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Gauging the impact of Ethiopia's productive safety net programme on agriculture: Application of targeted maximum likelihood estimation approach

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Abstract

The Productive Safety Net Programme (PSNP) is Ethiopia's poverty reduction strategy that forms the most important pillar of the country's agricultural transformation into a more productive and competitive sector. However, the extent to which the PSNP is linked to agriculture is unclear. This paper evaluates the impact of the PSNP on a range of agricultural outcomes. We use data from the Living Standard Measurement Study—Integrated Survey on Agriculture and apply the targeted maximum likelihood estimation method. We find no evidence that PSNP participation improved technology adoption, time spent in agriculture, household-level access to agricultural services, or women's control over agricultural assets. However, PSNP participation increased access to credit, the share of non-farm income, hours spent on casual work, community access to irrigation water, ownership of agricultural tools, community service in crop and livestock production, natural resource management, and access to credit. We also observe that PSNP households have a lower level of endowments compared to non-PSNP households. Given the observed lack of impact on household-level agricultural outcomes, we recommend integrating household-level interventions, such as increasing the transfer size and provision of

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productive assets, that could lift household endowments above an asset threshold that would allow the productive use of community assets. This may boost the productive impact of the PSNP at the household level, facilitate agricultural development and economic growth. To generate additional insights, we recommend further research with sufficient data on the causal pathways between safety nets and agriculture.

KEYWORDS

agriculture, causal inference, productive impact, productive safety net programme, targeted maximum likelihood estimation, technology adoption

JEL CLASSIFICATION

C13; O12; O02; Q16

1 | INTRODUCTION

Transforming smallholder agriculture into a more productive and competitive sector has received greater attention in Ethiopia's effort to eradicate poverty and promote rapid and inclusive economic growth (NPC, 2016). The Productive Safety Net Programme (PSNP) is among the most important poverty reduction strategies and pillars of agricultural transformation in Ethiopia. The high scale of operation and geographical focus in rural areas where the main source of income is agriculture makes PSNP candidate for fostering agricultural transformation. In 2020, the programme reached 8 million people in 382 food-insecure rural districts at an annual budget of \$2.3 billion.

The PSNP aims to reduce socioeconomic risks, vulnerability, extreme poverty, and deprivation (MoA, 2009, 2014). The programme has public work/direct support and a complementary asset-building plan that may improve agricultural outcomes by increasing certainty, relaxing financial constraints, encouraging investment in agriculture, and improving agricultural production and household welfare. Nevertheless, the extent to which the PSNP improved agriculture has not yet been thoroughly examined. With few exceptions, available studies provided inconclusive evidence about the impact of the PSNP on agricultural outcomes (Table 1). Results vary by programme modality, geographic area, household characteristics, duration of participation, and outcome type. While some studies report that the PSNP has a positive impact on agricultural asset accumulation, livestock ownership, and adoption of technologies (Berhane, Gilligan et al., 2014; Debela & Holden, 2014; Hoddinott, Berhane & Gilligan, 2012), others find no impact on such outcomes (Andersson, Mekonnen & Stage, 2011). A study by Debela et al. (2021) also shows lack of impact of Public Works (PW) on production diversity (Debela, Shively & Holden, 2021).

These studies used difference-in-difference, fixed effects, propensity score matching, and regression adjustment to estimate impacts. Although these methods are useful to estimate counterfactual outcomes under solid assumptions, they are prone to model misspecification biases, outliers and sparsity.¹ This is particularly important considering the programme design

¹Sparsity refers to a situation where information contained in a given dataset for estimating the target parameter is low. For more information on this see Gruber & van der Laan (2010).

TABLE 1 Review of studies on the impact of the PSNP on agricultural outcomes

Author (year)	Data source	Data Year	Sample size	Coverage	Outcome(s)	Treatment	Model	Results
Andersson et al. (2009)	Survey in South Wolo	2002–2007	560	Yes	TLU # of trees grown	PSNP (FFW/CFW) other FFW programmes	Regression analysis	No impact of the PSNP on livestock holding. Positive impact on tree holding.
Hoddinott et al. (2012)	Food Security Survey		3038	Yes	Agricultural output, productivity, fertiliser use, and investments in water retention	5 PW payment (+ HABP) vs. 1-year PW payment	Dose-response model	No impact of PW on cereal production, area planted, and yield, but PW increases the likelihood of investing in fencing. When coupled with HSBP, PW increased yield, probability of fertiliser use, and investment in terracing and fencing.
Berhane et al. (2014)	Food Security Survey		3140	Yes	TLU Holding of tools and other capital assets Net transfer	5 PW payment (+ HABP) Vs. 1-year PW payment	Dose-response models	5 years PW payment increased livestock holding by 0.38TLU and holding of tools by ETB221. No significant effect on net private transfers. When 5 years PW payment was coupled with OFSP/HABP, increased livestock holding by 0.999TLU.
Debela et al. (2021)	Survey in Tigray	2001–2011	1426	Yes	Crop production diversity (cereals, legumes, nuts and seeds; vegetables; fruits; and spices)	PSNP (CFW/FFW)	Fixed effects, difference-in-difference, dose-response model)	No impact on crop production diversity.
Debela & Holden (2014)	Survey in Tigray	2003–2010	400	Yes	TLU	PSNP (CFW/FFW)	Endogenous treatment effects	Increase livestock holding by 2.68–2.69 TLU.

(Continues)

TABLE 1 (Continued)

Author (year)	Data source	Data Year	Sample size	Coverage	Outcome(s)	Treatment	Model	Results
Zewdu (2015)	Young Lives	2002–2009	1770	Yes	TLU	PSNP(FFW/CFW) other FFW programmes	Propensity score matching	Increased livestock holding by 0.57 TLU. Increased livestock holding by 0.73 TLU for drought-affected households (model has imbalance in some covariates). Increased livestock holding by 0.78 TLU for male-headed households. Increased livestock holding by 0.88 TLU in Tigray region.
Alem & Broussard (2017)	Ethiopian Rural Household Survey	1999–2009	FFW: 456 FD: 464	Yes	Fertiliser use per hectare	Food for work and free distribution	Difference in-difference; Inverse propensity weighting	FFW increased the likelihood of adopting fertiliser in the short run (18 months), but no impact in the long run (7 years). No impact of FD on fertiliser use.
Araya and Holden (2018)	Survey in Tigray	2006–2015	280	Yes	Kilograms (kgs) of fertiliser use	PSNP (CFW/FFW)	Correlated random effect	No impact of FFW/FD on fertiliser use per hectare. FFW has a higher impact (3.2%) for each 10% increase in value from the village mean of livestock holdings. Increase the likelihood of fertiliser use. No significant effect on total fertiliser use.

(Continues)

TABLE 1 (Continued)

Author (year)	Data source	Data Year	Sample size	Coverage	Outcome(s)	Treatment	Model	Results
Gilligan et al. (2009)	Food Security Survey	2006	3700	Yes	Food gap; asset holdings; use of credit and use of improved agriculture practices such as fertilisers	PSNP-(PW)	PSM	Participants with access to both the PSNP and packages of agricultural support are more likely to borrow for productive purposes, use improved agricultural technologies, and operate non-farm own business activities. However, beneficiaries did not experience faster asset growth.
Tadesse (2018)	Southern region, Ethiopia	2005–2007	278	Yes	Input use (fertiliser adoption) and access to credit	PW	IV-2SLS; Tobit estimation	Households who participate in PW are less likely to use the low wage income from the Employment Generation Scheme to purchase farm inputs including fertiliser.

Abbreviations: CFW, Cash for work; DID, Difference in difference; ERHS, Ethiopian Rural Household Survey; FD, free distribution; FFW, food for work; HABB, household asset building programme; IPTW, Inverse Probability Treatment Weighting; IVM, Instrumental Variable Method; OFSP, other food security programme; PSNP, Productive Safety Net Programme; PW, public work; TLU, Tropical Livestock Unit.

and the complexity of the relationship between PSNP participation and agriculture. Considering the design, PSNP participation is based on community and asset-based criteria. Hence, participants and non-participants are different with respect of certain observable and unobservable characteristics. Moreover, the relationship between participation in the PSNP and agricultural outcomes is complex and involves several intermediary variables along the causal pathway. Hence, impact estimation by analysing these complex relationships using observational data is prone to confounding and model misspecification biases.

To address these shortcomings, we use targeted maximum likelihood estimation (TMLE). TMLE is a variant of a doubly robust estimation technique that integrates machine learning algorithms and double robust property (Van Der Laan & Rubin, 2006). The application of TMLE allows us to eliminate possible model misspecification biases and provide estimates that are less prone to outliers and sparsity. We believe that a better understanding of the impact of the PSNP on agriculture has high policy relevance given the Ethiopian government's emphasis on agriculture as a driver of rapid and inclusive economic growth.

2 | METHODS

2.1 | Description of the PSNP

Before 2005, food aid in Ethiopia was mostly addressed via an *ad hoc* distribution of food following drought. While food aid was effective in sustaining lives, it did not solve the underlying problems of famine. In response, the Government of Ethiopia and development partners launched the PSNP in 2005. The PSNP is a part of Ethiopia's food security programme that aims to improve household food security, build household assets, improve livelihoods and resilience to shocks, and break the intergenerational cycle of poverty (Gilligan, Hoddinott & Taffesse, 2009; MoA, 2014; Sharp, Brown & Teshome, 2006). Since its launch, the programme has undergone four phases, evolving in its coverage and modality.

During phase 1 and 2, from 2005 to 2010, the programme reached about 4.8 million people in Amhara, Oromia, Tigray, and the Southern, Nations, Nationalities, and People's regions. Targeting was based on geographic and community criteria. The programme had two components: Public Work (PW) and Direct Support (DS). The PW component was targeted to households who have able-bodied members to participate in labour-intensive public work projects to build community assets, such as rehabilitation and construction of roads, irrigation canals, and water harvesting schemes, for cash or in-kind (food) payments. The DS component was given to households who had no able-bodied members to participate in labour-intensive public work projects. During these phases, PSNP was complemented by an asset-building programme called the Other Food Security Programme (OFSP). The aim of OFSP was to increase household income from agriculture and aid asset accumulation via transfers and provision of other services such as access to credit, agricultural extension, seeds, fertiliser, irrigation, water harvesting schemes, and soil and water conservation.

Phase 3 of the PSNP operated from 2011 to 2015 with the objective of ensuring food security among chronically food insecure rural households (MoA, 2009). It was targeted to food-insecure households in PSNP woredas using asset-based criteria. During this phase, households in PSNP woredas that become food insecure due to transitory shocks were also included in the programme. Vulnerable groups, namely women, youth and pastoral communities, were given special attention. Two new regions, Somali and Afar, were included in the PSNP. The programme also achieved notable improvements in the quality of PWs and timeliness of transfers. A considerable shift in the modality of transfer from food to was made. Similar to in PSNP 1 AND 2, Other sub-components complemented the programme. These includes the Household Asset Building Programme (HABP); Complimentary Community

Investment (CCI); and the Resettlement Programme. The HABP was aimed at diversifying sources of income and increasing productive asset endowments. The CCI's objective was to ensure access to enabling infrastructure for PSNP beneficiaries. It targeted food-insecure households who engage in voluntary resettlement and have able-bodied members. It involves capital intensive community infrastructure development in selected woredas that can best utilise the benefit of CCIs. The Resettlement Programme's objective was to ensure access to adequate food and income, as well as to enable the natural environment, infrastructure and services for resettled households.

Phase 4 of the PSNP operated from 2016 to 2020. This phase's goal was to enhance livelihoods, improve household resilience to shocks and improve food security and nutrition. It was targeted to chronically food-insecure households and households who suddenly became food insecure due to shocks. This basic criterion was supplemented by other criteria, such as household assets, household agricultural and non-agricultural income, and household vulnerability. As in previous phases, the PSNP had two components: DS and PW. Pregnant and lactating women were also assigned to the PW programme, receiving temporary direct support for 12 months. The PSNP was also complemented by other programmes, namely livelihoods and social services. The livelihood component is exclusively targeted to PSNP households based on self-selection criteria. The programme offers a tailored and sequenced package of support for clients in the on-farm, off-farm and wage employment pathways to diversify income sources in addition to asset accumulation (Hoddinott et al., 2012; MoA, 2009, 2014).

2.2 | Theoretical framework: How cash transfers improve agricultural outcomes

In Ethiopia, there is a strong overlap between social protection beneficiaries and agricultural households. Smallholder agriculture is not only a major contributor to employment, the economy, and hope for economic growth, but is also a source of risk and vulnerability (Dorward, Guenther & Wheeler, 2008). Rural livelihoods are vulnerable to shocks (Demeke, Keil & Zeller, 2011; Dercon & Christiaensen, 2011; Dercon, Hoddinott & Tassew Woldehanna, 2006). Credit and insurance markets are not only imperfect, but are often missing.

In this context, household consumption, production and labour supply decisions are interdependent—profit and utility maximisation decisions are not separable. Households could use transfers for consumption smoothing purposes for both the consumption of goods and services and the purchase of inputs for farm production. Hence, although improving agricultural productivity is not the primary objective of the PSNP, the PSNP could affect agricultural outcomes both directly and indirectly by altering spending behaviour, risk behaviour, intrahousehold resource allocation, and participation in social networks, as well as by stimulating the local economy (Tirivayi et al., 2013).

Based on the Tirivayi et al. (2013) framework, we identify plausible pathways through which the PSNP and agriculture are linked (Tirivayi et al., 2013). First, transfers from the PSNP alleviate credit constraints, improve savings and reduce liquidity constraints (Figure 1). This, in turn, alters household spending, investment and risk behaviour, as well as encouraging investment in agricultural inputs and assets. Second, predictable transfers from the PSNP increases certainty and provides insurance against, for instance, weather-related production shortfalls and allows consumption smoothing. Therefore, the PSNP can encourage investment in high-risk, high-return activities and reduces the likelihood of taking adverse risk coping practices, such as selling agricultural assets, and improving agricultural outcomes (Alem & Broussard, 2018).

Third, the PSNP could improve access to agricultural inputs, technology and finance, especially when programmes such as the OFSP, HABP or LH are included. Fourth, public

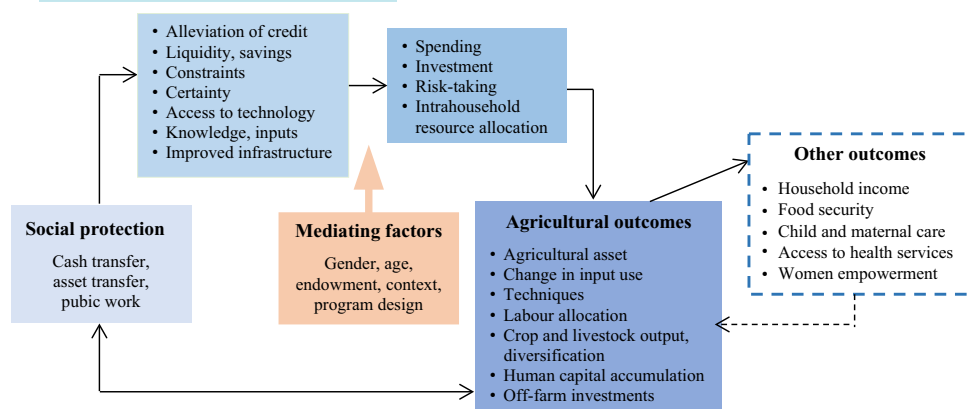


FIGURE 1 Conceptual framework of social protection and agriculture linkages. *Source:* Adopted from Tirivayi et al. (2013). [Colour figure can be viewed at wileyonlinelibrary.com]

infrastructure constructed as part of the PSNP programme improves access to infrastructure and factors of production, such as roads and irrigation water, and improves community assets and the natural resource base, which positively impacts agricultural outcomes. Fifth, given the large number of female recipients in the PSNP, women's access to resources and information from participating in the PSNP improves their bargaining power, increases investments in child human capital (Barrientos, 2012), and positively impacts agricultural production in the long run. Moreover, improved agricultural production also boosts agricultural outcomes by improving household income, food security, women's empowerment, and investment in child health and nutrition (see the dashed line in Figure 1). Participation in the PSNP also creates a platform for participating households to broaden their social network for risk-sharing and acts as social insurance. Furthermore, social protection interventions could have spillover effects to the local economy. For instance, an increase in income from social protection interventions injects cash into the local economy and may alter local demand. This, in turn, stimulates labour markets and demand for goods and services and raises productivity and wages.

Several factors, such as gender, age of beneficiaries, household endowments, programme design and implementation, mediate the relationship between social protection and agriculture. For instance, while interventions targeted to women increase women's bargaining power and bring about greater investments in child health and education (Barrientos, 2012), the higher time investment in social protection activities may reduce care for young children and affect child welfare negatively. Considering the age, household composition, labour supply and time use response, a household with a higher number of able-bodied members are less likely to be affected by labour contribution to public work. Concerning initial human capital, wealthier households are more likely to invest income in agriculture than poorer households. Furthermore, the economic, socio-cultural and environmental context, such as prices, infrastructure, markets, location, susceptibility to natural hazards, social norms, access to services, and so on, also play a greater role in how social protection affects agriculture. For instance, high food prices reduce the purchasing power of income from transfers and savings and investment in productive activities, whereas access to services, such as health care, education and markets, increases the productive impact of social protection and ability to cope with environmental hazards, such as drought, floods and landslides. Finally, programme design, such as targeting, modality, implementation, adequacy, coverage, etc., could affect the impact of social protection on agriculture. For instance, a higher transfer level for a longer duration is proven to have a stronger impact on agricultural assets.

2.3 | Data

We use the second (2013/14) and third (2015/16) waves of the Living Standards Measurement Study—Integrated Surveys on Agriculture (LSMS-ISA) for Ethiopia, which is a nationally representative household panel survey. We have not used the first wave of the LSMS-ISA for two main reasons. First, there were some inconsistencies on how variables were used between the first versus the second and third waves of the survey. Second, while the first survey round was not nationally representative, the second and the third are. Since we are interested in the link between the PSNP and agricultural outcomes, our analysis is limited to the rural sample of LSMS-ISA. The LSMS-ISA survey employed a two-stage probability sampling method. Primary sampling units/enumeration areas (EAs) were selected in each region, based on probabilities proportional to their sizes, followed by the selection of households from each EA. For the rural sample, a total of 12 households were randomly selected from each EA, of which 10 were randomly drawn from the sample of 30 agricultural households and two were randomly drawn from non-agricultural households. The survey gathered detailed crop- and plot-level data, along with a rich set of household- and community-level factors. These include socioeconomic, demographic, asset accumulation, technology adoption, time use, agricultural production, livestock production, input use, marketed produce, community access to services and price level variables. For more details, see <http://surveys.worldbank.org/lsmis>.

2.4 | Measurement

PSNP participation was measured as a dummy variable—‘1’ if any household member participated in the PW component of the PSNP and ‘0’ otherwise.² The main outcome variables considered are ownership of agricultural assets, the share of non-farm income, log value of land, livestock count, fertiliser and improved seed use, access to irrigation water, and hours spent in agricultural and casual work. Details on how these outcomes were measured and coded, as well as their respective covariates that were used when estimating impact are provided in our Table S1.

2.5 | Identification strategy

Causal inference using observational studies is a growing interest to researchers and policymakers. Programmes/policies are often administered based on a certain set of criteria to reach a specific population group more reliably than chance would predict. This often results in systematic differences in participants and non-participants (hereafter, treatment and control) making treatment and control groups not directly comparable. In such conditions, impact estimation is made by carefully adjusting for confounders using causal inference techniques that are based on the Neyman-Rubin potential outcome framework. These techniques rely on structural causal assumptions: conditional exchangeability, positivity, consistency and correct model specification. Methods based on the Neyman-Rubin potential outcome framework, including propensity score matching, inverse probability treatment weighting, and augmented inverse probability treatment weighting, have evolved to become closer to these assumptions. Yet, often model misspecification is a concern, especially when estimating impacts using observational data with a rich set of variables and potentially complex relationships between

²Ideally, we would like to have been able to distinguish between different forms of participation in PSNP. However, due to data limitations (lack of data on whether households participated in complementary programmes of PSNP, for how long, how much income they received, etc.) we had no option but to use a dichotomous measure.

them. Recent advances that integrate machine learning techniques to reach the best possible model, such as TMLE, help reduce bias due to model misspecifications.

TMLE is a doubly robust maximum likelihood-based estimation method that includes a secondary ‘targeting’ step to optimise the bias-variance trade-off for the parameter of interest (Van Der Laan & Rubin, 2006). TMLE is a semiparametric method that improves the chances of correct model specification by allowing a flexible estimation using machine-learning techniques, particularly the Super Learner which is a cross-validation based estimator selection approach. TMLE is related to other outcome- and treatment-based models, such as G-computation and propensity score methods, as it involves estimating the outcome model $E(Y|A, X)$ and treatment model $P(A = 1|X)$ (Van Der Laan & Rubin, 2006). However, unlike PSM and G computation that rely on modelling only the treatment or the outcome mechanism, TMLE models both the outcome and treatment model, a characteristic termed as doubly robust. Thus, TMLE yields unbiased estimates of treatment effects if either the outcome or the treatment model is consistently specified (Van der Laan & Rose, 2011).

TMLE has several features that make it particularly attractive for causal inference in observational data (Van der Laan & Rose, 2011). First, TMLE is an asymptotically efficient estimator when both the outcome and exposure mechanisms are consistently estimated. Unlike conventional methods in which analysts choose the functional form, TMLE maximises the chance of correct model specification using ensemble learning algorithms to reach the best fitting model. Second, TMLE is doubly robust, giving less biased estimates when either the treatment or outcome models are incorrectly specified. Third, unlike other doubly robust estimation techniques, such as Inverse Probability Weighted Regression Adjustment and Augmented Inverse Probability Weighting, TMLE is less sensitive to near positivity violations (estimated propensity scores are close to 0 and 1) and bias due to the overfitting problem from poor overlaps between treatment and control observations.

We followed the below four steps to implement TMLE:

Step 1: Generate an initial estimate of outcomes of interests ($E(Y|A, X)$): This step involved estimating the conditional expectation of outcomes of interests³ (Y) given the exposure status of the PSNP (A) and the other covariates⁴ (X) to obtain the potential outcomes Y^1 and Y^0 , corresponding to $A = 1$ and $A = 0$, respectively. To do this, we used G-computation, a maximum-likelihood-based substitution estimator that relies on the estimation of the conditional expectation of the outcome given the exposure and covariates.

Step 2: Estimate the probability of receiving the PSNPP ($A = 1, X$): Here, we estimated the conditional probability of receiving PSNP benefits given the observed cofounders, $P(A = 1|X)$. The predicted probability of receiving treatment PSNP benefits given observed covariates, $P(A = 1, X)$, and the predicted probability of not receiving PSNP benefits $P(A = 0, X)$ was computed for each observation.

Step 3: Update initial estimate of our outcome of interest ($E(Y|A, X)$): In this step, the estimated values of Y^1 and Y^0 from the first step were used to update the estimates to reduce the bias of confounding variables, T . To do so, the clever covariate $H_a(A = a, x) = \frac{I(A=1)}{\hat{\pi}_1} - \frac{I(A=0)}{\hat{\pi}_0}$ was introduced. In other words, for each observation we calculated $H_1(A = 1, x) = \frac{1}{\hat{\pi}_1}$ and $H_0(A = 0, x) = -\frac{1}{\hat{\pi}_0}$ with each observation's Y , H_1 , and H_0 , in a logistic regression model with the assumption of a constant intercept. This model was fitted as:

$$\text{Logit}(E^*(Y|A, X)) = \text{Logit}(\hat{Y}_a) + \delta * H_a,$$

³See Table 2.

⁴See Table 2..

where the δ is a fluctuation parameter consisting of two values (δ_1 and δ_0) for the model. $1/\hat{\pi}_1$ was used to generate $\hat{\delta}$, leading to the following model:

$$\text{Logit}(\hat{Y}_1^*) = \text{logit}(\hat{Y}_1) + \hat{\delta} * H_1) \quad \text{and} \quad \text{Logit}(\hat{Y}_0^*) = \text{logit}(\hat{Y}_0) + \hat{\delta} * H_0),$$

where H_a is the predefined covariate used in the targeting step for the average treatment effect (ATE). Then, updated (“targeted”) estimates of the set of potential outcomes that incorporate the clever covariate were generated. These potential outcome estimates have the same interpretation as the initial estimates of the potential outcomes obtained in Step 1, but are numerically distinct.

Step 4: Generate the targeted estimate of the target parameter: With the new individual-specific Y_1 and Y_0 from Step 3, we estimated the targeted ATE as:

$$\widehat{ATE} = \frac{1}{n} \sum_{i=1}^n [\hat{Y}_1^* - \hat{Y}_0^*],$$

where *ATE* is the causal difference in the outcome of interests that would be observed if all individuals in the population of interest were PSNP beneficiaries compared to no exposure to the PSNP.

Alternatively, the causal model could be explained by the diagram in Figure 2.

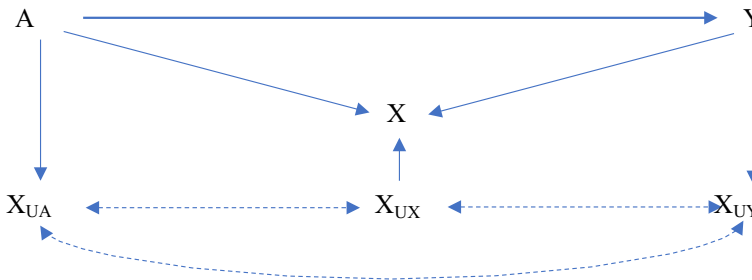


FIGURE 2 Causal diagram. *Source:* Authors. [Colour figure can be viewed at wileyonlinelibrary.com]

where *A* is the treatment, *Y* is the outcome variable, *X* is a confounder of the association between the *A* and *Y*, and *U* denotes unmeasured confounders.

All analyses were conducted using Stata version 16.0 (StataCorps, 2019). Particularly for the estimation of ATE using TMLE we used the ‘*eltmle*’ command in Stata that uses the SuperLearner R package v.2.0–21 developed by Polley, Rose and Van der Laan (2011) and the default SuperLearner algorithms used in the base installation of the *tmle-R* package by Keino et al. (2014) Gruber & Van der Laan (2010) which was implemented using R version 4.0.3. For more information see Luque-Fernandez (2019).

2.6 | Robustness check

To estimate the average effect of PSNP treatment (or exposure) on outcomes of interests, we did additional analyses using inverse probability of treatment weighted regression adjustment. Results are comparable with findings from the TMLE (File S1).

3 | RESULTS

3.1 | Demographic and socioeconomic characteristics

Table 2 shows the demographic and socioeconomic characteristics of the study sample by their respective PSNP participation. As far as household characteristics are concerned, compared to non-PSNP households, PSNP households have less-educated adult members, are more likely to be headed by a literate head, spend less on food and non-food items, own fewer durable assets (but own more agricultural tools), and have fewer employed-household members. Regarding input use, PSNP households are less likely to use fertiliser, herbicide/pesticide, and improved seeds compared to non-PSNP households. Moreover, PSNP households are more likely to have experienced shocks (drought, illness of a family member, and loss of livestock) and sell livestock to cope with shocks. Considering other characteristics, PSNP households own less land, spend more hours on agricultural work (but less on non-agricultural work) in the past 7 days, live farther from large weekly markets, obtain more income from the sale of livestock (but less from the sale of crops), are less likely to participate in agricultural extension and obtain advisory services, and produce fewer diversified crops. As far as community

TABLE 2 Socioeconomic and demographic characteristics of the sample

Factors	Non-PSNP (N = 7811)	PSNP (N = 843)	p-value
Average age of adult household members*	38.9 (12.6)	38.4 (10.0)	0.21
Number of adult household members*	2.2 (0.9)	2.3 (0.9)	0.23
Adult members who can read and write (%)*	0.4 (0.4)	0.3 (0.3)	<0.001
Household head age (years)*	45.7 (15.4)	45.8 (13.7)	0.88
Household head is male	5615 (71.9%)	611 (72.5%)	0.72
Household head is literate	3625 (46.4%)	478 (56.7%)	<0.001
Real expenditure per adult*	2.9 (3.1)	2.5 (2.2)	<0.001
TLU at the time of survey*	2.5 (2.8)	2.5 (3.0)	0.99
Household is in the lowest agricultural asset tercile	2724 (34.9%)	244 (28.9%)	<0.001
Household is in the lowest durable asset tercile	2726 (34.9%)	422 (50.1%)	<0.001
Total area (ha)*	1.3 (1.5)	0.8 (1.0)	<0.001
Agricultural work in the past 7 days*	36.0 (46.9)	53.6 (52.2)	<0.001
Non-agricultural work in the past 7 days*	9.0 (23.7)	6.2 (17.9)	<0.001
Casual work in the past 7 days*	2.2 (9.5)	2.3 (9.6)	0.88
Any employment in the past 12 months	1437 (18.4%)	123 (14.6%)	0.006
Non-farm enterprise in the past 12 months	811 (10.4%)	74 (8.8%)	0.14
Use of credit services	947 (15.0%)	111 (14.1%)	0.5
Distance to the nearest large weekly market (km)*	5.7 (12.2)	11.2 (17.2)	<0.001
Female makes decision on livestock management	442 (7.0%)	50 (6.4%)	0.48
Drought in the past 12 months	1088 (13.9%)	339 (40.2%)	<0.001
Illness of a household member in the past 12 months	1141 (14.6%)	143 (17.0%)	0.068
Great loss/death of livestock in the past 12 months	364 (4.7%)	95 (11.3%)	<0.001
Coping strategy: Relied on own savings	1167 (14.9%)	123 (14.6%)	0.79
Coping strategy: Sold livestock	608 (7.8%)	138 (16.4%)	<0.001

(Continues)

TABLE 2 (Continued)

Factors	Non-PSNP (N = 7811)	PSNP (N = 843)	p-value
Household uses fertiliser	4085 (66.1%)	437 (56.1%)	<0.001
Kg of fertiliser used per hectare*	61.9 (639.8)	35.3 (123.4)	0.25
Household used improved seed	1083 (19.5%)	102 (15.5%)	0.013
Kg of improved seed used per hectare*	0.4 (1.0)	0.4 (1.1)	0.37
Household used pesticide/herbicide	1669 (21.4%)	115 (13.6%)	<0.001
(Log) value of livestock sold*	3.9 (3.9)	4.5 (3.8)	<0.001
(Log) value of crop sales per hectare*	4.3 (3.7)	3.0 (3.4)	<0.001
Participated in agricultural extension	2322 (36.8%)	222 (28.2%)	<0.001
Borrowed credit over the past 12 months	947 (15.0%)	111 (14.1%)	0.5
Obtained advisory services	3,536 (56.0%)	373 (47.3%)	<0.001
Simple count of food crops produced*	5.3 (3.9)	3.8 (3.0)	<0.001
Simple count of food livestock produced*	2.5 (1.7)	2.5 (1.6)	0.31
Improved advisory services about crop production**	4166 (53.3%)	537 (63.7%)	<0.001
Improved advisory services about natural resources**	4324 (55.4%)	563 (66.8%)	<0.001
Improved advisory services about livestock production**	3912 (50.1%)	464 (55.0%)	0.006
Able to find fertiliser in the community**	3266 (41.8%)	354 (42.0%)	0.92
Able to find pest/herb distributors in the community**	1877 (24.0%)	137 (16.3%)	<0.001
Able to find improved seed in the community**	3123 (40.0%)	389 (46.1%)	<0.001
# of farmers using an irrigation scheme*	179.5 (346.3)	254.4 (398.0)	<0.001
Proper rain in the past growing season	2474 (31.7%)	222 (26.3%)	0.001

Notes: HH, Household; TLU, Tropical Livestock Units; * = mean (Standard Deviation); and ** = compared to 2 years ago.

characteristics are concerned, PSNP households are more likely to live in communities that have experienced improvements in advisory services related to crop production, livestock production and natural resource management, less connected to markets, have better access to improved seeds (but less access to agrochemicals,) are less likely to receive proper rainfall (perceived) and have a higher number of farmers who have access to irrigation compared to non-PSNP households.

3.2 | The impact of PSNP participation on agricultural outcomes

Table 3 presents TMLE results of the effect of participation in the PSNP on different domains of agricultural outcomes. In the asset domain, we find that PSNP participation improved ownership of agricultural tools, as well as the value of land and livestock sales. However, PSNP participation reduced income from crop sales and had no impact on livestock ownership or crop and livestock count. Considering household-level agricultural services, PSNP participation has no impact on access to extension and advisory services. However, PSNP participation improved household participation in watershed activities. Considering input use, we find that PSNP participation has no impact on the adoption and intensity of fertiliser and improved seed use. When it comes to time allocation, we observe that while PSNP participation

TABLE 3 Impact of the Productive Safety Net Programme on agricultural outcomes

	Average Treatment Effect	Standard Error
Productive asset ownership		
Own any type of agricultural tool	0.020***	0.007
Livestock (TLU today)	0.024	0.200
Livestock (TLU one year ago)	-0.100	0.200
(Log) value of livestock sale	0.500***	0.200
(Log) value of land reap per hectare	0.013**	0.006
(Log) value of crop sale	-0.900***	0.200
Agricultural services		
Better advice on crop production from an extension agent	0.105***	0.018
Better advice on natural resource management from an extension agent	0.122***	0.016
Better advice on credit from an extension agent	0.081***	0.021
Better advice on livestock production from an extension agent	0.068***	0.019
Community access to irrigation water	0.102***	0.018
# of household in the community who have access to irrigation water	98.900***	17.400
Household received advice from an extension agent	-0.004	0.019
Household borrowed credit in the past 12 months	0.015	0.017
Household obtained advisory services	-0.014	0.019
Household participated in watershed activities	0.148***	0.014
Input use		
Household used fertiliser in the past 12 months	0.002	0.020
Kg of fertiliser use per hectare	-0.300	0.100
Household used improved seed in the past 12 months	-0.010	0.017
Kg of improved seed used per hectare	-0.001	0.006
Count of crops produced	0.200	0.300
Count of livestock produced	0.000	0.100
Time allocation		
Hours spent on agricultural work	9.200***	2.200
Hours spent on non-agricultural work	-0.011**	0.004
Hours spent on casual work	0.001	0.006
Share of non-farm income	10.700***	1.000
Other outcomes		
Borrowed credit over the past 12 months	0.062***	0.020
Female member makes decision about crop and/or livestock production	0.001	0.006

Notes: β is targeted maximum likelihood estimation of average treatment effects. The model accounted for durable asset quantile, total expenditure, food gap, agroecological zones, household size, number of adults, number of adults who can read and write, adult age, access to credit, shocks (drought, loss of livestock, illness), distance to the market, change in TLU, non-farm enterprise, household head sex, and area of land owned. Kg stands for kilograms.

increases time spent in agricultural work, it had a marginally negative impact on time spent in non-agricultural work and no significant effect on casual work time. Moreover, PSNP participation improved the share of income obtained from non-farm sources and borrowing on credit over the past 12 months. Regarding women's control over resources, PSNP participation has not improved women's control over resources as measured by land and livestock ownership.

PSNP participation improved advisory services for crop and livestock production, natural resource management, and credit at the community level. Moreover, PSNP participation improved access to irrigation water and the number of households using irrigation water in a given community.

4 | DISCUSSION

Transforming smallholder agriculture into a more productive and competitive sector has received greater attention in Ethiopia's goal to eradicate poverty and promote rapid and inclusive economic growth (NPC, 2016). Despite being one of the important avenues for agricultural transformation, the extent to which the PSNP has contributed to improving agricultural outcomes is not well documented. In this paper, we estimate the impact of the PSNP on various agricultural outcomes. Although we find no impact of the PSNP on technology adoption, women's control over income, crop and livestock count, and access to extension service at the household level, PSNP participation increased ownership of agricultural tools, the value of livestock sale, the share of non-farm income, time spent on agricultural work, access to credit at the household level, community access to irrigation water, and improved advisory services on natural resource management, credit, and crop and livestock production.

We find that PSNP participation improved ownership of agricultural tools, land value and livestock sales, but had no impact on crop and livestock production count or livestock ownership. Our results are consistent with Berhane et al. (2014), who report a positive impact of the PSNP on ownership of agricultural tools, as well as Anderson et al. (2011) and Gilligan et al. (2009) who reported no impact of the PSNP on livestock holdings (Andersson, Mekonnen & Stage, 2011; Gilligan, Hoddinott & Taffesse, 2009). In contrast, Berhane et al. (2014) find that PW participation alone increased livestock holdings by 0.38TLU and Debela and Holden (2014) report a 2.68TLU gain from PW participation in the Tigray region (Debela & Holden, 2014). Zewdu (2015) also find a significant positive impact of PW on livestock holdings. A positive impact of the PSNP on tree holdings has also been reported (Andersson, Mekonnen & Stage, 2011; Zewdu 2015).

As far as production diversity is concerned, we found no impact of PSNP on both crop and livestock production. Similarly, a study by Debela et al. (2021) showed that participation in a food for work programme had no impact on crop production diversity as measured by the production of cereals, legumes and seeds, vegetables, fruits, and spices (Debela, Shively & Holden, 2021). Debela et al. (2021) argue that this result indicates lack of displacement of labour from agriculture to PW that may influence production choices and hence lack of impact of PW in crowding out labour for own agricultural production (Devereux & Guenther, 2009). A number of studies show that production diversity, to a certain level, is associated with improved household diets (Bahru, 2021; Jones, 2016; Jones, Shrinivas & Bezner-kerr, 2014; Sibhatu, Krishna & Qaim, 2015; Sibhatu, & Qaim, 2018). However, this possible indirect impact was not found in our study.

For indirect linkages, through improving human capital such as household food security and nutrition, which possibly alter agricultural outcomes in the long run, the literature shows mixed evidence (Bahru et al., 2020). While some studies show a positive impact of PSNP in narrowing the food gap (Berhane et al., 2014; Gilligan, Hoddinott & Taffesse, 2009), reducing concerns about lack of adequate food and reducing child chronic undernutrition (Porter & Goyal, 2016), increasing child meal frequency (Bahru et al., 2020; Berhane et al., 2011), reducing acute child undernutrition (Debela, Shively & Holden, 2015; Porter & Goyal, 2016), others have shown lack of impact of PSNP on child chronic and acute undernutrition, and child dietary diversity, and household food security (Bahru et al., 2020; Berhane et al., 2017). This evidence is also indicative of the lack of impact of PSNP on underlying factors such as improved

agricultural outcomes, which ultimately improve household food security and nutrition and exert a backward influence on agricultural outcomes.

Given the strong need to improve agricultural productivity and food security in Ethiopia, understanding drivers of productivity-enhancing modern agricultural inputs is important. Our study finds no impact of the PSNP on the adoption and intensity of fertiliser and improved seed use. Similar to asset ownership, the literature on the impact of the PSNP on fertiliser and improved seed adoption is not definitive—the impact varies greatly by household wealth status, sample population, programme modality and duration of participation (Table 1). Considering only PW participation and all highland regions, some studies find no impact of the PSNP on adopting fertiliser and improved seed (Gilligan, Hoddinott & Taffesse, 2009; Hoddinott et al., 2012). Using data from six peasant associations across rural Ethiopia, Alem and Broussard (2018) find no impact of FFW on fertiliser adoption in the long run (1999–2009), and find a positive impact in the short run and for households with more livestock (Alem & Broussard, 2018). Drawing data from the Tigray region and PW participation, Araya and Holden (2018) find a positive impact of the PSNP on the adoption of fertiliser, but no impact on the intensity of fertiliser use (Araya & Holden, 2018; Bezu & Holden, 2008). Moreover, Gilligan et al. (2009) and Hoddinott et al. (2012) find a positive impact of the PSNP on fertiliser and improved seed use when coupled with an asset-building programme (Gilligan, Hoddinott & Taffesse, 2009; Hoddinott et al., 2012).

Previous studies in Ethiopia show that safety nets, in particular FFW, can increase fertiliser adoption by acting as insurance for *ex-post* consumption risk (Alem & Broussard, 2018) and by relaxing liquidity constraints (Bezu & Holden, 2008). However, low expected consumption in the aftermath of a harvest failure and the lack of insurance to smooth consumption trap households in low-risk, low-return activities and perpetuate poverty (Dercon & Christiaensen, 2011). Moreover, evidence shows that the increase in the intensity of fertiliser use is observed for relatively wealthier beneficiaries (Alem & Broussard, 2018). A recent meta-analysis also finds a strong effect of wealth on fertiliser adoption (IFAD, 2020). However, in our sample, PSNP households own significantly less livestock, household durables, and agricultural assets and are more likely to experience shocks than non-PSNP households (Table 2). This may have hindered farm households from taking high-risk, high return activities. Hence, the lack of impact on technology adoption in our study could be due to risk aversion in fear of an *ex-post* consumption decline due to shocks and the low asset endowment of beneficiary households. This shows that interventions that increase household endowments via asset transfers in addition to PW transfers, may increase household endowments and enable households to take high-risk, high return activities.

A framework by Tirivayi et al. (2013) shows that cash transfers could improve agricultural outcomes by alleviating credit and liquidity constraints, increasing certainty and by acting as insurance against risks, and improving access to inputs (Tirivayi et al., 2013). Moreover, cash transfer programmes, such as Ethiopia's PSNP that has public work components, could improve access to infrastructure, community agricultural assets, and access to agricultural markets. We also find that PSNP participation increases household access to credit, household participation in watershed activities, and community-level advisory service on crop and livestock production, access to credit, and natural resource management. However, at the household level, PSNP participation has no impact on extension and advisory services. The lack of impact at the household level could partly be because the PSNP is a geographically targeted programme where most interventions, especially for PW infrastructure, happens at the community level. Community asset creation does not guarantee that all community members, including PSNP beneficiaries, could utilise assets created due to lack of initial endowments, such as land and livestock, to utilize created assets. This is likely to hold true for PSNP households given their lack of endowments as can be seen from our descriptive analysis (Table 2). Moreover, this finding points to the fact that transfer levels might be too low to

enable households to cross an asset threshold. Both levels and combinations of assets are necessary to engage in productive activities—one needs to have access to a certain plot of land to use irrigation water for crop production (Carter & Barrett, 2007). This finding, along with the low level of endowment of PSNP households, suggests that asset transfers that are high enough to lift households above asset thresholds might help create productive impacts.

We find that PSNP improved community access to irrigation water. Others have also shown that PSNP improved water harvesting, retention and utilisation approaches including irrigation systems (Solomon et al., 2015). Moreover, implementation of integrated soil and water conservation and soil fertility measures in combination with irrigation and fertiliser on a cropland improves dry matter yield in PSNP areas (Solomon et al., 2015). As shown in other studies, improved access to irrigation water is associated with good welfare outcomes, such as crop diversity, improved food security, better nutrition, and poverty reduction (Cafer et al., 2015; Hagos et al., 2017). Access to irrigation, credit and extension packages is also seen to enable households to be self-resilient and to lead to graduation (Sabates-Wheeler, Tefera & Bekele, 2012). However, despite the positive impact on access to irrigation water, no impact was observed on the outcomes at the end of the causal chain, such as income from agriculture. Although improvement in access to irrigation water is a good outcome and may affect households directly through use in agricultural production and indirectly through increasing food production, lowering food prices and smoothing seasonal price fluctuation, the low endowment of PSNP households may not have enabled them to use the benefit of improved access to irrigation water. This suggests that household-level interventions would improve the productive capacity of households to make better use of community assets.

As suggested by Tirivayi et al. (2013), context, gender, age of beneficiaries, initial endowments, programme design and implementation mediates the relationship between social protection and agricultural outcomes (Tirivayi et al., 2013). Our data also shows that PSNP household characteristics do not generate positive mediating effects (Table 2). PSNP households have lower household durable and agricultural assets, are more likely to have a female, older, and less-educated household head, have older adult members, have less educated members, and are more likely to experience shocks. For instance, the proportion of households headed by women is higher among PSNP beneficiaries. Hence, participation might have increased women's time burden and allowed them less time for productive activities, such as agricultural production. Moreover, PSNP households were headed by older members and had a higher number of older adult members compared to their non-PSNP counterparts. Therefore, more labour requirements from the PSNP mean less time invested in agricultural activities. Considering endowments, PSNP households have fewer adult and educated members, own a smaller plot of land, own less livestock, and have fewer durable assets than non-PSNP households. As far as access to markets is concerned, PSNP households lived farther away from markets than their non-PSNP counterparts.

5 | STRENGTH AND LIMITATION

This study contributes to a growing body of literature related to social protection and agriculture by providing a rigorous assessment of the impact of the PSNP on a range of agricultural outcomes. The use of large sample size, a wide range of outcomes considered, and the application of method that improves model specification, outliers and sparsity is among the strengths of this study. Nevertheless, this study is not without limitation. Although the dataset used in this study is nationally representative, whether this data has enough power to detect the impact of the PSNP on agricultural outcomes is subject to debate. Moreover, in this study, we measured PSNP participation as a 0/1 variable, which is far from ideal. PSNP participation could bring different levels of benefit depending on whether households participate in other

complementary programmes of the PSNP such as the household asset building programme for which PSNP households are given priority. Hence, the measurement of our treatment variable may cast some doubt on whether the consistency assumption holds. In addition, although some outcomes are endogenously determined by PSNP participation, we were not able to address this issue due to lack of valid instruments.

6 | CONCLUSION

Ethiopia has made significant strides to improve smallholders' agricultural productivity and alleviate chronic food insecurity. Social protection has been implemented to address food insecurity and vulnerability of millions of Ethiopians and was one of the most important pillars of Ethiopia's agricultural transformation into a more productive and competitive sector. In this study, we use two rounds of representative panel data from the LSMS-ISA to measure the impact of the PSNP on agricultural outcomes. We use a novel identification strategy that maximises the chance of a correct model specification and highly robust to outliers, and near positivity violation. At the household level, we find no impact of the PSNP on technology adoption, women's control over assets, and access to advisory services. However, PSNP participation increased income from livestock sales, the share of income from non-farm sources, and access to credit. Paradoxically, we observe that PSNP participation improved access to irrigation at the community level, agricultural advisory services on crop production, livestock production, access to credit, and participation in watershed activities. Although we cannot rule out all pathways, our results suggest low capability of PSNP households to make use of improved community access to inputs and advisory services, which reflects their lower level of endowments. Moreover, others have reported delays and underpayment of entitled public work transfers (Berhane et al., 2014; Gilligan, Hoddinott & Taffesse, 2009), which may have reduced the productive impact of the PSNP. We recommend integrating household-level interventions that could lift household endowments to help households cross asset thresholds to allow PSNP households to take advantage of the productive use of created community assets. This could be achieved via complementing cash or in-kind transfers with productive asset transfers and improving the timeliness and size of cash or in-kind payments. Doing so may elevate the impact of the PSNP beyond the improvement in community access to inputs, promoting agricultural development and fuelling economic growth. To generate additional insights, we recommend further research on how PSNP induced community asset improves agriculture.

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CONFLICT OF INTEREST

None.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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