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DOES PARTICIPATION IN PUBLIC WORKS PROGRAMS ENCOURAGE FERTILIZER USE IN RURAL ETHIOPIA?

Laura Villegas
Department of Agricultural and Resources Economics
North Carolina State University, USA, Email: lvilleg@ncsu.edu

Vincent Smith
Department of Agricultural Economics and Economics
Montana State University, USA, Email: vsmith@montana.edu

Joe Atwood
Department of Agricultural Economics and Economics
Montana State University, USA, Email:jatwood@montana.edu

Eric Belasco
Department of Agricultural Economics and Economics
Montana State University, USA, Email:eric.belasco@montana.edu

Abstract

A sixth of the world's population receives inadequate nutrition. The problem is especially severe in Africa where agricultural sectors are dominated by subsistence farmers. African small-holder farmers could double crop yields by doubling their fertilizer use. Yet, in many countries, subsistence farmers do not utilize advanced inputs that are apparently available to them at subsidized prices. This study evaluates the impact of food aid programs on agricultural productivity via changes in participants' input decisions. It also identifies the main determinants of participation in public works programs and fertilizer use and examines whether these decisions affect one another. Using a unique cross-sectional sample of households from rural Ethiopia that permits us to examine the relation between fertilizer use and participation in a recently established safety net program, we apply novel econometric techniques to compute the marginal effects of a system of two simultaneous models with binary and censored latent dependent variables.

Keywords: *Aid Program, food aid, public works, fertilizer application, Ethiopia*
JEL Codes: O13, P45, Q10, Q12, Q19

1. Introduction

"Most of the people in the world are poor, so if we knew the economics of being poor, we would know much of the economics that really matter. Most of the world's poor people earn their living from agriculture, so if we knew the economics of agriculture we would know much of the economics of being poor."

~T.W. Schultz, 1980

A sixth of the world's population receives inadequate nutrition (FAO Hunger Report, 2009). The problem is especially severe in Africa where agricultural sectors are dominated by systems of subsistence small-holder farming. The adoption of new agricultural

technologies such as chemical fertilizer may be an essential prerequisite to enable these households, among the poorest in the world, to escape extreme poverty (International Fund for Agricultural Development, 2011). Various policies have been proposed to increase the adoption of new technologies and help families meet nutritional needs. One is the provision of economic assistance through aid-subsidized income safety net programs. In this paper, we examine the effect of one such initiative, the Ethiopian Productive Safety Net Program, on technology adoption in rural Ethiopia as represented by the use of chemical fertilizer.

Evidence of the general effect of food aid programs on the adoption of improved agricultural technologies among poor households is mixed and context-specific. With respect to Ethiopia, several previous studies that have examined the effects of food aid on agricultural production, labor supply and asset investment find no evidence that food aid provides disincentives for on-farm production, asset investment and technology adoption (Berhane et al., 2011; Bezu & Holden, 2008; Little, 2008; Yamano et al., 2005; Dorosh et al., 1995 & Bezuneh et al., 1988). These results are consistent with findings reported by several researchers for other countries and regions (Devereux et al., 2008; Hoddinott, 2008; Dercon, 2005; Abdulai et al., 2005; Lentz, 2003; Dorosh et el., 1995; Bezuneh et al., 1988). However, the evidence is not definitive. Therefore, in this study, we examine the impacts of the Ethiopian Productive Safety Net Program on technology adoption by Ethiopian small-holder farms. Our empirical results indicate that participation in public works programs and other income support programs to some extent increases the probability of using chemical fertilizers and the extent of their use.

This paper is organized as follows. Section 2 provides background information of Ethiopia's agricultural sector and describes the Ethiopian Productive Safety Net Program (PSNP from now on). In section 3, we provide a brief review of the literature. A theoretical model of agricultural household behavior that accounts for the potential effects of household members participating in a public food for work programs is presented in Section 4. Section 5 describes the data used in the empirical analysis and the methodology is described in section 6. Section 7 presents and interprets presents, interprets and discusses the implications of the estimation results the estimation results. In section 8 economic and policy implications are discussed. We conclude the paper with some final remarks in section 9.

2. Background Information

Agriculture is the most important sector of Ethiopia's economy, accounting for over 46% of GDP, 84% of exports and 80% of employment. Agricultural output in Ethiopia is, for the most part, produced by small-holder farm households. Households typically consist of 5-7 members farming 1 hectare of land primarily for household consumption. Food security is therefore a major concern for most of those families. To alleviate risks of food insecurity trough support from foreign aid, from January 2005 to December 2006, the Ethiopian government launched the Ethiopian Productive Safety Net Program.[1] In this initial phase, the Ethiopian Productive Safety Net Program distributed $370 million worth of food and cash donations, it covered 7 out of Ethiopia's 10 regions and targeted 318 out of 500 *woredas* or districts. Within these districts, it had a target caseload of 7.75 million people (9% of Ethiopia's population).

The PSNP operates as a safety net, primarily targeting transfers to chronically food insecure households in two ways: through Public Works (PW) wages and Direct Support (DS) payments. The assignment and the distribution of aid and wages are determined through a complex procedure which differs for PW and DS components. The aid assigned to DS programs is distributed to specific *woredas* according to their needs assessments and the overall quantities of food aid already received in the current period. The *woredas* council subsequently allocates quotas to *tabia* (a cluster of villages) and households. Households

eligible for DS transfers are those who, in addition to being chronically food insecure, have no labor and no other sources of support. (They may include labor-scarce households whose primary income earners are elderly or disabled, orphans, people who are sick, pregnant or lactating.) These households receive 30 Ethiopian birr ($3.5) or 15 kg of grain per person, per month, for six months each year.

In contrast, food and cash assistance delivered through PW are provided as an investment in agricultural production and conservation; thus, rather than distributing free aid to those in need, the PW concept requires able-bodied beneficiaries to work for food or a cash wage. The general idea of the program is to employ food-insecure farm workers during the slack season (when little work needs to be done on the farm) and pay them with food or cash to build public infrastructure like roads or irrigation canals, participate in afforestation activities, or work on building soil and water conservation structures. Geographic and household-level targeting is used to select PW beneficiaries. Drought-prone geographic areas are selected first. In these areas, the amount of food targeted for recipient *woredas* is based on the number of workdays needed to complete the projects proposed and designed by local administrative agencies. (The types of public works are determined at the local level and therefore differ from village to village.) Then, participants are selected by local community leaders are either given three kilograms of cereals (usually maize) or a cash payment of 6 Ethiopian birr ($0.7) per day of work. Beneficiaries are paid for up to five days of work per month per household member, for six months each year.[2] There is however, evidence that the payment rate varies between villages (Barret et al., 2002).

The bulk of the program's resources (85%) are distributed through public works wages (the remaining 15% of the resources are distributed through unconditional, direct support transfers).[3] The general idea of the public works program is to employ food-insecure farm workers during the slack season (when little work needs to be done on the farm) and pay them with food or cash to build public infrastructure like roads or irrigation canals, participate in afforestation activities, or work on building soil conservation structures with the objective of indirectly enhancing productivity growth in the long run. We examine the impact of participation in PSNP public works programs on technology adoption (measured as the kilograms of chemical fertilizer used by the household in preparation for the main harvest season in the year, the Meher, which occurs between October and January and accounts for 90-95% of the country's annual food output).

3. Literature Review

The issue of technology adoption as a mechanism for agricultural development and overall economic growth has received extensive attention in the form of theoretical and econometric studies. There is a broad consensus within the literature that technology adoption and diffusion are the result of a complex decision-making process, particularly when examined at the micro-economic level. Those decisions have been found to depend on a wide array of factors related to agro-ecological factors; farmer demographics and political, cultural and economic institutions of a particular social environment. Similarly, the literature on the role of food aid as a tool of rural development has been the focus of a rich debate. Some empirical results suggest that food aid distribution programs can encourage adoption of technologically advanced agricultural inputs (Gilligan et al., 2008; Bezu & Holden, 2008; Bezuneh et al., 1988). However, evidence of this aspect of agricultural development remains limited. With respect to Ethiopia, numerous reviews and evaluations have concluded that the PSNP is having a positive impact on food security. Yet, impact evaluations vary in their assessment of the extent of the program's contribution. In examining the impacts of food aid on agricultural productivity via technological change, this study seeks to contribute to the limited empirical literature devoted this issue. In this section we present a thorough review of

works in the areas of development and agricultural economics comprising key results regarding the impacts of social safety nets and food aid on innovation decisions among subsistence farmers.

In many sub-Saharan African countries, international aid provides the primary resources to sustain social protection or safety net programs (Barrett & McPeak, 2006). Several studies of agrarian societies have attempted to identify the effects of food assistance programs on rural and economy-wide economic development. On one hand, the argument that food aid programs are beneficial to African agriculture emphasize the role of food aid in increasing poor household's access to, and consumption of, food in the face of shocks, improving nutritional status, health, labor productivity, and income earning capacity of the beneficiaries (Abdulai et al., 2005). On the other hand, critics of food aid programs note that food aid deliveries depress food prices and discourage food production. One argument is that they create disincentives for work and investment (either on the farm or in the off-farm labor market) as a result of increased in income (Bezu & Holden, 2008; Holden et al., 2004; Gebremedhin et al., 2002). Nevertheless, several studies have reported that when careful controls for other potential effects are included in the analyses, food aid flows do not appear to have created disincentives for local agricultural production, labor supply, asset investment, or mutual support (Abdulai et al., 2005; Letz, 2003; Dorosh et el., 1995; Bezuneh et al., 1988).

Other critics of assistance schemes report that food aid programs have overall negative impacts on economic growth (and may have a role in perpetuating poverty among recipient countries) as they induce governments to reduce expenditure on the provision of relief (Agenor & Aizenman, 2010). Some provide evidence that food aid's characteristic volatility and poor timing have adverse impacts on household welfare and long-term development as future income uncertainty increases current consumption at the expense of investment (Desai & Kharas, 2010). In addition, questions have been raised about the longer term benefits of food aid programs and their impacts on labor markets. Recent studies have suggested that food payments may not be sufficient to compensate for the caloric requirement of the work performed, resulting in poor health and malnutrition of the participants (Gobostwand et al. 2008). Other analysts find that food for work programs have limited effects on the dietary diversity of rural households as participants shift crop mixes from nutritious to higher priced commodities (Uraguchi & Zenebe, 2011; Bezuneh et al., 1988). More recently, some researchers have asserted that the design of food for work programs is generally poorly informed and conceptually based on weak empirical evidence (Ravallion, 2012). They criticize the administrative and operational efficiency of food-for-work and food-for-training programs, question the adequacy food-based rather than cash forms of payment, the timing of payment deliveries, and doubt the efficient targeting of the programs.

Overall, the literature on international aid programs has provided only limited empirical evidence about their impacts on labor allocation and labor market participation decisions. Sometimes aid appears to encourage increased work and sometimes it does not; the results appear to be highly context-specific. In Ethiopia, most studies do not find evidence to support the existence of disincentive or dependency effects (Berhane et al., 2011; Bezu & Holden, 2008; Little, 2008; Yamano et al., 2005; Dorosh et al., 1995 & Bezuneh et al., 1988). On the contrary, recent research reports that social transfer programs facilitate savings and investments, encourage innovation, and offer new employment opportunities that have the potential of improving the community's human capital (Bezuneh et al., 1988). Some analysts suggest that social protection programs help to address market failures and alleviate economic pressures by providing the beneficiaries with liquid assets and a reliable source of income (Gilligan et al., 2008). On balance, the net effect of food aid on agricultural production, labor markets and overall poverty alleviation may not be negative (Bezu and Holden, 2008).

4. Theoretical Framework

Technology adoption decisions are particularly complex when examined from the perspective of farm-households as economic agents. Within agricultural households, the intricate relationship between production and consumption via changes in prices and farm income limits the use of standard consumer models for the comparative statics analysis of microeconomic behavior in agrarian societies. Agricultural small-holder household analyses modify the familiar utility-maximization problem in consumer theory by introducing production and time constraints that capture the endogeneity of farm income and resolve the apparent contradictions found in empirical research. As a flexible analytical framework, the agricultural household model has been modified to represent many different scenarios and used in analyses ranging from crop portfolio selection and technology adoption to deforestation and income diversification strategies (Taylor & Adelman, 2002).

In the remainder of this section we develop a household production model that allows farm labor to be allocated to leisure, on farm labor, off farm market labor, and food for work programs to obtain predictions and formulate hypotheses about the relation between food aid wages and the use of fertilizer. These hypotheses are examined empirically in section 6.

Drawing on the agricultural household model proposed by Singh, Squire and Strauss (1986), in this study we develop a static, non-recursive representation of farmer behavior that assumes risk neutrality. Prices are assumed to be exogenous and deterministic and there are no markets for land or credit. In this model of household production, agents maximize utility subject to a time constraint, an income constraint and a production or technology constraint with the standard concavity properties.[4] Households obtain utility from the consumption of leisure, goods purchased in the market, and staple foods produced in the farm.[5] Our theoretical framework allows farm labor to be allocated to leisure, on farm labor, off farm market labor, and food for work programs (L_{PW}). The extent to which farmers participate in public works programs is modeled in terms of the hours a household is willing to allocate to them. An exogenously determined food-wage per unit of labor devoted to donor-funded public works programs (α) is also introduced to reflect the potential effects of food and cash wages on fertilizer adoption. Finally, the agricultural technology adoption and intensification decision is characterized by the household's use of a capital input.

Define variables as follows:

$P =$ Market price for farm output
$W =$ Market wage for labor
$W_X =$ Market price of the composite capital input
$\alpha =$ Food wage per unit of labor devoted to public works activities
$Q =$ Farm output
$M =$ Household income
$C =$ Composite consumption good
$X =$ Composite capital input for farm production
$L_{hired} =$ Hired farm labor
$L_e =$ Leisure
$L_{on} =$ Household farm labor
$L_{off} =$ Household nonfarm labor
$L =$ farm labor (the sum of L_{on} and L_{hired})
$L_{PW} =$ Labor allocated to public works programs (PW)
$T =$ Total time endowment of the farm household (sum of L_{on} , L_{off} , L_e and L_{PW})
$\alpha L_{PW} =$ in kind (food) compensation for labor allocated to public wokrs projects

$P\alpha L_{PW} =$ Monetary compensation for public works labor

The household's optimization problem is:

$$Max\ U(C, L_e)$$

$$X, L, C, L_e, L_{PW}$$

$s.t.$

$$PC + W_X X + WL_{hired} = PQ + WL_{off} + P\alpha L_{PW} \quad (1)$$
$$Q = Q(X, L) \quad (2)$$
$$T = L_{on} + L_{off} + L_e + L_{PW} \quad (3)$$

Equations (1)—(3) represent, respectively, the income, technology and time constraints. They can be combined to obtain the following full income constraint:

$$PQ(X, L) + W(T - L_e - L_{PW} - L_{on}) + P\alpha L_{PW} = PC + W_X X + WL_{hired} \quad (4)$$

Hence,

$$PQ(X, L) - WL - W_X X + WT + L_{PW}(P\alpha - W) = PC + WL_e$$

The Langrangian for the optimization problem is:

$$Z: U(C, L_e) + \lambda[PQ(X, L) - WL - W_X X + WT + L_{PW}(P\alpha - W) - PC - WL_e] \quad (5)$$

The first order conditions (FOCs) are:

$$Z_C: U_C - \lambda P = 0 \quad (5a)$$

$$Z_{L_e}: U_{L_e} - \lambda W = 0 \quad (5b)$$

$$Z_{Li}: \lambda\left(P\frac{\partial Q}{\partial L} - W\right) = 0 \quad (5c)$$

$$Z_X: \lambda\left(P\frac{\partial Q}{\partial X} - W_X\right) = 0 \quad (5d)$$

$$Z_{L_{PW}}: \lambda(P\alpha - W) = 0 \quad (5e)$$

$$Z_\lambda: PQ(X, L) - WL - W_X X + WT + L_{PW}(P\alpha - W) = PC + WL_e \quad (5f)$$

From equations (5a)-(5d) the standard tangency conditions and standard demands for production inputs and consumption good can be derived. Conditions (5a) and (5b) imply the marginal rate of substitution equals the price ratio for any two goods.[6] Conditions (5c) and (5d) imply that the value marginal product of labor equals the market wage, the value

marginal product of X equals its market price, and the marginal rate of technical substitution equals the ratio of the inputs' prices.[7] Equation (5e) implies that the money value of the food wage from participating in PW equals the market wage for labor. Condition (5f) is a re-statement of the full income constraint.

In the absence of corner solutions, conditions (5a) through (5f) imply that the farm-household's utility maximizing bundle of goods and leisure occurs at a point tangent to the full income constraint, which is derived from both the farm-household's production frontier and the wage rate in the labor market. Thus, given an interior solution, the market wage rate equals the value of food aid wages and the value marginal productivity of farm labor ($W = P\alpha = \mathrm{P}\frac{\partial Q}{\partial L}$). This result informs the selection mechanism guiding the household's choice about participating in PW programs (Holden et al., 2006). Households participate in PW programs only if the returns to farm work are as low as food aid wages and market wages, in which case households will allocate labor to equalize the marginal returns to labor in agriculture, salaried work and public works (if access to PW is unconstrained).

4.1 Key Comparative Statics: The Effects of Food Wages (α)

By inspecting the problem's first order conditions, it is relatively easy to see how a change in the food aid wage may affect a household's decisions over consumption, use of hired production inputs, and time allocation between leisure, on farm work, off farm work, and public works. Even with a simple model, these effects are ambiguous and generally difficult to isolate without additional knowledge. Greater precision would require further assumptions about the behavior of the production function and restrictions over the domain of the parameters. We will focus the discussion on the effect of food for work programs (when food-wages are positive) on fertilizer adoption.

The comparative statics with regards to capital input use and changes in public works wages are derived as follows:

$$\frac{\partial X}{\partial \alpha} = \frac{dX}{d\alpha} - \frac{\partial X}{\partial M^*} \cdot PL_{PW} \tag{6}$$

Equation (6) shows the effect of increasing the food wage on fertilizer use, holding everything else constant. Fertilizer use can be positively ($\frac{\partial X}{\partial \alpha} > 0$), negatively ($\frac{\partial X}{\partial \alpha} < 0$) or not related ($\frac{\partial X}{\partial \alpha} = 0$) to food aid wages depending on the behavior of relevant functions and relations.

Although not explicitly captured in the above model, the following issues should be considered. Food aid wages and public works employment may affect households' consumption and production choices through many channels. Food-aid employment activities typically involve labor-intensive work such as road construction. If food payments do not suffice to compensate for the caloric requirement of the work performed, participation in public works could result in poor health and malnutrition. Additionally, strenuous physical work has direct impacts on farmers' productivity and farmers' demand for food, and therefore indirect impacts on the use of capital inputs in the farm. Alternatively, if the form of kind payment improves overall nutrition, food aid wages may provide additional health benefits to participants and enhance the marginal productivity of labor, hence indirectly influencing capital input use. These scenarios illustrate the general result that whether households choose to intensify the use of capital or technology input largely depends on the substitutability or complementarity between capital and labor as farm inputs.

There may also be a psychological component related to food wages and a public works employment that could alter participants' behavior and farm decisions. Working conditions and contractual functionality (such as timely payment for the labor provided) may affect participants' morale and shape their expectations of future economic opportunities, thereby influencing farmers' productivity (which may occur if they are suddenly motivated and optimistic about the prospects of their future) and consumption-investment decisions: in light of prospect future benefits, farmers may choose to invest on production inputs or to allocate more of their income towards consumption in the present period.

Lastly, public works programs may also affect households' decisions through the infrastructural dividend from erected physical assets: constructed road networks facilitate access to market centers, schools and hospitals. Similarly, built irrigation systems and soil conservation structures improve the productive capacity of cultivated lands. Ready access to markets and information may encourage farmers to develop their farms for commercial purposes and therefore increase their use of technological inputs. Greater productive potential derived from improved-quality soils may also induce farmers to intensify the use of capital inputs in their plots. However, if irrigation systems and other inputs are considered substitutes of production, the opposite may follow.

The absence of unambiguous predictions obtained from the theoretical analysis highlights the need for empirical research to assess the effects of food for work programs household behavior in general. The results obtained from the theoretical model indicate that the decision to participate in aid-funded public works programs and the decision to use more or less of the technology input are likely to be simultaneously determined and a function of multiple exogenous variables such as the price of the agricultural commodity produced by the farm, off-farm labor market conditions, biophysical characteristics of the cultivated area and farmer-specific demographic characteristics. To test the hypotheses mentioned above, in this study we estimate a sophisticated econometric model of participation in public works programs and chemical fertilizer adoption using data from rural Ethiopian households.

5. Data

The Productive Safety Net Program is an international safety net program that offers relief aid to those in risk of extreme food insecurity. With its focus on shifting from food to cash transfers, the program seeks to accomplish two objectives. First, it aims at smoothing consumption and preventing asset depletion among chronically food insecure households by providing them with predictable and adequate transfers of cash and/or food. Second, the program aims at building community assets and to indirectly enhance productivity growth in the long run.

The question posed by this study is whether or not public works programs encourage fertilizer use among rural Ethiopian households. In this study, we also seek to identify the factors that determine participation in food for work programs and therefore fertilizer use. We hypothesize each choice to be determined by similar explanatory variables that include demographic characteristics of the interviewed household, specifics about production environment of the farm, and regional characteristics that define the geography and the institutions found in the village where the respondent resides. The analysis of input use is focused on the use of chemical fertilizer measured as the number of kilograms of DAP or urea used in the household's farm in preparation for the largest harvest season in the 2008/2009 agricultural year. Participation in public works is measured by an indicator variable that takes on the value of one when respondents had participated in public works programs administered by the PSNP. Variable definitions and descriptive statistics are provided in Table1.

This study uses data from the Ethiopian Rural Household Survey.[8] The data was collected between April and July of 2009. The survey covers 1577 randomly selected households in 15 villages in four political regions of the country (Tigray, Amhara, Oromia and the Southern Nations Nationalities and People's Region or SNNP) chosen to represent the diversity of farming systems in the country (the sample is not nationally representative as it excludes information from households in pastoralist regions of the country). Within each village, samples are stratified by landless and female headed households. Respondents are personally interviewed and topics addressed in the survey include household demographics, agriculture and livestock ownership, food consumption habits, health indicators, and off-farm activities. The dataset also contains community-level data on access to labor markets, electricity and water, sewage and toilet facilities, health services, and education; NGO activities; migration patterns and local marketing conditions.

The sample size for this study was 231. A disproportionate number of these observations correspond to individuals from regions were fertilizer is used more intensively. Our sample focuses on households from the Tigray region and largely misrepresents the national fraction of rural households in the Oromia region. No observations are taken from the SNNP region.[9]

Of the farmers represented in the sample, 40 percent are illiterate (or at least had not received any form of formal education). The majority of them are middle-age men who head an average household of five people (12 percent of the interviewed households were headed by females). Around 60 percent of the households report suffering severe farm losses due to natural catastrophes during the past 5 years. Over 90 percent of the farmers use some positive amount of fertilizer. Of that group, 79 percent use organic fertilizer while 83 percent apply chemical fertilizer; 68 percent use both. The sample average amount of chemical fertilizer per hectare of land during the largest harvest season, the Meher, is 19 kilograms. Yet, there is wide variation in the data of chemical fertilizer. Although the majority of fertilizer users apply between 4 and 20 kg of fertilizer per hectare, the average is likely to be driven by some extreme observations. The average farm revenue corresponding to the few intensive users of fertilizer quadruples the mean farm revenue of the examined sample.

In our sample, 5 percent of the respondents are PW participants (43 percent of them are females), 2 percent are beneficiaries of freely distributed assistance, and 28 percent of them had been beneficiaries of food for work programs previous to the establishment of the PSNP. This composition largely misrepresents the rural population covered by the ERHS in 2009 (8 percent of households are self-reported participants of public works programs; 13 percent are self-reported beneficiaries of freely distributed aid).

6. Empirical Methods

The results from the theoretical analysis suggest that fertilizer use and participation in public works programs are likely to affect one another and be determined simultaneously. To evaluate the impact of participation in public works on fertilizer use we estimate the following structural form econometric representation of the joint decision model:

$$PW_i^* = \alpha_0 + \alpha_1 X_i + \alpha_2 Y_i + \alpha_3 Z_i + \alpha_4 PREVIOUS_PW_i + \alpha_5 SEVERE_SHOCK_i + \delta_1 FERT_i^* + \varepsilon_{1i}$$

$$FERT_i^* = \beta_0 + \beta_1 X_i + \beta_2 Y_i + \beta_3 Z_i + \beta_4 PREVIOUS_FERT_i + \beta_5 ORGANIC_i + \delta_2 PW_i^* + \varepsilon_{2i}$$

The dependent latent variables are PW_i^* and $FERT_i^*$. PW_i^* is a binary measure of public works participation decision by farmer i that takes on the value of 1 if the farmer is a current participant in the public works program administered by the Ethiopian Productive Safety Net

Program. $FERT_i^*$ measures the kilograms per hectare of chemical fertilizer applied by farmer i. $PREVIOUS_PW_i$ is a binary variable measuring whether any member in the household had worked in public works programs prior to 2005 (when the Ethiopian Productive Safety Net Program was established). $SEVERE_SHOCK_i$ is an indicator of (self-reported) severe crop damage suffered by the household in any of the five years between 2004 and 2009. $ORGANIC_i$ is a binary variable indicating whether or not households use manure to cultivate their fields during the surveyed period. Lastly, $PREVIOUS_FERT_i$ is a binary variable measuring whether any member in the household had used chemical fertilizer in any of the 5 years between 2004 and 2009.

Vectors X_i, Y_i and Z_i consist of exogenous variables and include farmer-specific attributes, farm-specific variables and regional characteristics, respectively. The variables included in vector X_i are age, gender, household size and indicator variables for different levels of educational attainment. Vector Y_i includes variables that characterize the production capacity of the farm, and off-farm opportunities for the employment of household labor. Variables that characterize farm capacity include farm revenue, an indicator variable for irrigation use, the total area and number of plots under cultivation, size of owned livestock herd, value of owned assets, and an indicator variable of membership in *Equibs* (a type of informal risk-sharing institution). Other variables include nonfarm income, average local market wage, and an indicator variable of free assistance receipts (whether in food or cash).

Vector Z_i includes variables that define the socio-economic and agro-ecological situation of the region where the farmer resides. Variables that describe a farmer's ability to access information and services include the number of secondary schools, and a measure of distance to market centers as a function of time. Agro-ecological variables include a continuous variable representing tree coverage in the plot farmed by each household, and an index measure that indicates how adequate the household's land is for cultivation. Lastly, ε_{ni} is the error term.

We estimate the system of simultaneous equations with limited and binary dependent variables using probit and tobit procedures and instrumental variables to correct for endogeneity. The methodology is analogous to the Two-Stage Limited Dependent Variable model proposed by Nelson and Olsen (1977) with the inclusion of a third stage for the correction of the latent variance. The procedure is the following. In a first stage we obtain the reduced form predictions using the continuous fitted values retrieved from the estimation of the reduced model. A probit procedure is used to model farmers' decision to participate in a public works program; the fertilizer use decision is regressed using a simple tobit model with censoring point at zero.[10]

In a second stage we estimate the structural equations by replacing the endogenous (and possibly censored) and right-hand side variables with the continuous fitted latent instruments constructed in the first stage. The methodology described above provides consistent and unbiased estimates. However, given the use of instruments in the second stage, the reported parameter standard errors are not accurate. Also, the latent nature of the endogenous dependent variables implies that the underlying relationship between explanatory and response factors differs fundamentally from conventional models. Thus, to estimate marginal effects we follow the procedure proposed by Atwood and Bittinger (2011).

In a third stage we transform the reduced form estimates, standard errors, and p-values obtained from Maximum Likelihood Estimation using standard jack-knife bootstrapping method of 1000 draws of 140 observations with replacement. Finally, after correcting the variance-covariance matrix of estimated disturbances, the average marginal effect of the exogenous variables is calculated by taking the mean of all the individual marginal effects.[11]

Table 1. Variable Definition and Summary Statistics

Variable	Definition	Min	Med	Mean	Max	S dev
Fert	Level of chemical fertilizer in the last planting season	0	10	17.1	182	28.31
PW	Participant in PW of the PSNP	0	0	0.04	1	0.21
Prev_Fert	1 if user of chemical fertilizer in any of the past 5 years	0	1	0.9	1	0.22
Prev_PW	1 if participant before the PSNP	0	0	0.28	1	0.45
Organic	1 if user of organic fertilizer	0	1	0.8	1	0.4
Gender*	Gender	0	1	0.89	1	0.31
Age	Age	22	49	51	99	15.3
Literacy_Prg	1 if attended literacy programs	0	0	0.18	1	0.38
Prim_Ed	1 if some primary education	0	0	0.17	1	0.37
Sec_Ed	1 if some secondary education	0	0	0.22	1	0.41
High_Ed	1 if some university education	0	0	0.01	1	0.09
HH_size	Family members	1	5	5	11	2.1
Farm_size	Farm area (hectares)	0	0.9	3	150	15.6
V_assets	Value of assets in Ethiopian Birr	0	222	340	3167	370.8
TLU[ł]	Tropical Livestock Units	0	2	3.5	27.9	4.7
Irrig	Access to irrigation	0	0	0.2	1	0.41
Farm_Rev	Farm revenue	0	160	1090	8340	5672.3
Nonfarm_Rev	Nonfarm revenue	0	180	497.6	13800	1235.2
DS	Direct Support beneficiary	0	0	0.02	1	0.15
Equibb	Member of Equibb	0	0	0.2	1	0.43
Market_W	Average market wage in the respondent's village	11.5	11.5	13.6	21.6	3.25
Ext_visits	Number of extension-service visits in last year	0	1	1.5	15	2.2
Sec_schools	Number of secondary schools in the respondent's village	0	1	0.7	2	0.56
Travel_time	Time to a market center (minutes)	0	10	21.	300	31.9
Soil_quality	Index of soil quality; 1 is "poor" and 3 is "good"	1.1	1.5	1.4	1.9	0.28
Trees	Number of trees in the respondent's farm	0	70	445.6	10000	1222.9
Severe_shock	1 if severely affected by a natural shock in any of the past 5 years	0	1	0.6	1	0.49

* Summary statistics for variable Gender correspond to a sample with 183 observations; the other statistics were obtained from the larger sample of 231 observations obtained when the variable gender is not taken into consideration.

Ł Based on Ramakrishna and Demeke (2000), Tropical Livestock Units (TLU) values are 1 for cattle, horses, and mules, 0.15 for sheep and goats, 0.005 for poultry, 0.65 for donkeys, and 1.45 for camels.

7. Results

In the 2008/2009 harvest period about 80% of the Ethiopian farmers in our sample used chemical fertilizer in the form of DAP and/or urea. The average kg of chemical fertilizer applied per hectare of land was 17 kg per year; that statistic was 30 kg for the group of farmers that were participants in public works. The results from the probit-tobit simultaneous regressions show that farm households that participate in public works programs use more fertilizer than those who do not. Furthermore, fertilizer use is also positively associated with participation in other public support programs, in this case freely distributed aid and aid wages. Additionally, fertilizer appears to have a positive, although small, effect on the public works participation decision. All the results are disclosed in Table 2. They are in general consistent with previous findings in Kenya and Ethiopia (Bezu & Holden, 2008; Barret et al. (2001) & Benuzeh et al.,1988).

Other results from the econometric model are standard or fairly standard and are well known. The previous use of both chemical and organic fertilizer appears to have substantial impacts on the amount of current fertilizer use. Also, variables measuring human capital, wealth and access to income also have a positive impact on fertilizer use. In contrast, soil quality and access to irrigation have negative impacts on the amount of fertilizer used by small-holder farmers. Although we will not discuss in detail the effects on public works participation and fertilizer use from other factors, comments on some counter-intuitive findings are provided.

Based on our empirical findings, a pure income effect from PSNP transfers would translate into an increase in fertilizer use by 18 kg per beneficiary household. This would be equivalent to doubling the amount of input used by average households. However, as evidence shows, PSNP benefits do not behave as we predict pure income transfers would.[12] In our study, beneficiary households increase their use of fertilizer only by a fraction of the predicted level. Moreover, the results indicate there is an effect differential between pure transfers and conditional transfers (those with a labor-intensive participation requirement). Such discrepancies admit for interesting insights on the targeting efficiency of the program and on the existence of unintended incentives attached to food wages that may be inducing participants to modify their choices of fertilizer use.

By design, only chronically food insecure households with no physically-able members are entitled to direct support transfers. That these households are among the most vulnerable may explain why the overall impact of unconditional assistance on fertilizer use is lower than the expected effect of making additional income available to them. It is possible that direct support beneficiaries are using additional resources to meet basic consumption requirements rather than to invest in farm production; indicating that PSNP resources are adequately targeting disadvantaged populations. However, that the predicted income effect from aid transfers is almost offset when adding a labor requirement to the program is not explained by the demographic differences between participants and non-participants. We examine various angles of the data to identify potential unintended incentives attached to public works that could almost offset the expected positive income effect from freely distributed assistance.

The potential discouraging effects on fertilizer use imposed by the labor requirement are not explained by lower labor availability during planting or harvesting seasons. Also, we do not find statistical support to the hypothesis that differences in household consumption decisions are driving the effect differential on fertilizer use between beneficiaries of unconstrained and conditional transfers.[13] Instead, we suspect that the effect differential may be largely determined by delays in the payment of the transfers.[14]

Table 2. Estimated Parameters Using 2SLDV

Variable	Effect	p-value	Variable	Effect	p-value
PW Participation Equation			Chemical Fertilizer Equation		
Fert	0.001 (0.004)	0 ***	PW	1.792 (1.111)	0.02 **
Age	-0.003 (0.015)	0.005 ***	Age	-0.162 (0.135)	0.059 *
Age2	0 (0.000)	0 ***	Age2	0.001 (0.001)	0.08 *
Prim_Ed	0.097 (0.136)	0 ***	Prim_Ed	1.366 (1.7414)	0.104
Sec_Ed	0.046 (0.169)	0.021 **	Sec_Ed	-0.751 (1.215)	0.167
High_Ed			High_Ed	15.946 (3.926)	0 ***
Literacy _Prg			Literacy _Prg	1.69 (1.534)	0.061 *
HH_size	-0.004 (0.026)	0.028 **	HH_size	-0.024 (0.186)	0.383
Farm_size	-0.013 (0.021)	0 ***	Farm_size	0.298 (0.202)	0.017 **
V_assets			V_assets	0.002 (0.001)	0.029 **
TLU			TLU	0.262 (0.09)	0 ***
Irrig			Irrig	-13.621 (1.505)	0 **
Farm _Rev			Farm _Rev	0.0005 (0.000)	0 ***
Nonfarm _Rev	0 (0.000)	0.001 ***	Nonfarm _Rev	0.004 (0.000)	0 ***
DS	0.117 (1.204)	0.027 **	DS	8.948 (5.390)	0.025 **
Equib			Equib	3.482 (0.877)	0 ***
Market _W			Market _W	0.545 (0.234)	0.015 **
Ext_visits			Ext_visits	1.004 (0.191)	0 ***
Sec _schools	-0.06 (0.139)	0 ***	Sec _schools	-8.353 (1.755)	0 ***
Travel _time	-0.004 (0.002)	0.083 *	Travel _time	0.08 (0.024)	0.003 ***

Table 3(Continued). Estimated Parameters Using 2SLDV

Variable	Effect	p-value	Variable	Effect	p-value
PW Participation Equation			Chemical Fertilizer Equation		
Soil _quality	-0.058 (0.243)	0 ***	Soil _quality	-7.692 (2.271)	0 ***
Trees			Trees	0.001 (0.000)	0.026 **
Prev_PW	0 (0.000)	0 ***	Prev_Fert	50.478 (6.890)	0 ***
Severe _shock	-0.013 (0.097)	0.056 *	Manure	6.212 (1.051)	0 ***

Notes: ***,**,* denote significance at the one, five and ten percent level
Standard errors are presented beneath the estimated coefficient in parenthesis
A value of 0.000 means it is less than 0.0001

7.1. Other Effects on Fertilizer Use

Although most results are in line with previous findings in the literature, there are some unexpected results. The first is the positive effect of average market wage for non-farm labor on fertilizer use. It had been hypothesized that if average market wage reflects the opportunity cost of farming, whenever the opportunity cost of farming is high, farmers would dedicate less labor to farming activities. The observed positive relation may be reflecting overall regional economic performance or market and information accessibility. Another unexpected result was the negative impact from additional secondary school on fertilizer use. The number of secondary schools was expected to be positively correlated with market interactions, and therefore fertilizer use. This counter-intuitive finding may be driven by unobserved relations between the number of secondary schools and other important socio-economic characteristics—like population pressure.

Also surprising is the positive relationship between remoteness or geographical isolation, measured as the distance to market centers, and fertilizer use. We were expecting a negative relation since $Travel_Time$ is likely related to transportation-induced transaction costs and limited access to information. This result may derive from the lack of variation and overall small values of the explanatory variable measuring travel time to market centers.[15] A fourth unexpected result is, considering the level of enthusiasm in the literature with regards to livestock ownership as a measure of wealth, the apparently small magnitude of impact of an additional tropical livestock unit on fertilizer use. Lastly, visits by extension agents are noticeable for their negligible impact on fertilizer use.

8. Policy Implications

Our results provide an optimistic evaluation of the design and potential effects of PSNP transfers. However, the observed impact differential between freely distributed assistance and public works wages raises questions about the adequacy of the program to encourage fertilizer use. In addition, the following lessons regarding fertilizer adoption in Ethiopia can be derived from our empirical results:

First, in our study the variable with the greatest explanatory power in the fertilizer use decision is familiarity with fertilizer as measured by previous use. This provides some evidence in favor of the hypotheses that technology intensification is a dynamic process and that it takes time for farmers to adjust their expectations to new knowledge and experience.

Second, our evidence also shows that higher education is an important factor for the development of Ethiopia's agricultural sector. (We found that for households headed by an

individual who had received education beyond high-school level the expected use of fertilizer is 16 kg greater than that of households headed by illiterate individuals.) Our results may provide evidence of a positive externality from the scheduled expansion of Ethiopia's higher education system.

Third, *equib* membership was found to be persistently significantly and positively related to fertilizer use. (According to our results, average farmers belonging to these institutions use 23 percent more fertilizer than their counterparts.) These findings indicate that informal risk-sharing and credit providing associations may be important instruments to elude market failures in rural Ethiopia.

Fourth, in our data, it is difficult to disencumber the correlation between poor soil quality and increased use of chemical fertilizer. It is not clear whether farmers are using fertilizer to compensate for the poor quality of their soils or whether input intensification (maybe related to intensive cultivation) is driving the decay in soil quality. Given that community development projects devote many of their resources towards afforestation efforts and the construction of soil conservation structures like stone terraces, more scientific research on the biological stability of ecosystems in rural Ethiopia is recommended.

Finally, the negligible success of policy initiatives aimed at familiarizing small-holder households with modern technologies suggests there is room for improving government-sponsored agricultural extension service and outreach programs.

9. Conclusion

Increasing the use modern agricultural inputs (in particular fertilizer) is seen by many agricultural experts as a prerequisite to increase agricultural production and therefore reduce the risks of food insecurity and chronic poverty in sub-Saharan Africa. In this study, we use household data from rural Ethiopia to examine whether the Ethiopian Productive Safety Net Program encourages the use of fertilizer.

Above all, the results from a probit-Tobit simultaneous equation model for fertilizer use and participation in a safety net program do not support the disincentive effects hypothesis that international aid discourages investment in farm production among aid recipients. Instead, the results indicate that participants of public works administered by the Ethiopian PSNP use significantly greater amounts of fertilizer than nonparticipants. In addition, this study identifies various significant determinants of public works participation and fertilizer use. The results show that previous use of fertilizer is an important determinant of fertilizer adoption and intensification. In addition, the evidence indicates that educational attainment positively influences fertilizer use among small-holder farmers in Ethiopia. Finally, the findings suggest that membership in community-based, risk-spreading and credit-providing institutions has a positive impact on fertilizer use.

The results of this study provide evidence that participation in a public works program positively influences participants' use of fertilizer. The results also raise important questions regarding the performance of the Ethiopian Safety Net Program, the largest development aid program in Ethiopia. Specifically, the findings question whether the safety net program is efficiently targeting the poorest households in rural Ethiopia, and whether the timely delivery of the payments affects production and consumption decisions of the beneficiaries.

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Appendix

Table 3. Model Selection for the PW Participation Decision

Variable	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variable: PW Participation **Method:** Probit					
Fert	0.024*** (0.000)	0.016*** (0.000)	0.015*** (0.000)	0.014*** (0.000)	0.014*** (0.000)
Prev_PW	-0.199** (0.158)	-0.219** (0.094)	-0.193** (0.094)	-0.167* (0.126)	0.000*** (0.000)
Age	-0.006 (0.003)	-0.035*** (0.000)	-0.032** (0.000)	-0.028** (0.000)	-0.040*** (0.000)
Age2	0.000** (0.000	0.000*** (0.000)	0.000*** (0.000)	0.000** (0.000)	0.000*** (0.000)
Prim_Ed	1.020*** (0.25)	1.149*** (0.000)	1.103*** (0.126)	0.838*** (0.09)	1.193*** (0.126)
Sec_Ed	0.541** (0.284)	0.653** (0.189)	0.544** (0.189)		0.570** (0.158)
High_Ed	-4.029*** (0.316)			-3.819*** (0.189)	
Lit_Prg	-0.538*** (0.79)				
HH_size	-0.043** (0.032)	-0.031* (0.032)	-0.037** (0.032)	-0.067** (0.032)	-0.051** (0.021)
Farm_size	-0.197*** (0.063)	-0.118*** (0.032)	-0.143*** (0.032)	-0.252*** (0.063)	-0.157*** (0.032)
V_assets	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	
TLU	0.019** (0.000)			0.011** (0.000)	
Irrig	0.273** (0.253)			0.364** (0.158)	
Farm_Rev	0.000 (0.000)				
Nonfarm_Rev	0.000* (0.000)				0.000*** (0.000)
DS	1.273** (3.478)	1.234** (1.075)	1.167** (1.075)	1.213** (1.264)	1.436** (1.201)
Equib	0.281** (0.158)			0.313*** (0.094)	

Table 3.(Continued) Model Selection for the PW Participation Decision

Variable	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Dependent Variable: PW Participation **Method:** Probit					
Market_W	0.002*** (0.032)			0.021* (0.032)	
Ext_visits	-0.087*** (0.032)	-0.068*** (0.032)			
Sec_schools	-0.629*** (0.189)	-0.686*** (0.126)	-0.666*** (0.126)	-0.334** (0.126)	-0.740*** (0.126)
Travel_time	-0.007*** (0.000)	-0.005** (0.000)	-0.004** (0.000)	-0.007** (0.000)	0.000* (0.000)
Soil_quality	-0.675** (0.316)	-0.592*** (0.221)	-0.648*** (0.221)	-1.066*** (0.284)	-0.709*** (0.252)
Trees	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)		
Severe_shock	-0.609*** (0.126)	-0.606*** (0.094)	-0.643* (0.094)	-0.587*** (0.094)	-0.155*** (0.094)
Degrees of Freedom:	224 Total; 200 Residual	224 Total; 208 Residual	224 Total; 209 Residual	224 Total; 206 Residual	224 Total; 209 Residual
Residual Deviance:	63.24	64.95	65.33	66.74	66.92
AIC:	**113.2**	**98.95**	**97.33**	**104.7**	**98.92**

Notes: ***,**,* denote significance at the one, five and ten percent level
p-values were calculated as the probability that the effect of the independent variable was equal to zero
Standard errors are presented in parenthesis; a value of 0.000 means it is less than 0.0001

Table 4. Model Selection for the Chemical Fertilizer Decision

Variable	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variable: Fertilizer Use (Kg) **Method:** Tobit					
PW	2.610** (1.075)	0.789* (0.822)	0.370 (0.727)	-0.116 (0.727)	2.718** (1.106)
Prev_Fert	76.167*** (7.463)	-0.993* (0.695)	-0.904* (0.695)	0.350 0.600)	76.574*** (6.893)
Manure	9.596*** (1.075)	-2.961*** (0.758)	-3.052*** (0.758)	-1.345** (0.790)	9.424*** (1.043)
Age	-0.317** (0.126)	-0.497** (0.126)	-0.424** (0.126)	-0.346** (0.126)	-0.246* (0.126)
Age2	0.002** (0.000)	0.004** (0.000)	0.003** (0.000)	0.003** (0.000)	0.001* (0.000)
Prim_Ed	2.251* (1.581)	2.100** (1.011)	2.901** (1.011)	4.268*** (1.043)	2.072 (1.707)
Sec_Ed	-1.370 (1.296)	-1.909* (0.980)			-1.139*** (1.201)
High_Ed	34.836*** (6.039)				24.189* (3.921)
Lit_Prg	3.905** (1.960)				2.563 (1.549)
HH_size	-0.074 (0.158)	0.257* (0.158)	0.174 (0.158)	22.779*** (3.858)	-0.037 (0.189)
Farm_size	0.454** (0.253)	0.028** (0.032)	0.030** (0.032)	0.023** (0.032)	0.452** (0.189)
V_assets	0.006*** (0.000)				0.003** (0.000)
TLU	0.328*** (0.094)			0.477*** (0.094)	0.397*** (0.094)
Irrig	-19.713*** (1.707)	-20.951*** (1.296)	-21.093*** (1.296)	-21.068*** (1.359)	-20.663*** (1.517)
Farm_Rev	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Nonfarm_Rev	0.005*** (0.000)	0.005*** (0.000)	0.005*** (0.000)	0.005*** (0.000)	0.005*** (0.000)
DS	12.933** (8.696)	14.368** (5.439)	14.337** (5.470)	16.730** (5.344)	13.573** (5.375)
Equib	4.176*** (1.170)			5.288*** (0.853)	5.282*** (0.885)
Market_W	0.764*** (0.221)			0.895*** (0.221)	0.827** (0.221)
Ext_visits	1.705*** (0.221)	1.645*** (0.221)	1.613*** (0.189)	1.492*** (0.189)	1.523*** (0.189)

Table 4.(Continued) Model Selection for the Chemical Fertilizer Decision

Variable	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variable: Fertilizer Use (Kg) **Method:** Tobit					
Sec_schools	-11.953*** (2.023)	-15.064*** (1.201)	-15.510*** (1.201)	-15.159*** (1.170)	-12.671*** (1.770)
Travel_time	0.134*** (0.032)	0.133*** (0.032)	0.132*** (0.032)	0.120*** (0.032)	0.121*** (0.032)
Soil_quality	-11.389*** (2.403)	-2.761** (1.581)	-2.966** (1.549)	-12.871*** (2.118)	-11.669*** (2.276)
Trees	0.001** (0.000)	0.000 (0.000)	0.000 (0.000)		0.001** (0.000)

Notes: ***,**,* denote significance at the one, five and ten percent level;
Standard errors are presented beneath the estimated coefficient in parenthesis.

[1] For thorough evaluations of the project see 2009 report by the International Food Policy Research Institute (IFPRI) "An impact evaluation of PSNP", and the 2008 report by the Institute of Development Studies (IDS): "Ethiopia's PSNP, assessment report".

[2] According to recent 2011 UN data, the average monthly income per capita in Ethiopia is equivalent to $23—which roughly translates into $0.77 per day per person.

[3] In 1993, a policy was brought stating that no able-bodied person should receive gratuitous relief. As a result, at least 80 percent of food aid resources in Ethiopia are committed to Public Works (PW) programs.

[4] The standard concavity properties imply positive but decreasing marginal utility and positive but diminishing returns to scale. That is, $U_C > 0, U_{CC} < 0$, $U_{L_e} > 0$, $U_{L_eL_e} < 0, Q_X > 0$, $Q_{XX} < 0, Q_{L_i} > 0$, $Q_{L_iL_i} < 0$, and $Q_{L_iX} > 0$.

[5] For convenience of exposition, the model treats staple foods and purchased goods, as a single composite consumption good. Assuming a relatively large income share is devoted to the purchase of food goods by typical small-holder in developing countries, there is no loss of generality by imposing such condition.

[6] When solved together, (5a) and (5b) imply that $\frac{U_C}{P} = \lambda = \frac{U_{L_e}}{W}$, which means that the marginal benefit from consumption per dollar spent on consumption goods equals the marginal benefit from leisure per dollar given up. Subsequently, $\frac{U_C}{U_{L_e}} = \frac{P}{W}$. This implies that the marginal rate of substitution between consumption and leisure equals the ration between the price of consumption goods and the forgone market salary per unit of labor.

[7] 5(c) and 5(d) imply $P\frac{\partial Q}{\partial L} = W$ and $P\frac{\partial Q}{\partial X} = W_X$. Implying that, at the optimal level of use, the marginal benefit of production factors equals their marginal cost. Additionally, these equations imply $\frac{\partial Q}{\partial X} \cdot \frac{\partial Q}{\partial L} = \frac{W_X}{W}$, which means that the marginal rate of technical substitution equals the ratio of the inputs' prices.

[8] The Ethiopian Rural household Survey is a comprehensive survey conducted by the University of Addis Ababa and the Centre for the Study of African Economies in collaboration with the University of Oxford and the International Food Policy Research Institute. The purpose of the survey is collect periodic statistics on a comprehensive set of household characteristics to study the response of households to food crises. Up to 2013, there are 7 rounds of the survey conducted between 1989 and 2009. Dercon and Hoddinott (2011) describe survey and sampling methodology, definition of variables and measurement units, specific characteristics of surveyed populations and survey periods.

[9] In the sample we used to estimate our models, 60 households (26 %) belonged to villages in the Amhara region, 20 (8.6 %) resided in the Oromia region, and 151 (65.4 %) were situated in the Tigray region. Based on the Ethiopian Rural Housheold Survey, 33 % of the country's rural households are

situated in the Amhara region, 22 % in the Oromia region, 11 percent in the Tigray region, and 44 % in the SNNP region.

[10] In study we chose probit over logit estimation because unlike a logit model, which assumes the error terms to be distributed logistically, a probit model assumes the error term be distributed normally; furthermore, probit estimation does not impose the restrictive independence from irrelevant alternatives (IIA) assumption. In regards to the selection of the tobit model to fit the censored latent variable measuring fertilizer use, we also considered various specifications of Heckman and double-hurdle estimating techniques. The choice of which model to implement is largely dependent on practical matters and the adequacy of the models should be evident in the data. We examined the fitness of the models empirically and found no evidence that double-hurdle estimation was superior to a tobit estimation—possibly in large part because of the small number of useable observations in our sample.

[11] This method is preferable to computing the marginal effect of the average value of each regressor, particularly since some of the explanatory factors are themselves measured by binary variables. Computing the average marginal effect using the mean value of the explanatory variable would imply using values that are not observed anywhere in the data.

[12] According to our results, receiving direct support assistance was associated with a 9 kg increase in fertilizer use, half of the estimated effect from a pure income transfer. In turn, participating in public works activities was related to a 1.8 kg increase in fertilizer use, a tenth of the predicted impact from pure income transfers.

[13] In the literature, it has been hypothesized is possible that, for whatever reason, public works participants are using aid subsidized wages to sustain higher levels of consumption instead of using them to improve the productivity of their farms (Barrett et al., 2001; Holden et al., 2004). However, in our data we do not find systematic differences between public works participants and non-participants in household consumption decisions. Our results are consistent with previous evaluations of the Productive Safety Net Program (Berhane et al., 2011).

[14] According to a World Bank assessment of the PSNP, in 2005 there were considerable delays with payment of transfers. By June 2005, half way through the first phase of the program, only 11 percent of transfers were completed. After considering the seriousness of the payment issue, it is not so surprising to find that public works participants increased their fertilizer use by only a tenth of what they would have had they been given their food wages worth in additional income. It appears that the availability of PSNP wages, or the lack of it, may help explain why public works participants are likely to increase their use of chemical fertilizer by much lower amounts than direct support beneficiaries. However, the role of payment volatility is an issue beyond the scope of our study.

[15] Bezu and Holden (2008) find a negative relationship between distance to market centers and fertilizer use in the Tigray region. If the result were not due to some measurement issue, it is possible that farmers living far from market centers purchase fertilizer in bulks to reduce average transportation costs per kg of purchased input.