The Impact of Ethiopia's Productive Safety Net Program on Fertilizer Adoption by Small Holder Farmers in Tigray, Northern Ethiopia

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Key words: Adoption Fertilizer PSNP control function

Introduction

With a view to increase productivity of agriculture, improved inputs and farming methods have been introduced throughout the developing world (Dadi et al. 2004; Doss 2006). The crusade to achieve higher agricultural productivity through improved agricultural inputs and methods, also known as the green revolution, had been a success story in Southeast Asia. However, when it comes to Africa, the green revolution did not succeed(Dadi et al. 2004; Feder et al. 1985). One of the reasons for failure of the green revolution in Africa is low adoption of the proposed inputs and methods by African farmers (Abebaw & Haile 2013; Dadi et al. 2004; Holden & Lunduka 2012; Holden & Westberg 2016; Kassie et al. 2013). For example, Holden and Lunduka (2012) citing (Heisey and Mwangi, 1995) point out that fertilizer use per hectare of maize crop is found to be 70 KGs in Zambia, 55 KGS in Zimbabwe and 26 KGS in Malawi. In Ethiopia around 45% of the national total crop area is treated with inorganic fertilizer with an average intensity of 81KGs per hectare(Zerfu & Larson 2010). In the same way (Abebaw & Haile 2013) stated that fertilizer adoption is very low in Ethiopia with only 12% of farmers adopting it in the main production season of 2009/2010.

Food security is aimed for in Ethiopia by stimulating agricultural intensification on the one hand and by providing a safety net to protect poor and vulnerable farm households and communities on the other hand. This study assesses the interphase and possible synergies between these two approaches. The government of Ethiopia has been trying to improve productivity of farmers by introducing improved agricultural inputs, methods and market access. The main agricultural inputs provided are improved seeds and fertilizer. The same endeavor is clearly stated in the second growth and transformation plan of the country which runs for 2015/16 to 2019/20 (National planning commission 2015). Use of improved seeds and fertilizer is also a component of the country's food security strategy and receives a very high focus by the government (Krishnan & Patnam 2014). The Productive Safety Net Program (PSNP), as a core element of the country's food security strategy, aims at enabling poor farmers to come out of food insecurity by means of preventing asset depletion at the household level and asset creation at the community level (Hoddinott et al. 2012; Ministry of Agriculture and Rural Development 2009). This program has two modalities. One is the public works program in which able-bodied members of the program are paid in terms of cash or food for works they do on various community level asset-building projects. The other modality is for those who are labour deprived and it provides them with an unconditional transfer of cash or food. This study focuses on the public works component of this program and assesses how it might have affected adoption of improved agricultural technologies taking fertilizer adoption as a case in point.

The PSNP, as stated earlier, is intended to enhance capability of poor farmers to come out of food insecurity. One of the farmers' capabilities that this program might affect is the ability of poor farmers to acquire knowledge about improved agricultural technologies and making use of them. Members of the PSNP have a frequent interaction with authorities at the *tabia*[1] level and the officials exert pressure on them to adopt fertilizer and improved seeds. This pressure is aimed at enabling them to reduce their economic vulnerability and graduate from the program by increasing their income. In fact, members of this program are given priority in access to the household asset-building program (HABP)[2]. This program aims at improving agricultural productivity and micro enterprise development (Hoddinott et al. 2012). The PSNP on the one hand can then influence adoption of fertilizer by providing program members with access to knowledge through the frequent interactions they have with relevant bodies. On the other hand, it may also affect fertilizer adoption by increasing the ability of member farmers to buy fertilizer through the

[1] *tabia* is the lowest administrative level in rural areas of Tigray.

[2] The HABP is a program designed by the government of Ethiopia to enhance food security via livelihoods improvement. This program consists of packages that are designed in the form of income generating activities that are targeted to poor households with a view to enable them to secure sustainable livelihoods. This program provides targeted households with training and credit so that these households will be able to access improved seeds, carry out soil and water conservation or engage in animal fattening and beekeeping and similar activities. This program gives priority to households nearing graduation from the PSNP with a view to ensure sustainable graduation.

predictable income they receive from the program. Farmers, usually drag their feet in adopting new technologies because they fear the new technology may not succeed in achieving its stated aims and could lead to loss of yield or additional expenditure with no improvement in output. In this regard, the PSNP can also serve as a kind of insurance since it provides them with a predictable income source, which could encourage adoption.

The issue of explaining adoption of improved technology by rural farmers has been a focus of several studies. Feder et al. (1985) made a good review of earlier studies on this topic while for a somewhat latter review of such studies one may see Doss (2006). These studies and other more recent studies as well focused on the factors, which explain the level of adoption of new technologies focusing especially on the factors that explain success or failure in the level of adoption of improved agricultural technologies. The studies conducted so far show the importance of household level and farm level features, institutional factors and risk related issues in determining adoption and intensity of modern agricultural technologies (Alem et al. 2010; Bezu et al. 2014; Doss 2006; Feder et al. 1985; Holden & Westberg 2016).

Though there have been quite plenty of studies on the factors which determine adoption of improved agricultural inputs and methods, studies which try to see how public programs, like the PSNP in Ethiopia, might affect the adoption of modern technologies, have been lacking. To the best of our knowledge, only (Gilligan et al. 2009) tried to assess the role of the PSNP on fertilizer adoption taking 2006 as the year after treatment. However, this period might not be sufficient to observe the impact since the program just started in 2005 and since there were lots of ambiguities regarding the program both at the level of implementers and targeted households, which needed quite some time to get settled.

This study tries to investigate the impact of PSNP membership on fertilizer adoption in Tigray, northern Ethiopia. We believe this study is important on three grounds. Firstly, we are investigating the impact of the PSNP, which is a public intervention program, on fertilizer adoption. The issue of fertilizer adoption itself is highly promoted by the government with a view to increase agricultural productivity in Ethiopia and as such, it can be viewed as a governmental initiative. This study, therefore, is interesting for two major reasons.

Firstly, it can show whether the two programs are reinforcing each other and expediting the poverty reduction objective of the country or not. The most important question that should be raised here is that does access to PSNP stimulate or discourage fertilizer adoption and intensity of adoption? There can be two hypotheses in relation to this question. One, PSNP membership is associated with higher adoption and intensity of adoption of fertilizer since households become more willing and able to take the risk of making such risky investments. Two, PSNP membership discourages such risky investments as PSNP is an alternative way to obtain food security through food for work rather than through own risky food production ventures using risky inputs such as fertilizer.

Secondly, we are investigating the impact of the PSNP on fertilizer adoption over a sufficiently long period (using panel data of four rounds between 2006 and 2015). This period includes both the first (2005-2009) and second (2010-2015) phases of the program. Having a long time span is important as adoption of new technologies by farmers could take a long time. This is due to the fact that farmers need to have full information regarding the attributes and potentials of the technology in order for them to adopt it. Thirdly, we are investigating both the adoption and the intensity of modern fertilizer use. This is important, as studies that look at both adoption and intensity are more informing both to academics and to policy makers (Asfaw et al. 2011)

Analytical Framework

The literature on adoption of new agricultural technologies distinguishes between individual and aggregate adoption. The former is defined to be the degree of use of a technology in long run equilibrium when the farmer has full information regarding the technology and its potentials while the latter is about the diffusion of the technology within a region (Feder et al. 1985). There is also the concept of intensity of adoption which refers to the amount of the input and can be measured by the share of farm area using the technology or the per hectare quantity of the input used where applicable (Feder et al. 1985). This study is concerned with the role of the PSNP on individual adoption and measures intensity of adoption by quantity of fertilizer used per *tsimdi*[3] (roughly a quarter of a hectare) of planted area.

In explaining the decision of the farmer regarding adoption of a technology, that decision at a given time is assumed to emanate from maximization of expected utility by the farmer from using the new technology in the face of constraints. The constraints can be availability of land and capital to acquire the technology. The farmer adopts the new technology if the expected utility gained from the new technology exceeds the expected utility gained from using the traditional technology (Feder et al. 1985; Shiferaw et al. 2008; Waithaka et al. 2007).

Limited dependent variable methods are used to explain farmers' decision process regarding adoption of agricultural technologies. In these models, it is assumed that farmers face two alternatives. The alternatives are adopt or not adopt and the choice depends on specific characteristics (Feder et al. 1985). Logit and probit models and their modifications have been used extensively in the empirical study of adoption of technologies (Doss 2006; Feder et al. 1985; Ghadim & Pannell 1999; Spielman et al. 2011). However, it is important to see the intensity of adoption too because looking at whether households use or do not use a technology may not be sufficient as the ultimate outcome depends not only on the use but also on the intensity of use of the technology (Marenya & Barrett 2007; Shiferaw et al. 2009; Waithaka

[3] *tsmidi* is an area of land which is equivalent to a quarter of a hectare.

et al. 2007). Tobit models have been used widely to explain the decision regarding whether to adopt a technology together with the intensity of use. Tobit models assume that both decisions are made jointly and hence the same set of factors explain both decisions.

Data and Descriptive Statistics

Data

Data for this study is collected from 12 *woredas* in the highlands of Tigray region, northern Ethiopia. This data set comprises a panel data of six rounds starting from 1998 and extending to 2015. This study employs the last three rounds; namely, the survey rounds in 2006, 2010 and 2015. We have 339 households in 2006, 440 households in 2010 and 631 households in 2015. The number of surveyed households had been increasing due to inclusion of more *tabias*. One *tabia* was added in 2010 while in 2015 two more *tabias* were added.

Stratified random sampling was used to ensure large variation in population density, market access, agro-climatic conditions and access to irrigation in the region (Debela & Holden 2014). Each survey round was carried out in the months June-September. Therefore, there will not be any bias due to seasonality. A questionnaire with predominantly the same structure and questions was used in all the rounds, which enables to avoid bias due to lack of comparability of survey instruments. The households were asked about household characteristics, asset ownerships, including land ownerships. A community level questionnaire too was used to capture village level information such as demographics, agricultural production structure, infrastructure, institutions (such as PSNP access) and land related issues.

Descriptive Statistics

A look at the overall level of fertilizer adoption in the sample area during the period of study shows that there has been a steady growth in the rate of adoption. In 2006, the rate of adoption was 52.8% and this grew to almost 80% by 2015. This could indicate that the massive campaign by the government to expand adoption of fertilizer as espoused by the agricultural growth strategy of the country is making a headway.

Table 1 Rate of fertilizer adoption during the panel survey years

Year	Non Adopters	%	Adopters	%	Total
2006	160	47.2	179	52.8	339
2010	149	33.86	291	66.14	440
2015	128	20.29	503	79.71	631

Source: (Mekelle University and NMBU survey)

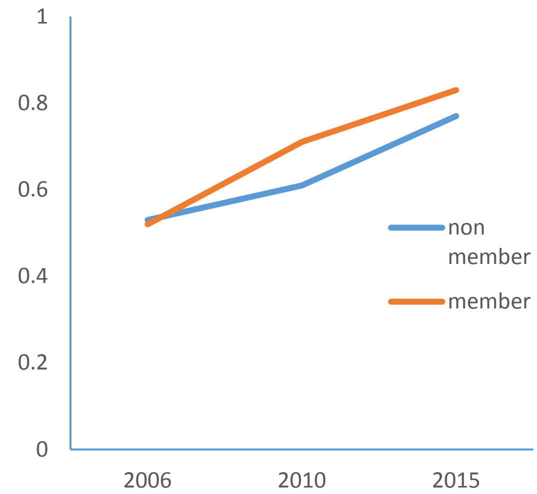
When we assess the intensity of fertilizer adoption across the survey years (table 2 below,) we see that it has been increasing through the survey years

Table 2 Amount of fertilizer used (kgs per Farm household)

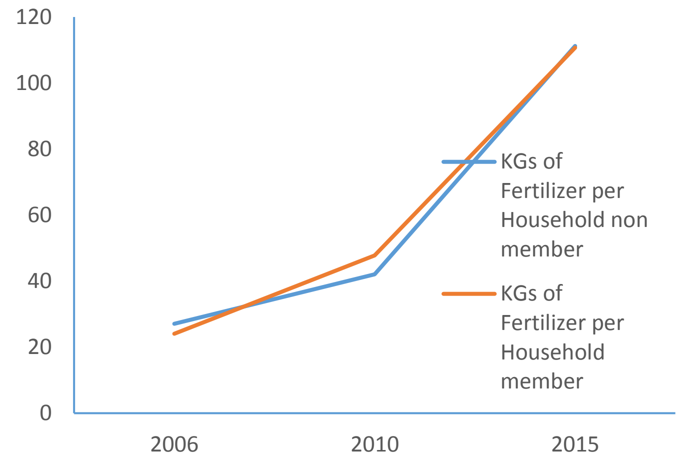
Year	Unbalanced panel			Balanced panel		
	Obs.	**Mean**	**S.D.**	**Obs.**	**Mean**	**S.D**
2006	339	25.76	39.77	280	24.55	35.36
2010	440	44.83	57.53	280	44.71	52.73
2015	631	110.98	111.75	280	128.57	121.2

Source: (Mekelle University and NMBU survey)

When we compare the two groups in terms of adoption and intensity of fertilizer use through the survey years (see table 3 below), it appears that fertilizer adoption was the same between the two groups in 2006, just one year since the start of the PSNP program. During the two ensuing survey rounds, however, it looks that members had started to adopt fertilizer more than their non-member counterparts (figure 1a below makes the comparison clearer).



a) Rate of Adoption



b) intensity of Adoption

Figure 1 Comparison of Fertilizer Adoption Rate by Membership status to the PSNP

The situation regarding intensity of use of fertilizer, as measured by the amount of fertilizer used per household, looks to show that the two groups do not have a statistically significant difference (figure 1 b above gives a more vivid illustration). Therefore, PSNP membership appears to influence only the decision of a household whether to use fertilizer or not.

Table 3 Mean Difference test of Fertilizer adoption and Intensity by public works membership status

Indicator of adoption	2006			2010			2015		
	Non-member	Member	t-value	Non-member	Member	t-value	Non-member	Member	t-value
Fertilizer adoption	0.53	0.52	0.24	0.61	0.71	-2.32**	0.77	0.83	-2.04**
Fertilizer kgs/HH)	27.08	24.06	0.63	42.06	47.83	-1.05	111.23	110.71	0.06
Fertilizer kgs/hec.	40.35	83.90	-1.87*	43.0	55.73	-2.18**	60.72	48.81	1.15
Observations	**174**	**165**		**229**	**211**		**334**	**297**	

Source: (Mekelle University and NMBU survey)
**significant at 1%, ** significant at 5%*

A comparison of adopters and non-adopters of fertilizer based on the control variables across the three survey years is shown in table 2 below. We see that in 2006, adopters had more livestock, lower land quality and more plots with irrigation. In 2010, adopters have more literate household heads, a larger household size, and more male adult members in the household and better quality plots. When it comes to 2015, the two groups are almost the same in relation to the control variables except that adopters look to have larger livestock units.

Table 4 ***Comparison of mean variables between adopters and non-adopters of fertilizer in 2006***

	Year 2006		
Variable	Non-adopters(N=184)	Adopters (N=155)	t-value
HH head education (literate=1)	0.32	0.35	-0.64
Household size	5.52	5.35	0.66
Total livestock units	1.73	2.16	**-1.99**
Total area of land owned	4.59	4.06	1.37
Male adult members	1.27	1.36	-0.76
Perception on Land quality	1.9	1.77	**2.09**
HH has irrigated plots	0.054	0.15	**-3.1**
Distance to road	67.26	81.92	**-2.02**
Distance to woreda center	188.29	159.36	**2.59**
	Year 2010		
Variable	**Non-adopters (N=176)**	**Adopters(N=264)**	**t-value**
HH head education (literate=1)	0.17	0.31	**-3.41**
Household size	4.72	5.48	**-3.49**
Total livestock units the HH owns	2.4	2.7	-1.52
Total area of land the HH owns	4.91	4.27	1.83
Male adult members	1.16	1.44	**-2.69**
Perception on Land quality	1.78	1.9	**-2.22**
HH has irrigated plots	0.19	0.37	**-4.2**
Distance to road	48.66	50.78	-0.46
Distance to woreda center	183.96	160.82	**2.55**
	Year 2015		
Variable	**Non-adopters (N=158)**	**Adopters (N=473)**	**t-value**
HH head education (literate=1)	0.32	0.3	0.33
House hold size	4.62	4.98	-1.58
Total livestock units the HH owns	2.3	2.93	**-2.54**

Total area of land the HH owns	4.87	4.5	0.98
Male adult members	1.22	1.3	-0.88
Perception on Land quality	1.89	1.99	-1.87
HH has irrigated plots	0.32	0.34	-0.55
Distance to nearest road	27.24	29.51	-0.72
Distance to woreda center	176.64	165.67	1.3

Empirical Approach

The literature on farmers' adoption decision regarding improved agricultural technology shows that various household level, farm level, village level and institutional as well as infrastructural factors determine the level of technology adoption (Bezu et al. 2014; Feder et al. 1985). The household features include factors such as the human capital of the household and risk preferences (Bezu et al. 2014; Holden & Westberg 2016) while in the farm level characteristics farm size receives the prime focus(Feder et al. 1985). The institutional features include factors such as access to credit and information, access to functioning input and output markets (especially whether there are markets for complimentary inputs) and tenure arrangements (Bezu et al. 2014; Feder et al. 1985; Waithaka et al. 2007). Access to appropriate transport facility is the top infrastructural factor that determines the rate of adoption of modern agricultural technologies(Feder et al. 1985). In addition to these factors, since fertilizer is believed to be a high yielding but risky input, the amount and the variability of rainfall are also included in fertilizer adoption studies as a proxy for external risk that the households face in relation to weather variability (Alem et al. 2010; Bezu et al. 2014; Holden & Westberg 2016).

Therefore, the model we want to estimate can be stated as follows. Suppose $\mathbf{F_{it}}$ stands for the amount of fertilizer (in kilograms) that a farm household used in a specific year t.

$$\boldsymbol{F_{it}} = f(\boldsymbol{K_{it}}, \boldsymbol{H_{it}}, \boldsymbol{A_{it}}, \boldsymbol{V_{it}}, \boldsymbol{M_{it}}) \qquad (7)$$

Where ***K*** refers to the labour and physical endowment of the household. In this category we take whether the household head is literate or not, total number of adult members in the household and area of land that the household owns. ***H*** refers to a vector of household level features. In this category, we take sex of the household head, age of the household head and household size. ***A*** refers to a vector of agro-ecological factors. In this category, we include the mean of rainfall in the current main rainy season (June-September) and mean rainfall of the previous two years main rainy season. In addition to these, we also include the standard deviations of the rainfall in the previous two years. Also included is farmers' perception on the quality of the plots they operate. ***V*** refers to proxy variables for infrastructure, market access and agricultural development support services such as microcredit and improved input supply. In this category, we include distance in walking minutes from the household's residence to the nearest road (as a proxy for transport infrastructure) and distance in walking minutes from the household's residence to the woreda center (as a proxy for market access and development support services) and whether the household has a plot with access to irrigation. ***M*** is the treatment variable and refers to whether the household is a member of the public works component of PSNP or not.

As shown in section 2, the observed amount of fertilizer used is a result of a latent relationship between the set of factors, which explain the utility comparison of the farmer between use of fertilizer and not using it. We assume that this equation (the latent) is linear and specify it as follows.

$$M_{it}^{*} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 K_{it}} + \boldsymbol{\beta_2 H_{it}} + \boldsymbol{\beta_3 A_{it}} + \boldsymbol{\beta_4 V_{it}} + \boldsymbol{\delta M_{it}} + \boldsymbol{c_i} + \boldsymbol{\varepsilon_{it}} \qquad (8)$$

We expect that the human and physical capital of the household (***K***) will affect fertilizer adoption positively. We expect that households with more adult members will be less constrained in using fertilizer while literate household heads are expected to have higher adoption of fertilizer as they can more easily become exposed to knowledge about fertilizer than their illiterate counterparts (Knight et al. 2003). Regarding the size of land the household owns, it is argued that it is positively related to adoption of fertilizer while the intensity of use is supposed to decrease with an increase in land size(Feder et al. 1985). Concerning the household features, we expect that female-headed households will be less adopters than male-headed households. The effect of household size on fertilizer adoption may not be known a priori. On the one hand, larger household size may encourage more use of fertilizer with a view to produce more and feed the household members. On the other hand, a larger household size may require use of available endowment for consumption so much so that the household becomes unable to buy fertilizer. This holds more strongly when access to credit is limited which is quite prevalent in developing countries(Sadoulet & De Janvry 1995). In the agro-climatic conditions category, we have include rainfall and its variability and we expect that while rainfall will affect adoption positively, its variability will affect adoption negatively. Concerning plot characteristics, we have included whether the household has a plot with access to irrigation and perception of the household head on the fertility of his/her operated plots. We expect that households who have plots with irrigation access will be more likely to adopt fertilizer and farmers with relatively less fertile plots will be more likely to adopt fertilizer. The term $\boldsymbol{c_i}$ is included to represent household level unobserved effects that are time invariant. The term $\boldsymbol{\varepsilon_{it}}$ is a zero mean identically and independently distributed error term, which is assumed uncorrelated with the other explanatory variables.

Membership in the PSNP is a result of a government plan to include poor farmers in to the program, which is based on identification of food insecure districts throughout the country and eligible households at the tabia level based on household wellbeing indicators. Specifically, districts are selected in to the program based on their status of food insecurity as indicated by whether the district had been receiving food aid for consecutive three years before the start of the PSNP in 2005. This makes the PSNP membership non-random. Therefore, the PSNP membership status variable in the model above can be correlated to the error term. Thus, we need to control for possible endogeneity of membership to the PSNP. To do this, we use the Smith and Blundell (1986) control function approach for controlling endogeneity in corner solution models. In this approach, we use the residual from a reduced form membership to PSNP equation as an additional regressor in the structural (fertilizer adoption) model. Thus, we estimate the PSNP membership (M_{it}) as a function of a set of variables which explain the fertilizer adoption decisionX_{it} and an instrument variable Z_{it} in the following form

$$M_{it} = B_i X_{it} + \gamma_i Z_{it} + V_{it} \tag{9}$$

The instrument variable we use is a dummy variable which indicates whether the household had been exposed to shortage of rainfall for three consecutive years before the start of the PSNP. Based on the rainfall data we have, first we computed the mean rainfall of all districts in our sample taking the main production season rainfall (June-September) for the three years before the start of the PSNP; i.e, for 2002, 2003 and 2004. Then we generated a dummy variable which takes 1 when the household is found to reside in an area which received less than this mean rain fall and zero otherwise. We argue that households in areas that received below the mean rainfall for the three consecutive years before 2005 are more likely to be exposed to persistent shortage of rainfall and hence are more likely to have been receiving food aid in those years. Since a household was selected to the PSNP based on whether that household had been receiving food aid in the prior three consecutive years, we expect that this dummy variable will perform well in capturing this situation. Our CRE probit regression of PSNP membership on a set of determining factors and this instrument variable shows that this variable is significant at 10% level of significance (see table 6 below).

Another problem we need to worry about in our model is the issue of unobserved individual heterogeneity both in the adoption and intensity regressions. In regressions using panel data, fixed effect panel data models have been the way to control for unobserved heterogeneity. In the case of none linear models, however, it is not possible to use fixed effects for the reason of incidental variable problem. We, therefore, use the correlated random effects model of Mundlack (1978) and Chamberlain (1984) as cited in (Bezu et al. 2014). This procedure adds the mean of time varying variables ($\bar{X}_t$) as additional regressors in the model. The included mean variables will control for time invariant unobserved heterogeneity (Wooldridge 2010)

After regression of the PSNP membership regression, we then proceed to the estimation of the fertilizer adoption probit and the intensity of fertilizer adoption tobit regressions (see table 7) using again the CRE framework to control for the effect of unobserved individual heterogeneity. In this regression, we include the residual from the membership to PSNP regression as an additional regressor to control for selection bias due to non-random PSNP membership as outlined above in the discussion of the control function approach. The regression result shows that this residual is significant at 1% indicating that selection issues regarding membership would have resulted in a bias in the adoption regression and hence using the control function approach is correct.

We should also deal with the issue of attrition as we are using an unbalanced panel data of three rounds. To handle this, we take the inverse Mill's ratio from a regression of the attrition dummy on variables, which we argue will affect attrition. In order to do this we do a probit regression of the attrition dummy which equals 1 for those households that were not surveyed in either of 2006, 2010 or 2015. We do such an attrition probit regression for attrition in each of the survey rounds taking the survey in 2003 as the basis for attrition in 2006, the survey in 2006 for attrition in 2010 and the survey in 2010 for attrition in 2015 (see annex C). We follow this procedure as there has been not only sample attrition but also additions to the sample in each of the ensuing surveys since the starting survey in 1998. Based on these regressions, we predicted the inverse Mills ratio for each of the survey rounds we used for this study (2006, 2010 and 2015). We then include the inverse Mill's ratio (attrition lambda) as an additional regressor in the model for fertilizer adoption to check, and at the same time control for, attrition bias problem. A significant coefficient of the attrition lambda, which is the result we obtained here, in the outcome model shows that attrition bias could have been a problem and including it as a regressor controls for that bias.

Results and Discussion

Before we go to the fertilizer adoption regression we first assess the situation regarding factors which influence membership to the public works component of the PSNP. With this purpose in mind, we run a CRE probit regression of membership on a set of variables that are supposed to influence membership (see table 5).

The result we obtain shows that households with older heads are less likely to be included in the PSNP program. This is a likely outcomes since households with older heads could be more likely to accumulate more wealth and hence be excluded from the program which targets poor households. In the case of very old and poor household heads, they could be more likely to join the direct support program. We also found out that households with female heads are less likely to be included in the public works program. This could be likely for such households could be labour deprived and hence qualify to the direct support program instead of the public works program which is labour intensive. Livestock ownership is found to have a negative and significant coefficient in this regression. This is more plausible as livestock ownership indicates the level of wealth that the household possesses and might have been used as an indicator to exclude households from membership in to the PSNP (Discussions with tabia level implementers confirm that livestock ownership, especially ownership of oxen, was used as an important indicator of wealth of households during the selection process).

One of the reasons to fit this membership regression was to see whether the instrument variable we selected for this study is significant or not. We found out that this variable (a three years consecutive shortage of main season rains before the start of the PSNP) is found to be statistically significant (at 10% level of significance).

Table 5 CRE Probit regression of Membership to the Public Works component of the PSNP [a]

VARIABLES	Membership to PW
Instrument variable (Dummy=1= there was rain shortage in the three consecutive years before start of PSNP)	0.193*
	(0.105)
Age of household head	-0.007*
	(0.004)
Sex of household head	-0.293*
	(0.152)
Whether HH head is literate (1= literate)	-0.010
	(0.032)
Household size	0.005
	(0.031)
Number of adult members in the HH	0.012
	(0.050)
Total livestock units the HH owns	-0.064***
	(0.018)
Total land area the HH owns	0.009
	(0.012)
Land quality (1= fertile)	0.073
	(0.088)
Access to irrigation (1= HH has access)	-0.028
	(0.096)
Distance from HH residence to wereda centre in walking minutes	0.001
	(0.001)
Distance from HH residence to road in walking minutes	0.001
	(0.001)
Constant	-0.002
	(0.006)
lnsig2u	0.285
	(0.203)
Observations	0.022
Number of hhid	(0.059)

Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

[a] We have included time mean of all variables and have controlled for location (woredas), but they are not reported here to save space

When we come to the fertilizer adoption regression we have two of them. The first, which is a probit regression, is carried out to see the impact of public works membership on the fertilizer adoption decision while the second, which is a tobit regression was carried out to see the impact of membership in public works on the amount of fertilizer (in KGs) that the household makes use of in the main production season of the year. In fitting these regressions, we included the residual from the public works membership regression to control for membership bias and the inverse Mill's ratio to control for sample attrition bias as discussed in the empirical strategy section. We found out that the coefficient of the residual from the membership regression is statistically which shows that our use of the control function approach was correct. We also found out that the coefficient of the IMR from the attrition probit regressions is statistically significant which shows that there could have been a sample attrition bias in our outcome regressions and controlling for it in this way was necessary (see table 6 below).

Table 6 CRE probit and tobit regressions of Impact of PSNP on Fertilizer Adoption and Intensity of use [b]

VARIABLES	Probability of Adoption	KGs of fertilizer per Farm HH
Public works membership	0.194**	9.150
	(0.095)	(6.056)
Lambda(attrition IMR)	-0.259**	-19.382**
	(0.130)	(8.110)
Residual PW	3.769***	351.524***
	(0.708)	(47.857)
Age of HH head	0.034***	2.896***
	(0.007)	(0.479)
Sex of HH head(1= female)	1.143***	89.942***
	(0.264)	(17.279)
Whether HH head is literate (1= literate)	0.067	6.328**
	(0.054)	(2.704)
Household size	-0.028	-6.843***
	(0.037)	(2.641)
Number of adult members in the HH	0.018	3.542
	(0.061)	(4.006)
Livestock units the HH owns	0.253***	20.408***
	(0.053)	(3.309)
Total land area in Tsmdi the HH owns	-0.016	0.220
	(0.021)	(1.464)
Distance to woreda centre in walking minutes	-0.007***	-0.485***

	(0.001)	(0.071)
Distance to road in walking minutes	-0.003**	-0.506***
	(0.001)	(0.074)
Land quality	-0.106	-19.343**
	(0.120)	(8.362)
Access to irrigation	0.544***	23.788***
	(0.114)	(7.451)
Mean rainfall in the previous year main rainy season	0.028***	2.810***
	(0.008)	(0.413)
Previous two years main rainy season mean rainfall	0.013	-0.497
	(0.010)	(0.493)
Standard deviation of previous two years' rainfall	0.007	0.174
	(0.010)	(0.683)
Constant	0.000	0.355
	(0.007)	(0.465)
lnsig2u	-1.416***	
	(0.304)	
sigma_u		30.003***
		(6.009)
sigma_e		96.225***
		(4.791)
Observations	1,352	1,352
Number of hhid	657	657

Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1 (the standard errors for the tobit are bootstrapped)

[b] We have included time mean of all variables and have controlled for location (woredas), but they are not reported here to save space

The result in the above regressions show that coefficient on membership in to the public works component of the PSNP is positive and statistically significant (at 5% level) in the of fertilizer adoption decision while it is positive but not significant in the amount of fertilizer used regression. This shows that membership in the public works component of the PSNP appears to affect only the decision regarding whether to use fertilizer or not instead of the amount of fertilizer that the household makes use of in a production season. This result is palatable as member households are likely to be more exposed to knowledge regarding new technologies (due to their frequent interaction with woreda and tabia level implementers of the program) which influences farmers' decision regarding whether to use fertilizer. The amount of fertilizer to be used, however, depends mostly on the scientific requirement of the inputs per a unit of land and hence may not be directly affected by membership in the PSNP.

When we see factors which correlate with the probability of fertilizer adoption and the amount of it a household uses, from the category of household features, age of household head is found to be positively significantly correlated with adoption of fertilizer and the amount of it that the household uses. This result may indicate that with an increase in age of the household head, the household could be more likely to have learned from others regarding benefits of using fertilizer and might have also acquired the capacity to buy fertilizer overtime which enable the household to do so. Sex of the household head being female is also found to be positively and significantly correlated with both the Probability fertilizer adoption and the amount of it used. Prima facie this result could be less palatable. However, this result could be likely as such households often do not have other options and may tend to make an intensive use of the land that they have to maximize gains. This could push then in to making use of fertilizer. We also found out that household size does not affect the adoption decision but is negatively significantly correlated to the amount of fertilizer use. This may show that consumption needs of a larger household size tend to compete with investment on fertilizer. Whether the household head is literate is also found to affect positively only the amount of fertilizer to be used.

From the category of household level endowment variables, livestock ownership is found to be positively significantly correlated with both the probability of fertilizer adoption and the amount of it used. This result is likely as households who own more livestock could be wealthy households who will be more capable to pay for fertilizer. We also found that the quality of land that the household owns is negatively significantly correlated only with the amount of fertilizer the household uses. This is plausible as more fertile land may require less use of fertilizer.

From the infrastructure and institutional variables, distance to the woreda center and distance to road are found out to be negatively significantly correlated with adoption of fertilizer and amount of it used, while access to irrigation is found to be positively significantly correlated. This result is likely as households who live far from the woreda center will be less exposed to the fertilizer promotion campaign of officials and agricultural experts, while households who are far from roads will find it difficult to transport fertilizer. Access to irrigation has a positive effect on fertilizer adoption and use since one of the most important requirements for effective use of modern fertilizers is availability of water.

We also found out that the amount of rainfall during the main rainy season of the previous year is positively significantly correlated to the probability of fertilizer adoption and the amount of fertilizer used in the current production season. This may indicate that farmers' expectation is adaptive and hence a good rain in the previous year gives rise to an expectation of similar situation in the next production season and hence they tend to make more use of fertilizer in the current production season. It can also be argued that a good rain in the previous year might have ended up in good yield which could enhance farmers' ability to buy fertilizer. We included previous two years mean rain fall and standard deviation of it as well to see how trend and variation in rainfall over a relatively longer time span could affect adoption and use of fertilizer. We found out that both are not correlated with fertilizer adoption and amount of use. The purpose of including these variables was to see how farmers respond to external shocks in the form of variation in rainfall which increases the riskiness of fertilizer adoption. Our finding appears to show that long term rainfall variation is not important to farmers at least in relation to their decision regarding fertilizer adoption and amount of it that they use.

Conclusion

Ethiopia has been struggling to improve agricultural productivity and food security. Provision of improved farm inputs such as modern fertilizer and improved seeds and training farmers on better farming practices have been carried out with a view to increase agricultural productivity of small holder farmers, which predominate the agriculture sector in the country. The productive safety net program on its part was designed with the aim of enabling poor households achieve food security by way of getting payments for works that help in community and household asset building.

There could be plenty of ways that the PSNP and the programs which aim at enhancing agricultural productivity in the country could interact among each other. One thing that the PSNP could have an influence over can be the issue of technology adoption and use.

This paper set out to explore whether members of the public works component of the PSNP are more likely to adopt and make use of modern fertilizers than their non-member counterparts using a panel data of three rounds. We found that households that are members in the public works component of the PSNP are more adopters of fertilizer compared to their non-member counterparts, but they do no differ in terms of the amount of fertilizer that they use. This result may indicate that the PSNP is having a far reaching and positive impact beyond the immediate objectives of it by encouraging households to invest in modern technologies which will lead to a sustainable enhancement of the food security situation of rural small holder farm households in Ethiopia.

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Annex

A. *Table 7* ***CRE Probit Regression of Membership to the Public Works Component of the PSNP***

VARIABLES	pw
Instrument variable (Dummy=1= there was rain shortage in the three consecutive years before start of PSNP)	0.193*
	(0.105)
Age of household head	-0.007*
	(0.004)
Sex of household head	-0.293*
	(0.152)
Whether HH head is literate (1= literate)	-0.010
	(0.032)
Household size	0.005
	(0.031)
Number of adult members in the HH	0.012
	(0.050)
Total livestock units the HH owns	-0.064***
	(0.018)
Total land area the HH owns	0.009
	(0.012)
Land quality (1= fertile)	0.073
	(0.088)
Access to irrigation (1= HH has access)	-0.028
	(0.096)
Distance from HH residence to wereda centre in walking minutes	0.001
	(0.001)
Distance from HH residence to road in walking minutes	0.001
	(0.001)
Mean of Age of household head	-0.002
	(0.006)
Mean of Sex of household head	0.285
	(0.203)
Mean of Whether HH head is literate (1= literate)	0.022
	(0.059)
Mean of Household size	0.103**
	(0.050)
Mean of Number of adult members in the HH	-0.047
	(0.081)
Mean of Total livestock units the HH owns	-0.001
	(0.001)
Mean of Total land area the HH owns	0.000
	(0.002)
Mean of Land quality (1= fertile)	0.065
	(0.147)
_Iwereda_3	0.561***
	(0.189)
_Iwereda_4	-0.165
	(0.182)
_Iwereda_5	-0.167

	(0.216)
_Iwereda_6	0.234
	(0.214)
_Iwereda_7	0.153
	(0.243)
_Iwereda_8	0.301*
	(0.178)
_Iwereda_9	0.759***
	(0.254)
_Iwereda_10	-0.445**
	(0.206)
_Iwereda_11	-0.567***
	(0.183)
_Iwereda_12	-0.396***
	(0.151)
Constant	-0.233
	(0.521)
lnsig2u	-1.194***
	(0.319)
Observations	1,352
Number of Household	657

Standard errors in parentheses

B. *Table 8 CRE Probit and Tobit Regressions of Fertilizer Adoption and Intensity of Use*

VARIABLES	Fertilizer Adoption	Fertilizer per farm household (in KGS
Public works membership	0.194**	9.150
	(0.095)	(6.056)
Lambda(attrition IMR)	-0.259**	-19.382**
	(0.130)	(8.110)
Residual PW l	3.769***	351.524***
	(0.708)	(47.857)
Age of HH head	0.034***	2.896***
	(0.007)	(0.479)
Sex of HH head(1= female)	1.143***	89.942***
	(0.264)	(17.279)
Whether HH head is literate (1= literate)	0.067	6.328**
	(0.054)	(2.704)
Household size	-0.028	-6.843***
	(0.037)	(2.641)
Number of adult members in the HH	0.018	3.542
	(0.061)	(4.006)
Livestock units the HH owns	0.253***	20.408***
	(0.053)	(3.309)
Total land area in Tsmdi the HH owns	-0.016	0.220
	(0.021)	(1.464)
Distance to woreda centre in walking	-0.007***	-0.485***

minutes		
	(0.001)	(0.071)
Distance to road in walking minutes	-0.003**	-0.506***
	(0.001)	(0.074)
Land quality	-0.106	-19.343**
	(0.120)	(8.362)
Access to irrigation	0.544***	23.788***
	(0.114)	(7.451)
Mean rainfall in the previous year main rainy season	0.028***	2.810***
	(0.008)	(0.413)
Previous two years main rainy season mean rainfall	0.013	-0.497
	(0.010)	(0.493)
Standard deviation of previous two years' rainfall	0.007	0.174
	(0.010)	(0.683)
Mean of HH head age	0.000	0.355
	(0.007)	(0.465)
Mean of HH head sex	-1.416***	-109.516***
	(0.304)	(19.987)
Mean of HH education	-0.030	-12.408***
	(0.084)	(4.658)
Mean of HH size	-0.360***	-33.573***
	(0.095)	(5.877)
Mean of number of adult members in the HH	0.088	11.027**
	(0.096)	(5.586)
Mean of Total livestock units	0.105***	15.373***
	(0.039)	(2.741)
Mean of land area the HH owns	-0.014	-3.053
	(0.026)	(1.943)
Mean of distance to woreda center	0.005***	0.458***
	(0.001)	(0.103)
Mean of distance to road	-0.003	-0.121
	(0.002)	(0.117)
Mean of land quality	-0.540***	-32.983***
	(0.168)	(11.578)
Mean of main rainy season rainfall	-0.002	-2.301**
	(0.022)	(1.020)
Mean of previous two years main rainy season rainfall	0.037	3.889***
	(0.024)	(1.239)
Mean of Standard deviation of previous two years main rainy season rainfall	-0.025	-0.174
	(0.025)	(1.485)
3.wereda	-3.077***	-272.272***
	(0.521)	(31.034)
4.wereda	-0.025	32.338
	(0.332)	(22.199)
5.wereda	-0.292	-17.860
	(0.293)	(21.038)
6.wereda	-0.618*	-105.414***

	(0.355)	(20.759)
7.wereda	-0.449	-83.451***
	(0.378)	(22.991)
8.wereda	-1.327***	-140.455***
	(0.358)	(21.630)
9.wereda	-2.554***	-298.306***
	(0.644)	(38.160)
10.wereda	1.453***	93.125***
	(0.448)	(28.368)
11.wereda	1.027	93.697**
	(0.751)	(46.670)
12.wereda	0.085	45.275
	(0.408)	(29.157)
Constant	-1.193	-11.655
	(0.801)	(51.018)
lnsig2u	-2.113**	
	(0.833)	
Sigma u		30.003***
		(6.009)
Sigma e		96.225***
		(4.791)
Observations	1,352	1,352
Number of Households	657	657

Standard errors in parentheses (the tobit model standard errors are bootstrapped)
*** p<0.01, ** p<0.05, * p<0.1

C. Table 9 Probit Regression of Attrition (Attrition =1 for non-stayers)

VARIABLES	Attrition in 2006	Attrition in 2010	Attrition in 2015
Age of HH head	0.044	0.212	-0.222
	(0.239)	(0.208)	(0.207)
Sex of HH head(1= female)	-0.015**	0.011*	0.009
	(0.007)	(0.006)	(0.007)
Whether HH head is literate (1= literate)	-0.092	0.008	0.014
	(0.102)	(0.046)	(0.078)
Household size	-0.007	-0.010	-0.006
	(0.046)	(0.035)	(0.042)
Livestock units the HH owns	0.019	0.004	-0.029
	(0.039)	(0.044)	(0.042)
Total land area in Tsmdi the HH owns	-0.065*	-0.048	0.027
	(0.034)	(0.029)	(0.033)
Distance to woreda centre in walking minutes	-0.008***	0.001	-0.003
	(0.002)	(0.002)	(0.002)
Distance to road in walking minutes	0.002	0.000	0.001

	(0.001)	(0.001)	(0.001)
3.wereda	0.084	-0.240	-1.227***
	(0.468)	(0.311)	(0.263)
4.wereda	0.252	-0.689**	-1.838***
	(0.416)	(0.343)	(0.346)
5.wereda	0.051	-0.358	-1.522***
	(0.462)	(0.339)	(0.359)
6.wereda	-0.100	-1.639***	-1.353***
	(0.505)	(0.520)	(0.329)
7.wereda	0.393	-0.461	-0.859**
	(0.482)	(0.419)	(0.395)
8.wereda	-1.033*	-1.036***	-1.056***
	(0.579)	(0.344)	(0.272)
9.wereda	-0.831	-1.360**	-1.998***
	(0.606)	(0.553)	(0.472)
10.wereda	0.942**	-0.630*	-1.619***
	(0.439)	(0.380)	(0.364)
11.wereda	0.081	-0.783**	-1.009***
	(0.436)	(0.323)	(0.268)
Constant	0.117	-1.079*	0.052
	(0.778)	(0.601)	(0.690)
Observations	300	334	385

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1