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Impact of Ethiopia's productive safety net program on manure use by rural households: Evidence from Tigrai, Northern Ethiopia

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Data Appendix Available Online
A data appendix to replicate the main results is available in the online version of this article. Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

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Abstract

Although development intervention programs can have far-reaching impacts beyond their stated objective, there have been few careful studies on associated but unintended outcomes of such programs. This study assesses the impact of membership in the public works component of Ethiopia's productive safety net program (PSNP) on whether households use manure and the amount of it they use. This is done using the double-hurdle method based on survey data of 2015 on 11 agro-climatically diverse districts of the Tigrai region in Northern Ethiopia. Results show that PSNP member households are not different from their nonmember counterparts in terms of manure use. This may indicate that PSNP is helping member households catch up with nonmember households in terms of manure use, even though they have smaller livestock ownership. This might indicate that PSNP member households are becoming more aware of the benefits of using manure, and hence are using available manure more efficiently. Therefore, this could be taken as one additional positive contribution of the PSNP in Ethiopia's endeavor to improve food security of poor rural farm households by increasing their productivity.

KEYWORDS
impact, instrumental variable, manure, productive safety net program

JEL CLASSIFICATION
I38, Q12, Q240

1 | INTRODUCTION

Ethiopia has been at the forefront of aid-receiving countries due to its inability to ensure its food security due to recurring droughts and various other shocks (Abdulai, Barrett, & Hoddinott, 2005; Little, 2008). Aid had been provided in the form of relief to affected sections of the society for quite a long time. Since the early 1960s, however, efforts had been exerted to link aid with the rehabilitation of natural resources by means of the food for work (FFW) program (Gebremedhin & Swinton, 2001, 2003; MoARD, 2015).[1] Initially, the Ethiopian government mobilized national-level

[1] MoARD = Ministry of Agriculture and Rural Development (of Ethiopia).

soil and forest conservation projects based on the FFW program. Later, the FFW program expanded more, and in the late 1980s, several NGOs joined the work in addition to the government (Gebremedhin & Swinton, 2001). The most prevalent projects of the FFW program included road building, soil conservation measures, and small-scale irrigation (Holden, Barrett, & Hagos, 2006). The problem with most of the FFW programs before the productive safety net program (PSNP) was that they were not predictable because they had been reactions to droughts or had primarily conservation goals. In drafting the PSNP, the government of Ethiopia and collaborative donors aimed at achieving food security of rural households through asset building (MoARD, 2010). This program is fundamentally different from its predecessor FFW programs on one aspect. That difference is its predictability because it provides a continuous access to FFW/cash for work (and free food access to the labor-deprived sections of the society) for a period of five years (Gilligan, Hoddinott, & Taffesse, 2009). This program is extended and still underway after evaluation of the first and second phases of the program (MoARD, 2015). As stipulated in the start of the program, households were expected to graduate at the conclusion of the second phase of the program. The data used in this study show that 52 households have graduated from the 630 households in the sample. Because 297 households of the sample are still in the PSNP, the graduation rate based on this sample is around 15%.

There are studies on the potential impact of the PSNP on household food security, consumption, and poverty (Berhane, Gilligan, Hoddinott, Kumar, & Taffesse, 2014; Bishop & Hilhorst, 2010; Debela & Holden, 2014; Gilligan et al., 2009; Holden et al., 2006; Nega et al., 2010). Other studies assessed impact on access to credit, modern farming techniques, nonfarm business activities, asset accumulation, and economic growth (Alderman & Yemtsov, 2013; Andersson, Mekonnen, & Stage, 2011; Debela, Shively, & Holden, 2015; Gilligan et al., 2009; Sabates-Wheeler & Devereux, 2013). There are also studies on the impact of the PSNP on technology adoption and land-related investment by farmers (Adimassu & Kessler, 2015; Alem & Broussard, 2018; Hoddinott, Berhane, Gilligan, Kumar, & Taffesse, 2012), whereas other studies have tried to look at the issue of graduation from the PSNP (Arega, 2012; Sabates-Wheeler & Devereux, 2013). In the context of assessing the impact of a public intervention program on manure use, Holden and Lunduka (2012) studied whether Malawi's input subsidy program crowds out or crowds in manure use by rural farmers. They found out that it had limited effect on the use of organic manure by farmers. The input subsidy program aims at insuring food security in Malawi by increasing maize productivity through the provision of subsidized fertilizer. This program is similar with Ethiopia's PSNP as it aims at insuring food security by enhancing productivity of farmers (Holden & Lunduka, 2013; Lunduka, Ricker-Gilbert, & Fisher, 2013) but differs in its modality of achieving that objective. To the best of my knowledge, there has not been any study on the impact of Ethiopia's PSNP on manure use.

This study is important at least for three reasons. First, this study is exploring whether the PSNP is making an impact on rural poor households in terms of use of manure, which is a traditionally available, but highly productivity-enhancing and environmentally friendly technology. In doing so, this study is pointing out an interesting interaction between public programs and sustainable productivity enhancement and useful environmental outcomes. Second, this study is done in the Tigrai region of Ethiopia, which is known for recurrence of droughts and low agricultural productivity. Therefore, if the PSNP is making a headway in making poor farm households use traditional and environmentally friendly productivity-enhancing technologies such as manure, it should give a lot of hope for a better future of poor farmers elsewhere in Ethiopia and outside. Finally, the study employs several estimation approaches including the instrumental variable method because there could be unobserved issues in the selection process of the PSNP. Therefore, findings of this study may be more reliable and as such could be used as a trustable evaluation of the program, at least in relation to the outcome explored here.

This study focuses on the public works component of the PSNP. Thus, when I say PSNP, I mean the public works component of the PSNP. Essentially, the public works component of the PSNP provides households with income for work they do on community-asset-building programs. Therefore, the program, on the one hand, might enable households to maintain/increase their assets by the income they receive from it and, on the other hand, it might compete for existing household labor. One can argue here that because participation is voluntary, households do not join the program unless they do not perceive a positive net gain. This argument is partly true, but households may weigh the short-term food security benefits more than the long-term benefits of investments, such as enhancing the productivity of their land using manure. This study, then, sets out to assess whether the labor requirement of public works exceeds the investment outcomes of it or vice versa using manure collection and use as a specific productive investment by rural farmers in Tigrai. Such a study is important, as it will help to see if the program is helping households build capacity for sustainable productivity enhancement that ensures their long-term food security. The question here is that does this program internalize negative externalities or create growth multipliers that imply net positive returns to the program beyond the food security effect?

2 | OBJECTIVES AND ADMINISTRATIVE ORGANIZATION OF PSNP

The PSNP is a major component of the Ethiopia's food security program (Lavers, 2013). According to (MoARD, 2010, p. 5), PSNP aims "to assure food consumption and prevent asset depletion for food insecure households in chronically food insecure *woredas*[2] (districts) while stimulating markets, improving access to services and natural resources, and rehabilitating and enhancing the natural environment." This program was officially launched in 2005, although the consultation with development partners started in 2003 (MoARD, 2015).

The program mobilizes targeted households and provides them with food/cash to be engaged in public works such as soil and water conservation on hill slopes and small-scale infrastructure development. Cash/food is paid for up to five days of work in a month per a household member for six months per year. This continues until the recipient households graduate from the program. Graduation comes when the households are believed to have accumulated an asset and income level that enables them to meet 12 months of food needs and to withstand modest shocks (MoARD, 2015). The program has a direct support component for labor-deprived households. In this program, beneficiary households receive unconditional cash or food transfers (MoARD, 2015).

The program used a combination of geographic and administrative (community) targeting to select chronically food insecure households who live in chronically food insecure *woredas* (Berhane et al., 2014). Geographically, food insecure areas had been identified down to the *tabia*[3] level. When the program started in 2005, 190 *woredas* were selected based on their record of food aid that they received in the past (Berhane et al., 2014). Then *woreda* administrators determine the quota for each *tabia*. At the level of the *tabia*, a *tabia* committee selects beneficiaries, and this is reviewed at a general assembly of *tabia* dwellers. In order to handle complaints, appeal committees are available both at the *tabia* and *woreda* levels. Eligibility is based on a three-year continuous food gap of at least three months per a year. Dependence on food aid continuously for three years before the commencement of the PSNP served as a proxy indicator for this criterion (Gilligan et al., 2009). In addition to these, households who have suddenly become vulnerable due to a severe shock that made them lose their assets and be unable to support themselves and households who do not have family or any other form of support to sustain themselves are eligible (Sabates-Wheeler & Devereux, 2010). For selected households, all members qualify, but the adult members work for themselves and on behalf of members who cannot work, such as children.

[2] A *woreda* is a middle-level administrative unit, which is below the regional-level administration and above the tabia-level administration.

[3] A *tabia* (municipality) is the lowest administrative level in Tigrai, which is similar to *kebele* or peasant association in other parts of Ethiopia.

3 | MATERIALS AND METHODS

3.1 | Conceptual framework

A common approach in analyzing rural household decision-making is to use agricultural household models. In such models, households are both utility maximizing consumers and profit maximizing producers of agricultural goods, and they typically face imperfect markets. This framework guides the analysis in this study as the nonseparability of consumption and production decision is assumed. The rural household modeling framework as in De Janvry and Sadoulet (2006) is used to show PSNP membership and manure use are interconnected. The effect of PSNP membership on manure use cannot be known a priori, as there are two potentially opposing effects. On the one hand, PSNP membership might have enabled acquiring livestock. This increases the supply of manure and hence may lead to increased use of manure. On the other hand, membership in this program may compete for labor, which could have been used in other activities, manure being one of them. Moreover, membership may also provide means of consumption smoothing, which in turn might reduce the motive to work more on land–productivity-enhancing activities such as manuring. The question of which one happens on the ground should therefore be an empirical question. This study thus sets out to test the following two major hypotheses.

Hypothesis 1: Ceteris paribus, manure use of PSNP member households will be smaller than that of nonmember households due to its competing needs for labor, i.e., the substitution effect exceeds the income effect.

Hypothesis 2: Ceteris paribus, manure use of PSNP member households will be higher than that of nonmember households if they managed to acquire more livestock units than nonmembers, i.e., the income effect exceeds the substitutions effect.

The literature on the use of new agricultural technologies distinguishes between individual and aggregate use.

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 potential, whereas the latter is about the diffusion of the technology within a region (Feder, Just, & Zilberman, 1985). There is also the concept of intensity of use, which refers to the amount of the input and can be measured by the share of farm area or quantity per hectare that the input is used (Feder et al., 1985). This study is concerned with the role of the PSNP on individual use and measures intensity of use by kilograms of manure used per household.

In explaining the decision of the farmer regarding use of a technology, that decision at a given time is assumed a result of expected utility maximization by the farmer from using a certain technology facing constraints. The constraints can be availability of land and capital to make use of the technology. Capital in the case of manuring may be primarily having livestock or not. The farmer uses manure if the expected utility gained from its use exceeds the expected utility gained from using an alternative technology such as fertilizer or the state of not using any of the two (Feder et al., 1985; Shiferaw, Kebede, & You, 2008; Waithaka, Thornton, Shepherd, & Ndiwa, 2007).

3.2 | Sampling strategy, stratification, and description of data

Data for this study are collected in 2015 based on 11[4] *woredas* that were initially sampled in 1998 as part of the establishment of a panel data set by a collaboration of the Norwegian University of Life Sciences and Mekelle University. In this sample, 16 villages were selected from four zones[5] with differences in distance to market, population density and agricultural potential (Hagos, 2003). The zones are northeastern (was western zone at the 1998 survey and subdivided into two zones in 2006; namely, western zone and northeastern zone), central zone, eastern zone, southeastern zone (a new zone carved from the central and southern zones since 2006) and southern zone.

According to Hagos (2003), stratified random sampling was used to ensure large variation in population density, market access, agro-climatic conditions, and access to irrigation in the region. The stratification and sampling was done based on (1) the exclusion of low land areas (areas with an altitude of less than 1500 m.a.s.l.), (2) geographic zones that show a perceptible difference in rainfall, agricultural potential and development pathways, (3) distance to market, (4) population density, and (5) irrigation projects. Households in the villages were selected using random sampling based on the list of household head names in the village. This sample, however, expanded in 2006 by adding 25 more households from an additional village in the southeastern zone (AdisAlem) and still another one more village was added in 2010 (Kara Adishabo) from the southern zone. Finally, in 2015 two more village were added (Bagea Delewo and Wargiba) in the southern zone. This made the total number of villages to rise to 20 in 2015, and with this, the original 402 households in the sample became 632 in this survey round. Actually, there are 21 *tabias* in this data set now because one *tabia* (namely, Emba-Asmena) was split into two for administrative reasons by the authorities and only 4 of the 25 households sampled in this *tabia* continued to live there, whereas the rest happened to live in the new *tabia* (namely, Laelay Megaria Tsebri). See table 1 for the details of the sample breakdown in to zones, woredas and tabias

In the 2015 survey, the 632 households were surveyed using a structured questionnaire, of whom 630 became available for analysis after data entry and cleaning. Rainfall data for this study are obtained from the Relief Society of Tigray (REST) satellite measured rainfall data repository for all the *tabias* in the study area. REST is a local NGO working in community development and rehabilitation areas.

3.3 | Empirical strategy

Limited dependent variable methods are frequently used to model farmers' decision regarding use of agricultural technologies. In these models, it is assumed that farmers face two alternatives. The alternatives are using or not using a certain technology, and the choice depends on a set of specific characteristics (Feder et al., 1985). Logit and probit models and their modifications have been used extensively in the empirical study of technology adoptions (Doss, 2006; Feder et al., 1985; Ghadim & Pannell, 1999; Spielman, Kelemwork, & Alemu, 2011). However, it is important to see the intensity of use also because the ultimate outcome depends not only on the use but also on the intensity of use of the technology (Marenya & Barrett, 2007; Shiferaw, Okello, & Reddy, 2009; Waithaka et al., 2007). Tobit models have widely been used to explain the decision regarding whether to use a technology together with the intensity of its use. Tobit models assume that both decisions are made jointly and hence the same set of factors explains both decisions in the same way (Noltze, Schwarze, & Qaim, 2012). However, the decision to use

[4] The *woredas* were 12 when the sample was originally set up. However, when the 2015 survey was carried out, one of the *woredas* (Hintalo Wajirat) was dropped because respondents in the *tabia* of that *woreda* refused to participate in the study since the 2010 survey round (see Table 5 for the list of *tabias* and *woredas* in the sample).

[5] The zones became five later due to change in the administrative division of Tigray effected since 2006.

TABLE 1 List of zones, *woredas*, and *tabias* in the sample

S.N.	Zone	*Woredas*	*Tabias*
1	Northeastern	1. Laelay-Adyabo	1. Tsaeda-Ambora
			2. Hadegti
		2. Tahtay-koraro	1. May-Adrasha
			2. Adi-Menabir
2	Central	1. Degua-Temben	1. Seret
		2. Mereb-Leke	1. Adi-Selam
		3. Ahferom	1. Laelay Megaria Tsebri (Dibdbo)
			2. May-Keyahti
3	Eastern	1. Gulo-Mekeda	1. Hagere-Selam
		2. Saesie Tseda Emba	1. Emba-Asmena
			2. Emba-Mezwol
		3. Kilte Awulaelo	1. Kihen
			2. Genfel
4	Southeastern	1. Seharti Samre	1. Samre
			2. Adiss-Alem
			3. Womberet-AdidekiAla
		2. Enderta	1. May-Alem
			2. Mahbere-Genet
5	Southern	1. Raya Azebo	1. Kara Adishabo
			2. Bagea Delewo
			3. Wargiba
Total		11	21

manure and the decision regarding the amount of it used could be influenced by different factors and/or same factors may have different effects in the two decisions. Double-hurdle (DH) models are suited to handle such a situation (Asfaw, Shiferaw, Simtowe, & Haile, 2011; Simtowe & Zeller, 2006). This study will use either of the two approaches based on which one fits the data well.

The literature on farmers' decision regarding use of a certain agricultural technology shows that various household-level, farm-level, village-level and institutional as well as infrastructural factors determine the level of technology use (Bezu, Kassie, Shiferaw, & Ricker-Gilbert, 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), whereas in the farm-level characteristics, farm size is given importance (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 use of agricultural technologies (Feder et al., 1985). Another important determinant of a technology use is the risk that comes with it. In relation to manure use, the level of riskiness of modern fertilizer may affect the level of manure use. This is so because higher risk with modern fertilizer may encourage sticking to use of manure, whereas a lower risk may encourage more use of modern fertilizer and hence less manure.

Therefore, the model we want to estimate can be stated as follows. Suppose $\boldsymbol{M}$ stands for manure used by a household during the survey year in kilograms:

$$\boldsymbol{M} = \boldsymbol{f}(\boldsymbol{K}, \boldsymbol{H}, \boldsymbol{A}, \boldsymbol{V}, \boldsymbol{D}) \quad (1)$$

where $\boldsymbol{K}$ refers to the labor and physical endowment of the household. Variables included in this category are number of adult members in the household, total livestock units, and area of land that the household owns. $\boldsymbol{H}$ refers to a vector of household features. In this category, sex and age of the household head, whether the household head is literate or not and household size, are considered. $\boldsymbol{A}$ refers to a vector of agro-ecological factors. In this category, mean and variation of rainfall in the current and previous year main rainy season (June–September) are considered. The amount and the variability of rainfall are included because fertilizer (which is the alternative technology to manure) is believed to be a high yielding but risky input due to weather variability (Alem, Bezabih, Kassie, & Zikhali, 2010; Bezu et al., 2014; Holden & Westberg, 2016). This may make manure an alternative to fertilizer use. Also included in ***A*** are[6] farmers' perception on the quality of the plots they operate, average distance of plots from homestead, average slope, and shallowness of plots and whether the household owns plots with access to irrigation. ***V*** refers to proxy variables for infrastructure, market access, and agricultural development support services such as microcredit and improved input supply. These factors determine whether farmers tend and are able to use fertilizer and hence affect manure use indirectly. I do not have a direct measure of these variables. Instead, I use distance in walking minutes from the household's residence to the nearest road and distance to the *woreda* center measured in the same way. The distance to nearest road variable is supposed to serve as a proxy for transport infrastructure, while the distance to the *woreda* center is supposed to serve as a proxy for market access and development support services. At last, the variable ***D*** is the treatment variable and refers to whether the household is a member of the public works component of the PSNP or not. As discussed earlier, this is the variable of prime interest in this study.

The observed amount of manure use is supposed to be the result of a latent relationship between the set of factors, which explain the utility comparison of the farmer between use of manure and not using it. This equation (the latent) is assumed linear and can be specified as follows:

$$M^* = \beta_0 + \beta_1 K + \beta_2 H + \beta_3 A + \beta_4 V + \delta D + \varepsilon \quad (2)$$

In the above specification δ is the coefficient of main interest, and in the theoretical framework section it was argued that the sign of δ cannot be known a priori.

The human and physical capital of the household (***K***) are expected to affect manure use positively. Among the human capital of the household, having more adult members is expected to lessen the constraint of the household in using manure and hence is expected to be positively correlated with manure use. Total livestock units that the household owns is expected to affect manure use positively because livestock are the source of manure. Regarding land size the household owns, it is expected to be positively correlated with manure use and negatively so with the intensity of use as in Feder et al. (1985).

Concerning household features, female-headed households are expected to be less users of manure than male-headed households. This could be true as female-headed households may be more labor constrained (Marenya & Barrett, 2007) and/or they could be less favored in terms of getting the information and/or knowledge regarding technologies (Nkamleu & Adesina, 2000). The effect of household size on manure use may not be known a priori. On the one hand, larger household size may encourage more use of manure with a view to produce more and feed 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 acquire assets, livestock being the major forms of assets in rural households. This holds stronger when access to credit is limited, which is quite prevalent in developing countries (Sadoulet & De Janvry, 1995). Moreover, literate household heads are expected to be aware of the benefits of manure and hence may tend to use more of it.

In the category of agro-climatic conditions, rainfall may be negatively correlated with manure use and intensity. Availability of rainfall may encourage use of modern fertilizer and hence probably less use of manure. Rainfall variability (as measured by the coefficient of variation), however, may encourage more use of manure partly because modern fertilizer may not be used when there is high rainfall variability. Additional variables included in the category of plot characteristics are perception of the household head on the fertility of his/her plots, average slope of plots, average shallowness of plots, average distance of plots from homestead and whether that the household owns plots with access to irrigation. It is expected that households with an average perception of fertile plots will use less manure. The same is expected to hold for households with sloppy plots on average, whereas households with shallow plots are expected to use more manure. Households with farther away plots on average are expected to use less manure because distance increases the transaction cost of manuring. Regarding plots with irrigation access, there may be less use of manure if households tend to use fertilizer instead of manure (because water has become available). Finally, the term ε is a zero mean identically and independently distributed error term, which is assumed to be uncorrelated with the other explanatory variables.

Now let us come to the variable of prime interest for this study, namely, membership in the public works component of the PSNP. PSNP membership is a result of a government plan to include poor farmers into the program. The selection of households into the PSNP is based on (1) the identification of food-insecure districts throughout the country and (2) the identification of eligible households at the tabia level based on household well-being indicators. Specifically, districts are selected for 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. There could

[6] Households were asked to tell their perception on
1. fertility on each plot that they own (1 = infertile; 2 = medium; 3 = fertile)
2. slope of each plot that they own (1 = shallow; 2 = medium; 3 = deep)
3. shallowness of soil on each plot that they own (1 = plain; 2 = foothill; 3 = mid-hill; 4 = steep-hill)

also be inclusion of ineligible households and/or exclusion of eligible households at the tabia level due to targeting inefficiency. This makes the PSNP membership nonrandom. Therefore, the PSNP membership status variable in the above model can be correlated with the error term. Thus, there is a need to control for possible endogeneity of membership in the PSNP. To do this, I use the instrumental variable method with a two-stage estimation process. In the first stage, I estimate the latent equation for PSNP membership (D^*) as a function of a set of variables, which explain the fertilizer use decision (X) and an instrument variable Z in the following form:

$$D^* = \beta_0 + \beta_i X_i + \gamma Z + V \tag{3}$$

such that

If $D^* > 0$, the household becomes a member of the PSNP (i.e., $D = 1$)
$D^* \leq 0$, the household does not become a member of the PSNP (i.e., $D = 0$)

Then in the second stage, I include the predicted PSNP membership as a regressor in the manure use and intensity of use regressions.

The instrument variable used here 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, first, I computed the mean rainfall of all districts in the sample taking the main rainy season rainfall (June–September) for the three years before the start of the PSNP (namely, for 2002, 2003, and 2004). Then, I generated a dummy variable, which takes one if the household resides in an area that received less than this mean rainfall and this dummy takes the value of zero otherwise. I 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. Because a household was selected to the PSNP based on whether that household had been receiving food aid in the prior three consecutive years, this dummy variable is expected to perform well in capturing this situation.

Econometrically though, IV regression with a binary endogenous regressor has some issues. The issue is that using IV probit may not be proper because it assumes a continuous endogenous regressor (Cameron & Trivedi, 2009). Specifically, if we use IV probit, the predicted value of the endogenous regressor (in this case PSNP membership) will be linear. In order to handle this problem, several ways have been proposed in the econometric literature. In this study, I will try to employ a linear IV estimation of both the first and second stage regressions as suggested by Angrist and Pischke (2009). I will also fit a biprobit model for the manure use decision regression as suggested by Angrist and Pischke (2009) and the treatment effects regression model as suggested by Cameron and Trivedi (2009). The purpose of doing all these is to examine the endogeneity issue of PSNP membership in more detail and see whether results are sensitive to that or not.

4 | RESULTS AND DISCUSSION

Here, I will present the results in two subsections. In the first section, the descriptive results will be discussed, whereas in the second section, results of the econometric estimations will be presented and discussed.

4.1 | Descriptive statistics

An assessment of the level of manure use in the sample area during the period of study (see Table 2) shows that there is no significant difference between the two groups. This comparison holds for whether the household uses manure, total manure use by a household and per a hectare of crop planted area.

When the two groups are compared in terms of some key control variables (see Table 3), member households appear to have larger household size with more adult members, own smaller number of livestock, perceive their plots are fertile, live in villages that have lower mean main season rainfall with higher coefficient of rainfall variation.

TABLE 2 Comparison of manure use between members and nonmembers of the PSNP

Variable	Nonmembers	Members	*t* value
Use rate of manure	0.489	0.491	−0.05
KGs of manure per household	412.63	642.15	−1.54
KGs of manure per hectare of crop planted area	70.88	77.49	−0.13
Observations	333	297	630

Source: Authors' computation based on NMBU and MU Household Panel data survey.

TABLE 3 Comparison of mean variables between nonmembers and members of the PSNP

Variable	Nonmembers	Members	*t* value
Age of household head	57.4	57.3	0.07
Sex of household head (1 = female)	0.21	0.26	−0.97
HH head education (literate = 1)	0.30	0.31	−0.35
Household size	4.67	5.12	−2.3[a]
Male adult members in the household	2.52	2.74	−1.85[b]
Total livestock units the HH owns	3.04	2.49	2.54[a]
Total area of land the HH owns in *tsimdi*[7]	4.35	4.85	−1.59
Perception on land quality (1 = fertile))	0.58	0.66	−2.14[a]
Average slope of plots the HH owns (1 = steep)	0.35	0.33	0.64
Average shallowness of soil of plots the HH owns (1 = shallow)	0.19	0.21	−0.51
Plot distance from the homestead of the HH	0.51	0.49	0.57
HH has irrigated plots (1 = has plots with access)	0.33	0.34	−0.26
Mean rainfall of current rainy season	437.44	412.92	1.57
Coefficient of variation of current main season rainfall	1.203	1.20	0.09
Mean rainfall of previous rainy season	595.50	539.69	2.79[c]
Coefficient of variation of previous main season rainfall	1.12	1.18	−2.40[a]
Distance from HH residence to the *wereda* center	167.51	169.06	−0.21
Distance from HH residence to the nearest road	28.67	29.10	−0.16
Observations	333	297	630

Source: Authors' own computation based on NMBU and MU household panel data.
[a]Significant at the 5% level.
[b]Significant at the 10% level.
[c]Significant at the 1% level.
[7]*Tsimdi* is a local measure of land area, which on average is equal to a quarter of a hectare.

4.2 | Results from the econometric estimations

Before going straight to the discussion of manure use regressions, first I assess the situation regarding PSNP membership. All regressions of PSNP membership (see Table 4) show that the instrument variable is significant at the 1% level of significance, and its coefficients are stable around 8.6 except in the linear IV estimation. Moreover, post estimation statistics from the IV regression show that the instrument is valid with an F-value of 19.6 (see Table 7). Based on these then, the instrument variable looks to perform well in predicting PSNP membership. The test of endogeneity of PSNP membership based on the IV estimation, however, shows that endogeneity may not be an issue as we fail to reject the null hypothesis with a *P* value of 0.23 (see the test after Table 7). Nonetheless, given the analytical basis for the suspicion of endogeneity of PSNP membership, models will be estimated taking both cases into consideration. Therefore, I first estimate manure use and intensity regressions assuming PSNP is exogenous (given the statistical test result). Next, I estimate the outcome regressions assuming PSNP is endogenous. This estimation will have several alternatives to ascertain whether results are sensitive to specifications. My results show that results are robust (see Table 5). I have also done a Heckman selection model estimation to see the interdependence between the probit and tobit regressions involving manure use decision and its intensity. The result shows that even though the Heckman model indicates the Mills lambda is insignificant, overall fitness of the model is weak with a Wald chi(20) of 14.22 (see Table 10).

Looking at the determinant variables of PSNP membership, the first thing that is clearly visible is that the results are similar in all the specifications. Results show that in addition to the instrument variable, household size, total livestock units, and area of land that the household owns are statistically significantly correlated to PSNP membership. Household size and livestock are significant at 10%, whereas area of land is so at 5%. The positive correlation between household size and PSNP membership is likely because such households could be poorer and are more likely to be targeted for the program. The negative correlation between livestock ownership and PSNP membership too is plausible as livestock ownership might indicate wealth status of households and, as such, it might have been used as an indicator to exclude households from the PSNP. Discussion with *tabia* level implementers also

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TABLE 4 Regression of PSNP membership on its determinants and an instrumental variable

Variables	Simple probit	Linear IV of manure use	Biprobit of manure use	Treatment effects model
Instrument variable	0.859[a]	0.323[a]	0.855[a]	0.861[a]
	(0.202)	(0.074)	(0.202)	(0.200)
Age of the household head	0.030	0.011	0.031	0.031
	(0.026)	(0.009)	(0.025)	(0.025)
Age of the household head squared	−0.000	−0.0001	−0.000	−0.000
	(0.000)	(0.0001)	(0.000)	(0.000)
Sex of household head (1 = female headed)	0.142	0.055	0.142	0.142
	(0.133)	(0.049)	(0.133)	(0.133)
Whether household head is literate (1 = literate)	−0.033	−0.012	−0.026	−0.026
	(0.120)	(0.044)	(0.120)	(0.120)
Household size	0.057[c]	0.021[c]	0.057[c]	0.057[c]
	(0.032)	(0.012)	(0.032)	(0.032)
Number of adult members in the household	−0.029	−0.011	−0.030	−0.030
	(0.052)	(0.019)	(0.052)	(0.052)
Total livestock units the household owns	−0.039[c]	−0.014[c]	−0.041[c]	−0.041[c]
	(0.021)	(0.008)	(0.021)	(0.021)
Area of land the household owns in *tsmdi*	0.036[b]	0.013[b]	0.037[b]	0.037[b]
	(0.015)	(0.005)	(0.015)	(0.015)
Perception on the quality of plots owned (1 = poor, 2 = medium, 3 = fertile)	0.186	0.069	0.184	0.184
	(0.113)	(0.042)	(0.113)	(0.113)
Average slope of plots the HH owns	0.036	0.015	0.041	0.041
	(0.118)	(0.044)	(0.118)	(0.118)
Average shallowness of soil of plots the HH owns	0.117	0.043	0.114	0.114
	(0.136)	(0.050)	(0.137)	(0.137)
Plot distance from the homestead of the HH	−0.083	−0.032	−0.088	−0.088
	(0.128)	(0.044)	(0.129)	(0.129)
Whether the HH has plots with irrigation (1 = has irrigation)	0.061	0.024	0.060	0.060
	(0.112)	(0.042)	(0.112)	(0.112)
Mean rainfall of current rainy season	−0.000	−0.0001	−0.000	−0.000
	(0.002)	(0.0007)	(0.002)	(0.002)
Coefficient of variation of current main season rainfall	−0.665	−0.255	−0.652	−0.652
	(0.503)	(0.183)	(0.501)	(0.501)
Mean rainfall of previous rainy season	−0.000	−0.00006	−0.000	−0.000
	(0.001)	(0.0005)	(0.001)	(0.001)
Coefficient of variation of previous main season rainfall	−0.021	−0.009	−0.009	−0.009
	(0.553)	(0.204)	(0.554)	(0.554)
Distance from HH residence to the *wereda* center	0.000	0.0002	0.000	0.000
	(0.001)	(0.0002)	(0.001)	(0.001)
Distance from HH residence to the nearest road	−0.000	−0.0001	−0.000	−0.000
	(0.002)	(0.0006)	(0.002)	(0.002)
Constant	−0.858	0.143	−0.913	−0.927
	(1.419)	(0.515)	(1.414)	(1.415)
Observations	630	630	630	630

Note. Figures in parentheses are standard errors.
[a]Significant at the 1% level.
[b]Significant at the 5% level.
[c]Significant at the 10% level.

TABLE 5 Simple probit/tobit and double-hurdle regressions on manure use decision and KGs of manure used by a household

Variable	Probit/tobit regressions		Double-hurdle model		DH model with *tabia* clustering	
	Manure use	Log of KGs per HH	Manure use	Log of KGs per HH	Manure use	Log of KGs per HH
PSNP membership	0.051	0.366	0.004	0.269	0.004	0.269
	(0.111)	(0.456)	(0.112)	(0.166)	(0.104)	(0.191)
Age of the household head	0.045	0.235[b]	0.050[c]	0.042	0.050	0.042
	(0.027)	(0.117)	(0.028)	(0.049)	(0.035)	(0.055)
Age of the household head squared	−0.000[c]	−0.002[b]	−0.000[c]	−0.000	−0.000	−0.000
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Sex of household head (1 = female headed)	−0.369[c]	−1.727[c]	−0.388[c]	−0.300	−0.388[c]	−0.300
	(0.139)	(0.600)	(0.143)	(0.243)	(0.117)	(0.226)
Whether household head is literate (1 = literate)	−0.003	0.042	0.025	−0.010	0.025	−0.010
	(0.125)	(0.511)	(0.049)	(0.069)	(0.045)	(0.066)
Household size	−0.043	−0.157	−0.042	0.042	−0.042	0.042
	(0.034)	(0.138)	(0.034)	(0.048)	(0.042)	(0.048)
Number of adult members in the household	0.060	0.203	0.059	−0.015	0.059	−0.015
	(0.055)	(0.220)	(0.056)	(0.075)	(0.057)	(0.072)
Total livestock units the household owns	0.091[c]	0.411[c]	0.081[c]	0.113[c]	0.081[c]	0.113[c]
	(0.022)	(0.090)	(0.022)	(0.035)	(0.025)	(0.032)
Area of land the household owns in *tsmdi*	0.007	0.049	0.006	0.019	0.006	0.019
	(0.014)	(0.057)	(0.014)	(0.019)	(0.013)	(0.013)
Whether the HH has Plots with irrigation (1 = has irrigation)	−0.081	−0.556	−0.091	−0.193	−0.091	−0.193
	(0.118)	(0.492)	(0.119)	(0.187)	(0.156)	(0.221)
Average slope of plots the HH owns	0.063	0.239	0.083	−0.000	0.083	−0.000
	(0.122)	(0.509)	(0.124)	(0.194)	(0.068)	(0.195)
Average shallowness of soil of plots the HH owns	0.011	−0.033	−0.001	−0.242	−0.001	−0.242
	(0.143)	(0.587)	(0.144)	(0.216)	(0.141)	(0.213)
Plot distance from the homestead of the HH	−0.408[c]	−2.042[c]	−0.443[c]	−0.450[b]	−0.443[c]	−0.450[c]
	(0.136)	(0.569)	(0.136)	(0.205)	(0.147)	(0.142)
HH has Plots with irrigation (1 = has irrigation)	−0.027	−0.212	−0.049	−0.131	−0.049	−0.131
	(0.118)	(0.480)	(0.119)	(0.173)	(0.125)	(0.182)

(Continues)

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TABLE 5 (Continued)

Variable	Probit/tobit regressions		Double-hurdle model		DH model with *tabia* clustering	
	Manure use	Log of KGs per HH	Manure use	Log of KGs per HH	Manure use	Log of KGs per HH
Mean rainfall of current rainy season	−0.002	−0.015[c]	−0.002	−0.006[b]	−0.002[b]	−0.006[c]
	(0.002)	(0.008)	(0.002)	(0.002)	(0.001)	(0.001)
Coefficient of variation of current main season rainfall	−1.487[c]	−8.782[c]	−1.470[c]	−2.527[c]	−1.470[c]	−2.527[c]
	(0.553)	(2.051)	(0.554)	(0.704)	(0.254)	(0.484)
Mean rainfall of previous rainy season	−0.001	−0.001	−0.001	0.002	−0.001	0.002[c]
	(0.001)	(0.005)	(0.001)	(0.002)	(0.001)	(0.001)
Coefficient of variation of previous main season rainfall	−1.280[b]	−5.106[b]	−1.262[b]	0.427	−1.262	0.427
	(0.591)	(2.413)	(0.600)	(0.953)	(0.799)	(0.847)
Distance from HH residence to the *wereda* center	−0.000	0.001	−0.000	0.002[c]	−0.000	0.002[b]
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Distance from HH residence the nearest road	0.005[c]	0.014[b]	0.004[b]	−0.005[b]	0.004[c]	−0.005[c]
	(0.002)	(0.007)	(0.002)	(0.002)	(0.002)	(0.001)
Constant	3.226[b]	17.715[c]	3.049[b]	8.387[c]	3.049[c]	8.387[c]
	(1.484)	(6.026)	(1.505)	(2.276)		
Observations	630	630	615	615	615	615
Sigma		*4.927*	*1.369*[c]		*1.369*[c]	
		(0.226)	*(0.056)*		*(0.056)*	
LR chi²(20)	*144.52*	*160.82*	*117.24*[d]		–	
Prob > ch2	*0.0000*	*0.0000*	*0.0000*		–	
Log likelihood	*−364.3080*	*−1135.6575*	*−880.0365*		*−880.03647*	

Note. Figures in parentheses are standard errors.
[a]Significant at the 5% level.
[b]Significant at the 10% level.
[c]Significant at the 1% level.
[d]Wald $ch^2(20)$ for the DH model.

TABLE 6 Likelihood ratio test of the Tobit model versus the double-hurdle model

(Assumption: tobit is nested in the DH model)		
Likelihood ratio test	LR $chi^2(21) = 511.24$	Prob > $chi^2 = 0.0000$

confirms that livestock ownership, especially ownership of oxen, was used as an important indicator of wealth of households during the *tabia* level PSNP selection process. A result, which is contrary to expectation, is the positive correlation between land size that the household owns and PSNP membership. This may probably warrant a further investigation of the selection process.

Coming to the manure use and intensity regressions, I will rely on the simple probit/tobit regression versus the DH results. The reason for this is that all the above estimations and tests show that PSNP endogeneity may not be an issue of concern here. In support of this all, the alternative estimations that I have done on manure use and its intensity show that results are more or less the same in the without IV estimations (Table 5) and IV estimations (see Tables 8 and 9).

Now, I have to test whether the simple probit/tobit model or the DH model fits the data better. I employ the likelihood ratio test for this, and the result shows that the DH model fits better with a $\chi^2_{(21)}$ value of 511.24 and P value of 0.0000 (see Table 6). The results I obtain between the two specifications are not that much different except for the distance to road variable, which takes different signs between manure use decision (tier 1) and KGs of manure used (tier 2) in the DH model. I have also included a DH model estimation with tabia clustering. The clustering does not make any difference in coefficient sign, size, and level of significance. However, Stata fails to report the Wald chi^2 and Prob > chi^2 values in the tabia clustered estimation. Given this result, therefore, discussions of relations will be based on the DH model result without clustering.

The DH result shows that the coefficient of membership in the public works component of the PSNP has no statistically significant impact on the probability of using manure (tier 1) and the amount of manure that a household used (tier 2). This result is the same in all of the specifications that I tried. Taking this statistical result without any pinch of salt may appear to tell that there is no difference in manure use between members and nonmembers of the PSNP. However, a scrutiny beyond the statistics may tell a different story. An important issue to keep in mind to better grasp this result is that PSNP member households have smaller livestock ownership compared with nonmember households. Even though studies such as Berhane et al. (2014), Debela and Holden (2014), and Gilligan et al. (2009) indicate that PSNP has helped member households acquire more livestock, no studies show that member households have caught up nonmember households in terms of size of livestock ownership. Therefore, equal use of manure by members and nonmembers of the PSNP could indicate that member households are catching up with nonmember households in terms of manure use, though they have smaller livestock. This may indicate that the PSNP is making a headway in encouraging households to use natural yield-enhancing inputs such as manure.

Coming to the additional control variables included in the regressions, only four variables have a statistically significant correlation with both the decision to use and KGs of manure used. These variables are total livestock that the household owns, average distance of plots from the homestead, coefficient of variation of current main production season rainfall and walking minutes distance from household residence to the nearest road.

These results appear to be plausible given theory and empirics. The positive correlation between livestock ownership and manure use and intensity should be easier to understand, as livestock are the source of manure itself. The negative correlation between average distance of plots from the residence of the household and the outcome variables may also be intuitively understandable. The cost of manuring far away plots could be very high, and thus households may tend to manure nearby plots more. The negative coefficient of variation in current rainfall may be due to the possibility of low yield due to rainfall variability, which discourages households from manuring their plots. Distance to the nearest road is positively correlated with manure use decision and negatively to the amount of manure used. The positive correlation with the decision may indicate that households who live far from roads depend more on traditional technology to enhance yield (manure) than on modern technologies (such as inorganic fertilizer). However, the negative correlation with

TABLE 7 First-stage regression summary statistics from the linear probability IV regression of manure use

Variable	R-squared	Adj. R-squared	Partial R-squared	Robust F(1,592)	Prob > F
PSNP	0.0908	0.0610	0.0302	19.6025	0.0000

Note. Test of endogeneity (orthogonality conditions).
Ho: variables are exogenous.
GMM C statistic $chi^2(1) = 1.10464$ ($P = 0.2933$).
We fail to reject exogeneity of PSNP membership.

TABLE 8 Biprobit regression of manure use decision with PSNP membership being endogenous

Variables	Manure use	PSNP
Instrument variable		0.855[a]
		(0.202)
Predicted PSNP membership	−0.510	
	(0.552)	
Age of the household head	0.048[b]	0.031
	(0.027)	(0.025)
Age of the household head squared	−0.000[b]	−0.000
	(0.000)	(0.000)
Sex of household head (1 = female headed)	−0.316[c]	0.142
	(0.152)	(0.134)
Whether household head is literate (1 = literate)	−0.011	−0.027
	(0.124)	(0.120)
Household size	−0.030	0.057[b]
	(0.037)	(0.032)
Number of adult members in the household	0.055	−0.030
	(0.055)	(0.052)
Total livestock units the household owns	0.079[a]	−0.041[b]
	(0.026)	(0.021)
Area of land the household owns in *tsmdi*	0.014	0.037[c]
	(0.015)	(0.015)
Perception on plot quality (1 = poor, 2 = medium, 3 = fertile)	−0.033	0.185
	(0.126)	(0.113)
Average slope of plots the HH owns	0.049	0.040
	(0.121)	(0.118)
Average shallowness of soil of plots the HH owns	0.042	0.113
	(0.144)	(0.137)
Plot distance from the homestead of the HH	−0.421[a]	−0.089
	(0.134)	(0.129)
Whether the HH has plots with irrigation (1 = has irrigation)	−0.026	0.060
	(0.116)	(0.112)
Mean rainfall of current rainy season	−0.002	−0.000
	(0.002)	(0.002)
Coefficient of variation of current main season rainfall	−1.535[a]	−0.653
	(0.542)	(0.501)
Mean rainfall of previous rainy season	−0.001	−0.000
	(0.001)	(0.001)
Coefficient of variation of previous main season rainfall	−1.217[c]	−0.012
	(0.590)	(0.554)
Distance from HH residence to the nearest road	−0.000	0.000
	(0.001)	(0.001)
Distance from HH residence the *wereda* center	0.004[c]	−0.000
	(0.002)	(0.002)
Constant	3.416[c]	−0.913
	(1.459)	(1.414)
Observations	630	630
Log likelihood	−769.70	
Wald chi^2*(40)*	201.28	
Prob > chi^2	0.0000	
artro	0.372 (0.394)	
rho	0.356 (0.344)	
Likelihood ratio test of rho = 0 $chi^2(1)$ = 0.929153 Prob > chi^2 = 0.3351		

Note. Figures in parentheses are standard errors.
[a]$P < 0.01$; [b]$P < 0.1$; [c]$P < 0.05$.

TABLE 9 Treatment effects regression of manure use decision with PSNP assumed endogenous

Variables	Manure use decision	PSNP membership
Age of the household head	0.016[a]	0.031
	(0.009)	(0.025)
Age of the household head squared	−0.000[a]	−0.000
	(0.000)	(0.000)
Sex of household head (1 = female headed)	−0.110[b]	0.142
	(0.048)	(0.133)
Whether household head is literate (1 = literate)	−0.004	−0.026
	(0.042)	(0.120)
Household size	−0.010	0.057[a]
	(0.012)	(0.032)
Number of adult members in the household	0.017	−0.030
	(0.018)	(0.052)
Total livestock units the household owns	0.027[c]	−0.041[a]
	(0.008)	(0.021)
Area of land the household owns in *tsmdi*	0.005	0.037[b]
	(0.005)	(0.015)
Perception on plot quality(1 = poor, 2 = medium, 3 = fertile)	−0.015	0.184
	(0.042)	(0.113)
Average slope of plots the HH owns	0.012	0.041
	(0.041)	(0.118)
Average shallowness of soil of plots the HH owns	0.019	0.114
	(0.049)	(0.137)
Plot distance from the homestead of the HH	−0.147[c]	−0.088
	(0.047)	(0.129)
Whether the HH has plots with irrigation (1 = has irrigation)	−0.009	0.060
	(0.039)	(0.112)
Mean rainfall of current rainy season	−0.001	−0.000
	(0.001)	(0.002)
Coefficient of variation of current main season rainfall	−0.599[c]	−0.652
	(0.178)	(0.501)
Mean rainfall of previous rainy season	−0.000	−0.000
	(0.000)	(0.001)
Coefficient of variation of previous main season rainfall	−0.443[b]	−0.009
	(0.195)	(0.554)
Distance from HH residence to the *wereda* center	−0.000	0.000
	(0.000)	(0.001)
Distance from HH residence the nearest road	0.001[c]	−0.000
	(0.001)	(0.002)
PSNP (1 = member)	−0.180	
	(0.186)	
Instrument variable		0.861[c]
		(0.200)
Constant	1.872[c]	−0.927
	(0.499)	(1.415)
Observations	630	630
Log likelihood	−788.5187	
Wald chi^2*(40)*	160.69	
Prob > chi^2	0.0000	
Athrho	0.273(0.262)	
lnsigma	−0.790(0.049)	
Likelihood ratio test of rho = 0 $chi^2(1) = 1.02$ Prob > $\text{chi}^2 = 0.3115$		

Note. Figures in parentheses are standard errors.

[a]$P < 0.1$; [b]$P < 0.05$; [c]$P < 0.01$.

TABLE 10 Heckman selection model estimation

Variables	Log of KGs per HH		Manure use decision
PSNP membership	0.194		0.017
	(0.239)		(0.112)
Age of the household head	−0.013		0.049[a]
	(0.096)		(0.028)
Age of the household head squared	0.000		−0.000[a]
	(0.001)		(0.000)
Sex of household head (1 = female headed)	0.219		−0.383[b]
	(0.631)		(0.143)
Whether household head is literate (1 = literate)	−0.017		0.020
	(0.105)		(0.049)
Household size	0.093		−0.041
	(0.089)		(0.034)
Number of adult members in the household	−0.091		0.060
	(0.133)		(0.056)
Total livestock units the household owns	−0.028		0.086[b]
	(0.122)		(0.022)
Area of land the household owns in *tsmdi*	0.013		0.005
	(0.030)		(0.014)
Perception on the quality of plots owned (1 = poor, 2 = medium, 3 = fertile)	−0.092 (0.296)		−0.084 (0.119)
Average slope of plots the HH owns	−0.053		0.078
	(0.287)		(0.124)
Average shallowness of soil of plots the HH owns	−0.229		−0.003
	(0.310)		(0.145)
Plot distance from the homestead of the HH	0.060		−0.424[b]
	(0.643)		(0.136)
Whether the HH has plots with irrigation (1 = has irrigation)	−0.008		−0.058
	(0.261)		(0.119)
Mean rainfall of current rainy season	−0.002		−0.002
	(0.005)		(0.002)
Coefficient of variation of current main season rainfall	0.079		−1.502[b]
	(2.524)		(0.554)
Mean rainfall of previous rainy season	0.003		−0.001
	(0.003)		(0.001)
Coefficient of variation of previous main season rainfall	2.120		−1.288[c]
	(2.158)		(0.600)
Distance from HH residence to the nearest road	0.002		−0.000
	(0.001)		(0.001)
Distance from HH residence the *wereda* center	−0.010		0.004[c]
	(0.006)		(0.002)
Constant	4.598		3.211[c]
	(4.350)		(1.506)
Mills Lambda		−2.340	
		(2.226)	
Censored observations		313	

(Continues)

TABLE 10 (Continued)

Variables	Log of KGs per HH	Manure use decision
Uncensored observations	302	
Wald chi(20)	14.22	
Prob > chi[2]	0.8191	

[a]Significant at the 1% level.
[b]Significant at the 5% level.
[c]Significant at the 10% level.

the amount of manure use is out of expectation given the setup of this study and may merit further investigation.

In addition to the above variables, age and sex of the household head, coefficient of variation of previous season rainfall, and distance from homestead to the woreda center are found to have a statistically significant correlation with either of the outcome variables. Age of household head is positively correlated with manure use decision, whereas sex of household head is negatively correlated. Distance of the woreda center on its part has a negative correlation with KGs of manure used by a household.

The positive effect of age on manure use could be true, because with an increase in the age of the household head, the family may get larger (the need for manure) and the expertise (the ability) of the household to use manure might increase. The negative correlation between the household head being female and manure use may indicate that female-headed households participate less in land productivity-enhancing investments (manure being one). This could be due to lack of labor and/or information (knowledge) regarding manure use by female-headed households. The positive correlation between distance of the woreda center and KGs of manure use may indicate that the woreda center is the main market for inputs (such as fertilizer) and hence households far from it rely more on manure.

5 | CONCLUSION

Ethiopia has been struggling to improve agricultural productivity and attain food security for a long time. Several interventions have been implemented with a view to increase agricultural productivity in the country. The PSNP was designed with the aim of enabling poor households achieve food security through works that build assets at household and community level.

The PSNP might interact with farmers' own endeavors to improve farm productivity in several mechanisms. One mechanism could be through its effect on traditional technology use. Manure is an important component of traditional technologies with good long-term land productivity effect.

This study explored whether PSNP member households are more likely to use manure and whether they apply more amount of manure on their farms. The study finds that PSNP member households are not statistically significantly different from their nonmember counterparts in both the manure use decision and amount of it used. This result is obtained despite the fact that PSNP member households own smaller livestock. Therefore, as regards this aspect only, the PSNP program appears to have helped PSNP member households catch up with their nonmember counterparts in terms of using productivity-enhancing traditional technologies such as manure. This may indicate that the PSNP is making a headway in encouraging households to use natural yield-enhancing inputs and increase their productivity.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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