	**0.0291**	1.02	1.27	**0.0919**	0.71	0.91	0.2974	0.99	1.25	0.1827	1.05	1.25	0.4147	0.98	0.93	0.8235
	Sex	0.73	0.87	**0.0000**	0.87	0.87	0.9753	0.77	0.79	0.8440	0.73	0.85	**0.0178**	0.85	0.85	1.0000	0.84	0.82	0.8502
	Literacy	0.30	0.43	**0.0110**	0.44	0.43	0.7960	0.29	0.34	0.5743	0.31	0.41	0.1359	0.52	0.41	0.2465	0.51	0.46	0.6667
	Shock	0.21	0.31	**0.0260**	0.31	0.31	0.9220	0.30	0.34	0.6870	0.23	0.37	**0.0438**	0.37	0.37	1.0000	0.49	0.46	0.8356
	Soil Quality	1.78	1.77	0.9111	1.69	1.77	0.3892	1.99	1.88	0.5189	1.79	1.88	0.4481	1.94	1.88	0.6869	1.89	2.09	0.2195
	Member Majority:																		
	Ethnicity	0.91	0.89	0.4000	0.91	0.89	0.6379	0.98	0.97	0.7144	0.91	0.93	0.6946	0.98	0.93	0.1736	0.99	0.96	0.5436
	Religion	0.73	0.72	0.7654	0.75	0.72	0.5114	0.79	0.79	0.9849	0.73	0.81	0.1202	0.78	0.81	0.6366	0.90	0.86	0.5725
	Equb Member										0.15	0.20	0.3367	0.09	0.20	0.1063	0.11	0.14	0.6921
	Age										48.14	43.39	**0.0053**	41.63	43.39	0.4356	43.01	42.64	0.8844
	Remittance										0.11	0.06	0.1031	0.06	0.06	1.0000	0.04	0.07	0.5334
	Off Farm Income										0.37	0.30	0.2408	0.41	0.30	0.2305	0.31	0.39	0.4586
	Oxen Owned										0.23	0.43	**0.0050**	0.30	0.43	0.1638	0.24	0.29	0.6295
PA characteristics	Diffusion	0.12	0.12	0.8996	0.11	0.12	0.6439	0.07	0.08	0.7433	0.10	0.09	0.2435	0.09	0.09	0.7526	0.04	0.04	0.6803
	Distance to market	13.06	12.08	0.2011	12.98	12.08	0.3535	14.48	14.63	0.9247	13.03	12.76	0.7914	12.63	12.76	0.9284	13.91	14.25	0.8361
	Fractionalization:																		
	Ethnic	0.12	0.15	0.1925	0.13	0.15	0.5474	0.12	0.11	0.6617	0.12	0.13	0.9117	0.11	0.13	0.6390	0.09	0.10	0.6934
	Religion	0.37	0.37	0.9728	0.35	0.37	0.4347	0.29	0.29	0.9998	0.37	0.33	0.2291	0.34	0.33	0.8195	0.31	0.28	0.6086

Source: Author's calculations, based on ERHS and using the MatchingFrontier by King et al. (2014).
Note: Bold p-value indicates differences are significant at a 10% level or lower. The balance achieved for the full pooling sample is given by matched subsets of 282 and 104 observations for the L_1 and AMI respectively. Balance for the partial pooling sample is given by subsets of 108 observations for both matching algorithms.

5 Results and Discussion

Table 4 presents the estimated average effects of access to agricultural extension agents on chemical fertiliser adoption. The results across matching techniques and for both data samples show positive and significant impacts on fertiliser adoption decision by households without prior fertiliser usage. Farmers exposed to an extension agent are roughly 60% more likely to adopt fertiliser in the same year. When we consider the reduced data sample and thus we check for a broader set of variables, results are still highly significant and the average effect is large. The substantial size of the effect reveals the importance of extension agents as sources of information and access to fertiliser for first-time adopters. The focus on the initial adoption of a household makes it possible to identify the pure impact of extension service as potential adopters cannot rely on their own experience and depend mainly on the performance of the extension agent. The remarkable effect of the analysis indicates that the extension service fulfills its function as gatekeeper and successfully introduces fertiliser into a rather unaware and inexperienced environment.

By definition the ATT estimated by the L_1 imbalance measure reveals the impact of extension service on all treated units. In contrast, we allow pruning of non feasible treated observation for the AMI. The specification reduces the full sample by 71 treated households (38 of 109 treated households remain) and the partial pooling sample by 26 treated households (28 of 54 treated households remain). The elimination of treated households during the matching process makes it possible to remove the significant unbalance in farm size, which did not vanish if the algorithm is forced to keep all treated units.

Pruning treated households changes the average characteristics of the treatment group and the ATT estimates on the AMI matched samples do not hold for pruned treated households. Recalling the mean values after matching from Table 3, we can conclude for the two AMI matched samples, that the ATT draws on households with farm sizes below one hectare and large distances to market. The households almost entirely belong to the ethnic majority and are more affected by shock than pruned observations of the treatment group.

Table 4: *Effect of the agricultural extension service on fertiliser adoption*

Outcome	Treatment variable: contact to extension service			
	full pooling		partial pooling	
	L_1	AMI	L_1	AMI
Fertiliser adoption	0.616***	0.632***	0.593***	0.523***
	(0.039)	(0.060)	(0.071)	(0.060)
Observations pre-Match	4728		1907	
treated pre-Match	109		54	
Observations post-Match	282	104	108	108
treated post-Match	109	38	54	28

Source: Author's calculations, based on data from the ERHS. Calculations have been performed by the R package *MatchingFrontier* by King et al. (2014).
Note: According to King et al. (2016), our chosen specification of the AMI estimates the feasible sample average treatment effect on the treated (FSATT) as pruning of treated units is allowed and the selected specification of the L_1 algorithm without pruning of treated observations estimates the sample average treatment effect on the treated (SATT). To comply with literature we use the common expression, average treatment effect on the treated (ATT), for both cases. Significant results for *p<0.1; **p<0.05; ***p<0.01.

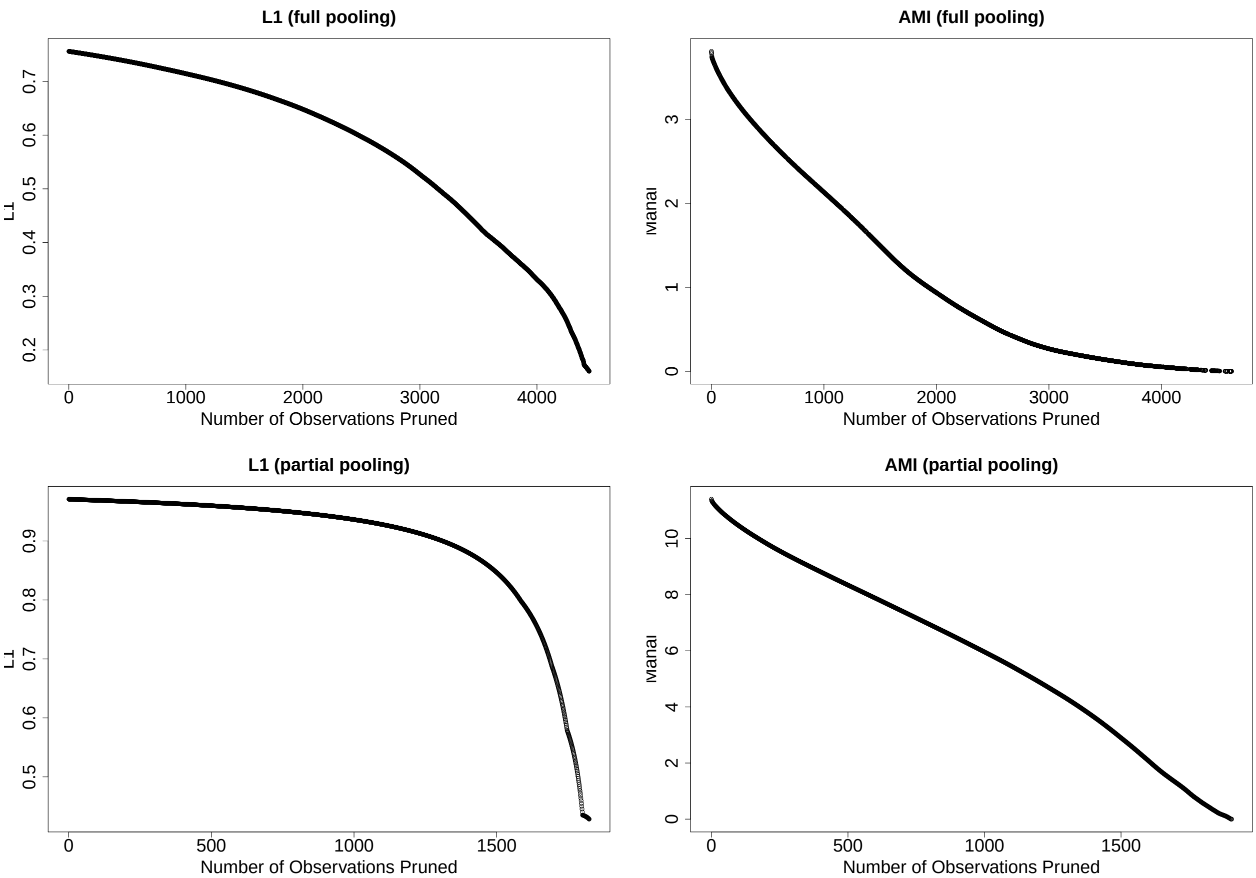
As shown in Table 3, the significant differences between and treated and control units have been removed for both samples independently of the matching algorithm. Figure 5 provides further information about the quality of pruning. The balanced sub-samples from the full pooling data sample portray the minimum distance achievable with both matching algorithms. In both cases the matching algorithm stopped as no further reduction in distance is possible, i.e. for full pooling: AMI = 0 and $L_1 = 0.16$. Given the characteristics of the matching frontier approach further pruning would not reduce imbalance.

In contrast, both sub-samples of the partial pooling sample are optimal and balanced but do not present the lowest possible distance like the full pooling sub-samples due to the broader scope of variables and the lower number of observations. However, the sub-sample size of 108 observations is sufficient to remove significant differences between treated and control units. Also, the distance between treatment and control group decreased remarkably from an AMI of 11.404 with zero pruning to 0.404 for the selected sub-sample and from 0.97 to 0.445 for the L_1[13] [14].

[13] Minimum distance achievable is zero for the AMI but requires pruning down to two observations and a L_1 distance of 0.428 for a sub-sample with more treated than control units.

[14] n order to inspect the robustness of the estimated ATT, the matching procedure has been iterated for

Figure 5: *Performance of imbalance reduction algorithms*



Source: Author's calculations, based on data from the ERHS. Calculations have been performed by the R package *MatchingFrontier* by King et al. (2014).
Note: Full pooling contains observations from every year between 1994 and 2004 but is limited to time invariant variables and variables with the possibility to calculate values for non-survey rounds, e.g. sex, farm size etc. Partial pooling uses observations from the ERHS 1994, 1997, 1999 and 2004 rounds and explores a broader set of variables.

6 Conclusion

The paper provides additional evidence on the importance of extension services programmes. The performance of the extension service is estimated in the context of a late blooming environment, i.e. in contrast to other works, we consider only the first fertiliser usage as an adoption and focus on households in villages with low fertiliser diffusion during the time of the

each year of the time period across all villages to analyse annual variations and to observe local differences relating to each village. Robustness checks are available upon request and present on a previous working paper version of this work (Jordan and Guerzoni, 2020) study launch in 1994. The restriction of the adoption definition implies that the household has never employed fertiliser before and hence cannot rely on previous personal experience during the adoption decision process. Our aim is to avoid spurious measurement of the extension service impact, as repeated fertiliser adoption of households over time potentially depends to a diminishing degree on extension service.

Results point at a positive impact of the extension service on the first fertiliser adoption and prove their importance to introduce new ideas, raise awareness and foster adoption. The effect appears to be relatively constant over time but differs between villages. While the impact is large in magnitude for farmers in Dinki, Doma, Haresaw and Shumsheha, extension agents fail to immediately spur adoption in Geblen and Imdibir.

Attempts to explain the poor performance in both villages additionally raise the question about the generally low participation rates in these PAs. Since we cannot observe the frequency and duration of extension agents visits in each village, inadequate supply provides a (non-testable) explanation. On the demand side, peasants in Imdibir reveal exceptionally low levels of trust in local and national authorities. The lack of trust may impede an appropriate collaboration and potentially explains the low participation levels as well as the missing impact on adoption. On the contrary, several farmers in Geblen adopt fertiliser but none of them due to extension service and we could not explain the case with observable economic or social variables.

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