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Returns to spending on agricultural extension: the case of the National Agricultural Advisory Services (NAADS) program of Uganda†

Samuel Benin[a,*], Ephraim Nkonya[a], Geresom Okecho[b], Joseé Randriamamonjy[a], Edward Kato[a], Geofrey Lubade[c], Miriam Kyotalimye[d]

[a]*International Food Policy Research Institute, 2033 K St. NW, Washington, DC, USA*
[b]*National Agricultural Advisory Services Secretariat, Plot 39A Lumumba Avenue, P.O. Box 25235, Kampala, Uganda*
[c]*National Agricultural Research Organization, P.O. Box 295, Entebbe, Uganda*
[d]*Association for Strengthening Agricultural Research in Eastern and Central Africa, Plot 5, Mpigi Road, P.O. Box 765, Entebbe, Uganda*

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Abstract

The aim of this paper is to assess the direct and indirect impacts of the agricultural extension system of Uganda, the National Agricultural Advisory Services (NAADS) program, on household agricultural income. Data from two rounds of surveys of Ugandan rural farm-households conducted in 2004 and 2007, as well as different program evaluation methods and model specifications, are used to estimate impacts and compute a rate of return. The direct and indirect impact of the program is estimated at 37–95% and 27–55% increase in per capita agricultural gross revenue between 2004 and 2007 for households participating directly and indirectly in the program, respectively, compared to nonparticipants. The rate of return on the program's expenditures is estimated at 8–49%. The program has been relatively more effective among male-headed, larger, and asset-poor households, as well as those taking up noncrop high-value enterprises and living further away from financial services, all-weather roads, and markets or located in the Eastern and Northern Regions. Policy implications of the results are drawn.

JEL classifications: C23, H43, Q16

Keywords: Agricultural extension; Program evaluation; Rate of return; Uganda

1. Introduction

The importance of agricultural extension in agricultural and rural development is widely known and so it is not surprising that agricultural extension has returned strongly to the international development agenda (World Bank, 2007a). Similar to agricultural research, to which it is supposedly closely linked, agricultural extension has attracted substantial investment of public resources since the 1950s when national agricultural advisory services (NAADS) began to be formally established (Anderson, 2007). With competing uses of public resources for promoting growth and equitable distribution in general and agricultural and rural development in particular, careful reflection by governments and development investors of the impacts of and returns to their investments in agricultural extension is necessary.

The most comprehensive review of the economic returns to investment in agricultural extension is found in a meta-study of several case studies by Alston et al. (2000). About 80 of them were on the returns to agricultural extension only and 628 were

*Corresponding author. Tel.: +1-202-862-4634; fax: +1-202-467-4439. *E-mail address*: s.benin@cgiar.org (S. Benin).

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Data Appendix Available Online

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

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on the returns to combined agricultural research and extension, with an average rate of return of 85% (ranging from zero to 636) and 48% (−100 to 430), respectively. The wide range of the estimated rates of return, although positively skewed, has raised the level of skepticism among policy makers and development practitioners on the effectiveness of investments in agricultural extension. The meta-study by Alston et al. (2000) and reviews by others (e.g., Evenson, 2001; Anderson, 2007) highlight concern over data quality and difficult methodological issues regarding causality between extension inputs and outcomes and quantification of costs and benefits. The case of the evaluation of the training and visit (T&V) extension system in Kenya in the 1980s is a typical example fueling those concerns, where previously estimated large and positive productivity impacts of extension (e.g., Bindlish and Evenson, 1997) were found to be grossly overestimated by Gautam and Anderson (1999) following their careful modelling of confounding factors, including initial conditions of productivity.

The aim of this study is to assess the direct and indirect impact of the new agricultural extension system of Uganda, the NAADS program, on household agricultural income and estimate the net benefits of the program, which has been operating since 2001. Panel data from two rounds of household surveys conducted in 2004 and 2007 and different program evaluation methods and model specifications are utilized to deal with the above and other concerns in program evaluation and to generate greater confidence in the policy implications of the resulting estimates.

In the next section, we briefly present the NAADS program, starting with an evolution of provision of extension services in Uganda. This is followed by a presentation of the conceptual framework in Section 3 and the data and evaluation methods used in Section 4. The results are presented in Section 5 and conclusions and implications in Section 6.

2. The NAADS program

The NAADS program was initiated in 2001 as one of seven areas of policy and institutional reform of the Ugandan government's multi-sectoral approach, the Plan for Modernization of Agriculture (PMA), aimed at accelerating growth and reducing mass poverty from the 1992 level of 56% to below 28% by 2014 (MAAIF and MFPED, 2000). This attempt to accelerate poverty reduction through agricultural growth is not surprising since agriculture is an important mainstay of the economy. Agriculture contributes about one-third to national GDP and one-half of export earnings, and employs four-fifths of the working population (World Bank, 2007b).

Agricultural extension in Uganda has undergone a number of transformations, which can be summarized as regulatory from 1920 to 1956, advisory from 1956 to 1971, dormancy from 1972 to 1981, and then various educational emphases from 1982 to 1997 (Semana, 2008). In 1997, the provision of agricultural extension and other agricultural support services became the responsibility of local governments, as per the Local Government (LG) Act of 1992. The decentralization process faced several challenges. For example, the proportion of local government budgets allocated to agricultural production and marketing was only up to 3% (Francis and James, 2003). Extension agents surveyed in Tororo district, for example, felt that decentralization had negative impacts on their ability to provide extension services (Enyipu et al., 2002), which is surprising. More generally, lack of funds and equipment for operations seem to be the main constraints to facilitating the work of extension agents at the local government level (Sserunkuuma and Pender, 2001).

In 2001, the government of Uganda initiated the demand-driven NAADS program as a key strategy to implementing the PMA. Through the development and use of farmer institutions, the NAADS program aims at empowering farmers to procure advisory services, manage linkages with marketing partners, and conduct demand-driven monitoring (M&E) of the advisory services and evaluation of their impacts. The goal of the program, planned as a 25-year program with an initial phase of 7 years, is increasing incomes and quality of life of farmers through increased adoption of profitable enterprises and improved technologies and practices, increased agricultural productivity, and increased proportion of marketed production.

The program is implemented according to an institutional framework that is defined in the NAADS Act of June 2001, involving farmer organizations; local governments; private sector; nongovernmental organizations (NGOs); a Board of Directors; a Secretariat; the Ministry of Finance, Planning and Economic Development (MFPED); and the Ministry of Agriculture Animal Industry and Fisheries (MAAIF). The program aims at targeting the economically active poor—those with limited physical and financial assets, skills, and knowledge, rather than destitute or large-scale farmers—through farmers' forums based on specific enterprises identified by farmers. The Secretariat works with program coordinators at the district and sub-county levels and farmer groups to contract and supervise private professional firms to provide specialized advisory services according to farmers' priority enterprises and needs. Some farmers, called community-based facilitators (CBFs), are also trained to provide quick follow-up advisory services according to farmers' needs.

Although the NAADS program is a public investment intervention, farmers have to decide whether to participate in the program or not. When a farmer decides to participate, he or she has to do so through membership of a NAADS-participating farmer group. Then, together with the members of the group, as well as with members of other NAADS-participating groups in the sub-county, they request specific technologies and advisory services associated with their prioritized enterprises. They also obtain grants for procuring the technologies and related advisory services. The grant is initially used to finance the establishment of a technology development site (TDS) that becomes the source of knowledge and skill development for farmers. The proceeds from the TDS, whether in kind or cash from sale of output, are used as a revolving fund for members of the group. Therefore, only farmers that belong to a NAADS-participating farmer group can access the program grants. This is the channel through which the program is expected to generate its direct benefits. However, the TDSs, service providers, and CBFs are accessible as sources of knowledge to all farmers in the sub-county, irrespective of a farmer's membership status in a NAADS-participating farmer group. This is the channel through which the program is expected to generate indirect or spillover effects.

2.1. Progress in implementation of the program

The NAADS program was initiated in 2001 in 24 sub-counties within six districts. By end of the 2006/07 financial year, the NAADS program had been extended to 545 sub-counties (about 83.1% of the total sub-counties in Uganda at the time) and about 40,000 farmer groups and 716,000 farmers (representing about 20% of the national farming households) had reportedly received services of the program (NAADS, 2007). By the end of the 2006/07 financial year also, about 110 billion Ugandan Shillings (UGX) (2000 constant prices) had been spent on the program.[1] About 1,622 contracts had been signed with private-sector agencies to provide various specialized services on more than 40 enterprises[2] that had been identified. In the process, about 2,516 CBFs had been trained to provide follow-up services and 40,000 farmer groups and 716,000 farmers (representing 20% of the national farming households) had received services from the program (NAADS, 2007). Information obtained on farmer groups participating in the program (Benin et al., 2007) shows that the NAADS program has helped to strengthen the institutional capacity and human resource skills of many farmers to potentially demand and manage the delivery of agricultural advisory services, as a majority of the groups participating in the program reported positively to having received training in several areas (which was found to be useful) and that individual members' participation in farmer groups' activities was high. Service providers were also rated very high on their methods used in the training and on their performance. However, participation in group activities was not always commensurate with the power it was supposed to bring to farmers, which can limit farmers' potential in achieving the expected outcomes of the program. For example, farmers' selected enterprises did not always materialize due to political interference in the enterprises selection process in some cases (ITAD, 2008). Since the NAADS program is enterprise-based and each sub-county has to prioritize three enterprises on which to receive advisory services, however, it is impractical to meet each farmer's needs even without political interference.

A few evaluation studies carried out in the early stages of the program have been quite favorable in terms of the program's impact on increasing use of improved technologies, marketed output, and wealth status of farmers receiving services from the program (Benin et al., 2007; ITAD, 2008; Nkonya et al., 2005; OPM, 2005; Scanagri, 2005). However, concerns about the NAADS program having little success in improving soil fertility management, which raises further concern about the sustainability of potential productivity gains from the program, has also been reported (Benin et al., 2007). With the first phase of the NAADS program ending in June 2008, it is important to rigorously assess the impacts of the program and evaluate the net benefits of the program. This study aims to fill those knowledge gaps by estimating the impact of the NAADS program on household agricultural income as well as the net benefit up until the end of the 2006/07 financial year.

3. Conceptual framework

The literature on agricultural development suggests that there are many factors that condition the relationship between extension inputs and outcomes, and these factors act in complex ways. To be simplistic, but consistent with the objectives of this paper as well as with the principles of implementation of the NAADS program, we show the pathways of impact between the NAADS program and agricultural income in Fig. 1. As explained about the program earlier, there are two main mechanisms through which the program aims to increase incomes of farmers through

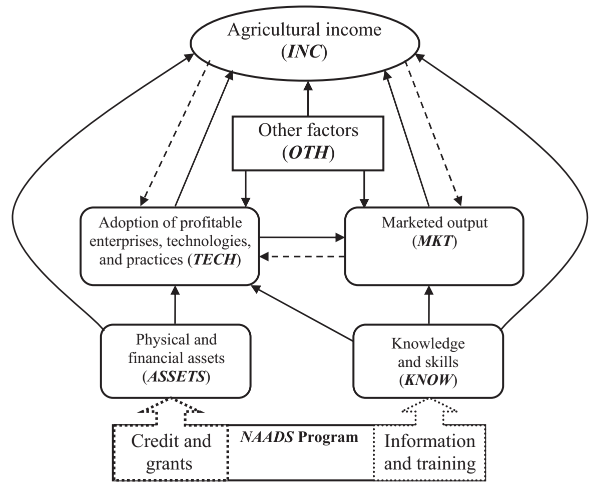

Fig. 1. Impact pathways of the NAADS program.

[1] These are the authors' calculations based on data received from the NAADS Secretariat. The total amount is equivalent to about USD 60.2 million (2000 constant prices) over the same period or about 0.5% and 0.2% of AgGDP and GDP per year, respectively, which were calculated using official exchange rate, consumer price index (2000 = 100), and GDP data obtained from the world development indicators (World Bank, 2007b). Development partners contributed the bulk of the resources, nearly 80%, while the central government, local governments, and farmers contributed the remaining 14, 4, and 2%, respectively. This amount does not include in-kind contribution of the community-based facilitators (CBFs) in terms of the opportunity cost of their time spent extending advisory services to farmers in the community, which is dealt with later when we analyze the benefit-cost ratio of the program.

[2] For crops, the major ones were banana, groundnuts, and rice, followed by vanilla and maize. Regarding livestock and other enterprises, the major ones were goats, poultry, and beekeeping, followed by cattle and piggery.

increased agricultural productivity and increased proportion of marketed agricultural output. The first mechanism is providing credits and grants to improve the physical and financial assets (*ASSETS*) of farmers so that they can adopt enterprises, technologies, and practices (*TECH*) that meet their local farm production and marketing constraints, which in turn is expected to lead to increased agricultural productivity and increased marketed output (*MKT*). This mechanism is only available to farmers that participate directly in the program through membership of a NAADS-participating farmer group. The other mechanism is through provision of information and training on profitable enterprises, technologies, and practices to improve the knowledge and skills (*KNOW*) of farmers, which are expected to lead to increased adoption and then increased productivity and marketed output. By linking farmers to markets, the program is also expected to have direct impact on increasing marketed output. This mechanism is available to all farmers irrespective of their membership status in a NAADS-participating farmer group. Together, increased adoption of profitable enterprises, technologies, and practices (leading to increased productivity) and increased marketed output contribute to higher agricultural income (*INC*).

However, whether farmers actually adopt the enterprises, technologies, and practices being promoted by the program or whether farmers sell more output is conditioned by several other factors (*OTH*), which include several farm and household level factors such as their endowments of land, labor, capital, and other household assets; livelihood options and activities; and access to credit, markets, and other rural services (Feder et al., 1985; Feder and Umali, 1993). Many of these factors are in turn shaped by local government factors as well as national-level and policy factors that are typically associated with overall infrastructure development, availability of nonfarm employment opportunities, and prices, among others. For example, availability of off-farm employment opportunities (or off-farm income) can contribute to agricultural income by providing resources to purchase inputs in general as well as the technologies promoted by the NAADS program in particular. On the other hand, off-farm opportunities may reduce farmers' incentive to invest in agriculture, as they become less dependent on the land and as the opportunity costs of their labor and capital are increased by having access to profitable alternatives (Holden et al., 2001; Nkonya et al., 2004). However, whether such changes result in more or less adoption, sale of output, and agricultural income, depends on the extent to which the technologies and practices being promoted by the NAADS program are suited to the labor and capital constraints of households, as well as how well the marketing channels identified by the program function to relax the constraints facing households.

Agricultural income is also influenced by several other factors, including many of those discussed above that influence technology adoption and sale of output. Agricultural income may also be influenced by factors beyond the household's control. For example, it will depend on agro-ecological, biophysical, and market factors that underlie many village-level constructs such as agricultural potential, markets access, and population density (Pender et al., 1999). These factors largely determine the comparative advantage of a location by determining the costs and risks of producing different commodities; the costs and constraints to marketing; local commodity and factor prices; and the opportunities and returns to alternative income-generating activities, both on and off the farm. They have generalized village-level effects and manifest themselves through, for example, their impact on village-level prices of commodities or inputs or on farm household-level factors such as average farm size.

Fig. 1 also shows that there are important feedback links underlying the relationships between the NAADS program and the adoption of technologies and practices, sale of output, and agricultural income. These are represented by the dotted paths. For example, households realizing an increase in agricultural production (or income) due to adoption of NAADS technologies in one season or year may decide to drop the adoption in the subsequent season or year if they were unable to sell their surplus outputs profitably due to low prices resulting from increase in aggregate supply. In the next section, we present the data and methods used for measuring and estimating the direct and indirect effects of the NAADS program and agricultural income, and for estimating the net benefits.

4. Data and methods

4.1. Data

The data used in this study are from two rounds of rural household surveys conducted in 2004 and 2007. The 2004 survey served as the baseline on which a stratified sample was based according to the year when the NAADS program was first implemented in the sub-county: (1) sub-counties where the NAADS program was first established in 2001/02, (2) sub-counties where the program began in 2002/03, (3) sub-counties where the program began between 2005 and 2007, and (4) sub-counties where the program had not been implemented at the time of the 2007 survey. This stratification was done to account for the effect of the rollout of the program that may result in a modified treatment among later entrants of the program due to learning from previous treatments among earlier entrants of the program (supply-side effects of the program), as well as from nonrandom preparedness of later entrants prior to receiving the treatment (demand-side effects). From the first stratum, representing the pilot phase, all the 24 sub-counties were selected. The sub-counties in the latter three strata were purposively sampled such that they had similar agricultural potential[3] and

[3] Agricultural potential is an abstraction of many factors—including rainfall level and distribution, altitude, soil type and depth, topography, presence of pests and diseases, presence of irrigation, and others—that influence the absolute (as opposed to comparative) advantage of producing agricultural commodities in a particular place.

market access[4] as the corresponding sub-counties in the first stratum, which was done to minimize the effect of national- and other higher-level conditioning factors that may affect the local conditions and livelihoods of different communities differently and are likely to significantly affect agricultural production and income. In these latter strata, 18 of the total of 72 sub-counties were sampled. From each selected sub-county, two parishes were randomly selected, then one village was randomly selected from each parish, and then 6 to 13 households were randomly selected from each village. Together, 900 and 1200 households were surveyed in 2004 and 2007, respectively, with a panel of 719 households on which the analysis is based.

Of relevance to this study, the information collected from the surveys includes use of improved agricultural technologies and practices, agricultural production inputs and outputs, marketing, and gross revenue. Secondary data were also collected at the sub-county level on various aspects of the program implementation including expenditures. In the analysis, all monetary values were converted into 2000 constant prices using the consumer price index as the deflator, which helps to exclude the influence of inflation and other temporal monetary and fiscal trends. All estimates are also corrected for stratification, clustering, and weighting of sample. The clusters were the villages and sampling weights (inverse of the probability of a household being selected in the sample) were calculated using parish-level population data (UBOS, 2003). Due to the nature of the sampling in the survey, the results are representative only of the selected sub-counties, since these were purposively selected.

4.2. Methods and estimation approaches

4.2.1. Estimation of the impacts

The main challenge with estimating the impacts of any investment program, including the NAADS program, lies with attributing change in the indicator of interest to the program. Basically, the impact of the NAADS program can be measured by the difference between the expected value of agricultural income (*INC*) earned by each farm household *j* participating in the program and the expected value income the farm household would have received if the farm household had not participated in the program. This difference, referred to as the average treatment effect of the treated (ATT_j), can be represented as

$$ATT_j = E\left[INC_{1j}|NAADS_j = 1\right] - E\left[INC_{0j}|NAADS_j = 1\right], \quad (1)$$

where INC_{1j} is the income of farm household *j* after participation in the program and INC_{0j} is the income of the same farm household *j* had the household not participated in the program. Unfortunately, we cannot observe the counterfactual, i.e., income of the farm household if the farm household had not participated in the program. In addition, since individual farm households may choose to participate in the program or not, those who choose to participate are likely to be different from those who choose not to participate. These differences, if they influence income, may invalidate the results from comparing income between the two groups, and, possibly, even after adjusting for differences in observed covariates (Imbens and Wooldridge, 2008).

Several methods have been proposed and employed in the literature to deal with these issues ranging from traditional approaches, including fixed-effect methods from panel data analysis and instrumental variables (IV) methods, to experimental and quasi-experimental methods that try to establish alternative scenarios to represent the counterfactual.[5] The underlying estimation problem can now be represented as a treatment-effects model of the form:

$$INC_{jt} = \alpha_j + \tau_t + \beta' x_{jt} + \delta NAADS_j + \varepsilon_{jt} \quad (2)$$

$$NAADS_j^* = \gamma' w_j + u_j$$
$$NAADS_j = \begin{cases} 1, & \text{if } NAADS_j > 0 \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

where x_j and w_j are the vectors of variables determining income and the decision to participate in the NAADS program, respectively; $NAADS_j = 1$ and $NAADS_j = 0$ represent participation in the program (or treatment) and nonparticipation in the program (control), respectively; α and τ capture the individual and time-specific effect, respectively; β and γ are the vectors of parameters measuring the relationships between the dependent and independent variables; and ϵ and u are the random components of the respective equations with joint normal distribution of means (μ, 0) and covariance matrix $\left[\begin{smallmatrix} \sigma_\epsilon^2 & \sigma_{\epsilon u} \\ \sigma_{\epsilon u} & 1 \end{smallmatrix}\right]$.

By design of the NAADS program, farm households or farmers self-select into participating in the program through membership in a NAADS-participating farmer group. Therefore, assessing the impacts (i.e., $\hat{\delta}$) from estimation of Eq. (2) by ordinary least squares (OLS) methods is likely to yield biased estimates of the benefits of the program.

Various methods have been proposed and used to estimate the parameters of such a model. A common method employed is the IVs method, which, as the name implies, tries to identify instruments or variables that are correlated with the participation decision (*NAADS*) but not ε to use in estimating the income equation (Greene, 1993). Another method is the fixed-effect method from panel data analysis where the assumption is that unobserved differences between the two groups are constant over time and are not correlated with the independent variables x_j, which is also correlated with the unobserved individual specific effect (α_j) (Greene, 1993). There are also experimental methods that try to establish alternative scenarios that represent

[4] Market access is measured as the potential market integration (estimated as travel time to the nearest five markets, weighted by their population (Wood et al., 1999)) and distance to an all-weather road.

[5] See Imbens and Wooldridge (2008) for review of issues and methods in program evaluation.

the counterfactual situation by ensuring that the composition of the treatment and control groups remains the same over the course of the treatment, i.e., that there is no bias arising from unobserved factors or that the bias arising from unobservable factors remains constant through time (Imbens and Wooldridge, 2008). Each method has its advantages and disadvantages given practical difficulties of testing the validity of the assumptions due to data limitations and quantitative requirements, among others. Cost is another issue. Finding suitable instruments, for example, is very difficult. Testing that there is no bias arising from unobservable factors or it remains constant through time could be explored to some extent with the omitted variable test (Greene, 1993), although it is useful only to the extent that potential omitted variables are available to be included in the participation decision model to begin with. To address these concerns and to generate greater confidence in the resulting estimates, we estimate $\hat{\delta}$ using two different approaches, difference-in-differences (DID) method and a two-stage regression method, in combination with matching techniques.

4.2.2. Propensity score matching method

The propensity score matching (PSM) method, which is a now commonly used quasi-experimental method in program evaluation, is first used to create a matched sample of treatment and control group on which the DIDs and the two-stage regression methods are applied. Typically, the PSM is used to select program participants and nonparticipants who are as similar as possible in terms of observable characteristics that are expected to affect participation in the program as well as the outcomes. The difference in the value of the outcome indicator between the two matched groups is interpreted as the impact of the program on the participants (Smith and Todd, 2005). In practice, the PSM method matches subgroups of program participants with comparable subgroups of nonparticipants using a propensity score, which is the estimated conditional probability of participating in the program.[6] In this case, only participants and nonparticipants that have comparable propensity scores or have matches are used in the estimation. Those that do not have comparable propensity scores or have no matches are dropped. The difference estimator is then used to estimate the impact of the NAADS program (i.e., $\hat{\delta}_{PSM}$) according to

$$\hat{\delta}_{PSM} = \sum_{j} \gamma_j (\widehat{INC}_{1j} - \widehat{INC}_{0j}) \quad (4)$$

where γ_j are weights based on propensity scores. Therefore, the PSM method requires econometric estimation of Eq. (3) only, using a binary-dependent variable model (probit or logit) to predict the conditional probability of participating in the program or being in the treatment group. The independent variables typically used for computing the propensity scores are those which affect participation in the treatment or the outcome. The basic PSM method is based on matching each participant with one nonparticipant only, which can limit any potential gain from matching participants with more than one nonparticipant with similar attributes. Thus, different matching techniques such as kernel and covariate nearest-neighbor are used to address this potential shortcoming. With the kernel matching, each treated individual is matched based on a weighted average of all controls that fall within a bandwidth and a smoothing parameter is used to estimate the kernel density and the weights are inversely proportional to the distance between the propensity scores of the treated and controls (Becker and Ichino, 2002). With the covariate nearest neighbor matching, each treated individual is matched with the nearest two, three, or any chosen number of control neighbors, while accounting for the difference in the mean values of the covariates between the matched treated and control groups (Abadie and Imbens, 2006, 2007). The main drawback in using these techniques fully by themselves in this paper to assess the impact has to do with the issue of correcting for stratification, clustering, and sampling weights according to the stratified sampling features of our data.[7] With the available software known to us for using these techniques, only stratification may be corrected for with the kernel matching (Leuven and Sianesi, 2003). The implication of this on the resulting estimates is that they will approach the true values to the extent that the within-group and across-group variation in the sampling weights are similar within a particular stratum. Compared to the kernel matching, the nearest neighbor matching allows specification of sampling weights, where the nearest neighbors are chosen such that their summed weights are equal to or just exceed number of matches specified (Abadie et al., 2004). This means that, irrespective of the number of matches specified, the actual number of matches that is used is likely to be different for different treatment observations and will depend on the value of the weight associated with the treated observation and those of its nearest neighbors. Since the sampling weights are positive numbers with values up to unity, the number of actual matches will be at least as large as the number of matches specified, with the number increasing as the weights associated with the treated observation and those of its nearest neighbors decreases. This is likely to introduce bias to the extent that the nearest neighbors are further away.

Therefore, we only use the matching technique to generate the propensity scores (i.e., matched sample) on which the DIDs and the two-stage regression methods can be applied, since the sampling features of the data can be properly dealt with. The probit model was used to estimate Eq. (3) and select the matched sample of treatment and control groups, and the "balancing test" (Dehejia and Wahba, 2002) was used to check whether and the extent to which any differences that existed between the two groups prior to the matching have been reduced or eliminated

[6] See Becker and Ichino (2002) on how to implement the PSM method.

[7] Correcting for stratification and clustering treats observations in the same stratum or cluster as having similar unobservable or omitted characteristics, while correcting for weighting of sample causes the contribution of each observation in the average estimate to be weighted according to their representativeness in the overall population or their likelihood of being included in the sample.

in the matched sample. Basically, this is a test of whether and the extent to which the matched comparison group can be statistically considered to represent a plausible counterfactual. The test comprises *t*-tests for equality of means in the treated and control groups both before and after matching and based on a regression of each explanatory variable on the treatment indicator. Before matching this is an unweighted regression on the whole sample, while after matching it is a weighted regression using weights based on the propensity scores of the matched sample.

4.2.3. Difference-in-differences method

Assuming that the outcome indicator of interest was growing or changing at the same rate between the treatment group and the control group prior to the treatment, the DID or double differencing method, which measures the average gain or change in income over time in the treatment group less the average gain or change in income over time in the control group, can be used (Ravallion, 2008). Albeit simple, this method removes biases in the comparison between the two groups that may be due to permanent differences between the two groups (e.g., location effect), as well as biases from comparison over time in the treatment group that may be due to time trends unrelated to participation. The impact of the NAADS program using this method can be obtained by estimating a difference equation of Eq. (2) without the covariates by OLS methods according to

$$\Delta INC_j = \hat{\alpha} + \hat{\delta}_{DID} NAADS_j + e_j \tag{5}$$

$$\Delta INC_j = \hat{\alpha} + \hat{\delta}_{DIDT} NAADS_j + INC_{jt0} + e_j \tag{6}$$

where $\Delta INC = INC_{t1} - INC_{t0}$, and INC_{t0} and INC_{t1} are the incomes in the initial (2004) and later (2007) periods, respectively. The estimated impact of the program ($\hat{\delta}_{DIDT}$) from Eq. (5) exploits the panel features of the data further by accounting for the initial value of the outcome, which is the preferred estimator. The DID method can be extended to include other factors (represented by the vector x_j in Eq. 2), which we explore next with the multivariate regression method.

4.2.4. Two-stage weighted regression method

To net out the effect of time-variant factors on the outcome over the period of treatment, a regression method is necessary. Because of the potential correlation between the covariates ($\boldsymbol{x}_j$) and the treatment ($NAADS_j$), conventional methods that are available for estimating Eq. (2) (e.g., fixed-effect methods with panel data analysis and instrumental variables methods) are not sufficient. Thus, we combine matching and multivariate regression methods in a two-stage weighted regression (2SWR) procedure (Imbens and Wooldridge, 2008; Robins and Rotnitzky, 1995; Robins et al., 1995). Following the probit estimation of Eq. (3), the propensity scores are then used as weights in a second-stage estimation of Eq. (2) to estimate

$$\Delta INC_j = \hat{\alpha} + \hat{\boldsymbol{\beta}}'_{2SWR} \Delta \boldsymbol{x}_j + \hat{\delta}_{2SWR} NAADS_j + e_j \tag{7}$$

$$\Delta INC_j = \hat{\alpha} + \hat{\boldsymbol{\beta}}'_{2SWRT} \Delta \boldsymbol{x}_j + \hat{\delta}_{2SWRT} NAADS_j + INC_{jt0} + e_j \tag{8}$$

where $\Delta \boldsymbol{x} = \boldsymbol{x}_{t1} - \boldsymbol{x}_{t0}$, and $\boldsymbol{x}_{t0}$ and $\boldsymbol{x}_{t1}$ are the initial and later period values of the explanatory variables, respectively, and, similar to the DID regressions, Eq. (8) exploits the panel features of the data further. The weighting is to be interpreted as removing the bias due to any correlation between $\boldsymbol{x}_j$ and $NAADS_j$, while the regression isolates the effect of $\boldsymbol{x}_j$ over time. In a typical two-stage estimation procedure, it is important to address the identification of the second-stage regression or endogeneity of the first-stage regression. A common procedure used is exclusion restrictions in the sense of excluding some of the explanatory variables used in estimating the first-stage probit from the second-stage regression (i.e., having $\boldsymbol{x} \subset \boldsymbol{w}$ or $\boldsymbol{x} \neq \boldsymbol{w}$ and corr $(w, \varepsilon/x) = 0$). In general, nonlinearity of the first-stage probit model as is the case here renders exclusion restrictions unnecessary for identification (Wilde, 2000).[8]

4.2.5. Direct and indirect effects, distributional effects, and enhancing/mitigating factors

We distinguish the average *direct effect* (represented by ATT_{DIR}) from the average *indirect effect* (represented by ATT_{IND}) based on direct participation (labeled $NAADS_{\mathrm{DIR}}$) and indirect participation (labeled $NAADS_{\mathrm{IND}}$) in the program, respectively.[9] To compare the results, we also estimate the *average total effect* (represented by ATT_{TOT}) by defining participation to include both direct and indirect participants (labeled $NAADS_{\mathrm{TOT}}$). The control group includes those that were never exposed to the program (labeled $NAADS_{\mathrm{NON}}$). According to these, the data show that about 9% of the sample was made up of direct participants and 52% as indirect participants, which together make up a total of 61% participants. The remaining 39% was classified as nonparticipants (see Table 1). Essentially, we estimate the different effects by estimating the models using data on the sub-sample representing the relevant treatment group and the control group. Assuming that the true average direct effect of the program is greater than the average indirect effect implies that the average direct effect is also greater than the average total effect. Therefore, assuming that the models are correctly specified and estimated, we would expect ATT_{DIR} to be greater than ATT_{TOT} or ATT_{IND} and can test for the differences using the students *t*-test.

To assess the distribution effect as well as factors that have enhanced or mitigated the effects of the program, we estimated the *ATT*s across several categories of variables representing different socioeconomic and demographic groups (including

[8] Furthermore, since we apply a fixed-effect and difference estimator in the second-stage regression, the condition is satisfied in the sense that $\Delta \boldsymbol{x} \neq \boldsymbol{w}$.

[9] Participation is measured using the status observed in 2007, which is essentially measuring participation at any point in time as there were no dropouts. This is important for the matching so that participants are matched with nonparticipants in all years to avoid duplication or crossover. This way, a treatment household is always a treatment household and cannot switch status; same for a control household.

Table 1
Variables associated with implementation of and participation in the NAADS program

Variable	Description	Mean	Standard error
$NAADS_{DIR}$	Proportion of households that are members of a NAADS-participating farmer group in 2007	0.09	0.01
$NAADS_{IND}$	Proportion of households that are not members of a NAADS-participating farmer group but accessed or received NAADS-related advisory services in 2007	0.52	0.02
NAADS_years	Proportion of sub-counties in which NAADS program was implemented by year (cf: never implemented)		
NAADS_year03/04	If after 2003/2004	0.05	0.01
NAADS_year02/03	If 2002/2003	0.28	0.02
NAADS_year01/02	If 2001/2002	0.52	0.02

Source: NAADS-IFPRI 2004 and 2007 household surveys (panel data).

gender, age, education, assets) and incidence of or access to different types of other public services (i.e., credit, roads, markets). For the continuous variables, low and high categories were created using cut-off points associated with the NAADS program with adjustments in some cases to ensure that there were enough observations in each category to be able to carry out the estimations reliably.[10]

4.2.6. Estimation of the net benefits of the program

Assessing the rate of return requires knowledge of the discounted benefits and costs. The basis for deriving the benefits was discussed in the preceding sections. The costs of the program include the costs associated with implementing the program,[11] and the opportunity cost of the time of CBFs. A standard technique for assessing the merits of a public investment project is cost–benefit analysis by calculating the benefit–cost ratio (*BCR*), which is the present value of benefits divided by the present value of costs (Dasgupta and Pierce, 1972). Let the benefits of the NAADS program in time t in this case be given by $ATT_t = \sum_j ATT_{jt}$ and the total costs by C_t. Then *BCR* is obtained by

$$BCR = \frac{\sum_{t=0}^{T}[ATT_t/(1+r)^t]}{\sum_{t=0}^{T}[C_t/(1+r)^t]}.$$

where T is the life span of the program and r is the discount rate to capture the relative importance of the program's net benefits to different members of society, including those who have not yet been born. We used an 8.5% discount rate to be consistent with the rate used by the government in appraising its public investment projects, but perform sensitivity of the results to choice of the discount rate by using a lower rate of 5%, which more reflects the discount rate found in Ugandan villages (Bauer and Chytilová, 2009), as well as a higher rate of 14%, which reflects the interest rate applied to the government's 364-day treasury bills (Bank of Uganda, 2008). The rate of return, which more reflects the efficiency of the program's investments, is the value of r for which the *BCR* equals 1.

4.2.7. Variables

Agricultural income (*INC*) is agricultural income per adult equivalent, which is measured as the total gross value of households' crop, livestock, beekeeping, and aquaculture output (or agricultural gross revenue) divided by the total number of household members in adult equivalents.[12] The choice of explanatory variables for the estimations was guided by the principles and design of the NAADS program as well as the literature on agricultural household models (de Janvry et al., 1991; Singh et al., 1986) and adoption of agricultural technologies (e.g., Feder et al., 1985; Feder and Umali, 1993) as presented in the conceptual framework (i.e., *TECH*, *MKT*, *ASSESTS*, and *OTH*). Adoption of improved technologies and practices (*TECH*) includes: use of crop improved varieties, use of recommended planting and spacing requirements, use of inorganic fertilizers, use of organic fertilizers, use of pesticides, and use of livestock improved breeds.[13] Marketed output (*MKT*) is measured as the percent of total agricultural (crop, livestock, beekeeping, and aquaculture) output sold by farmers. Household assets (*ASSETS*) are captured by size of farm operated–owned and cultivated, and value of agricultural productive assets (e.g., equipment, livestock, etc.). The other influential factors (*OTH*) are captured by: endowments of human capital (gender, age, education, and size structure of household); financial capital

[10] Gender and education were based on the original measures. For age, 40 years was used as the cut-off point to distinguish the young from adults. One acre was used in the case of access to land, while 0.5, 5, and 10 km were used for access to all weather roads, markets, and credit, respectively. Regarding assets, one-third and two-thirds of the range of the value of productive assets were used to define asset terciles. Details of the explanatory are discussed shortly.

[11] Note that public investment projects can impact the environment or have indirect negative impacts on society, the cost of which needs to be taken into consideration. In the NAADS program, a typical example of possible negative impacts could be from the development of fish ponds, which may become breeding grounds for human disease vectors and parasites (e.g., mosquitoes), thereby reducing productivity, raising health cost, and reducing welfare in general. Such possible indirect costs are not dealt with here as we have no information on them.

[12] We weight the household head, other adults (17 years and older), and children (16 years and younger) by 1, 0.924, and 0.595, respectively (based on Appleton et al., 1999), to make welfare comparisons across households with different size and demographic composition.

[13] Although farmers were asked in the survey to report on several other technologies and practices that they used, these were the technologies and practices with relatively high frequency of use to warrant meaningful econometric estimation.

(livelihood and income strategies); social capital (membership in other organizations); access to infrastructure and services (distance to nearest financial services, road, market); and regional dummy variables representing the four administrative regions of Uganda (Central, Eastern, Northern, and Western), which capture slowly changing factors associated with agroecology, biophysical, and socio-cultural factors. To assess some of the lagged effects of the program or rollout effect discussed earlier, we used a dummy variable representing the year when the NAADS program was introduced in the sub-county: implemented in 2001/02 (labeled early *NAADS_year01/02*), implemented in 2002/03 (labeled *NAADS_year02/03*), and implemented after 2003/04 (labeled *NAADS_year03/04*), against the comparative group where it was never implemented. Detailed description and summary statistics of all the variables for different groups, based on the panel data of 719 households from the 2004 and 2007 household surveys (or 1,438 total observations), are given in Tables 1 and 2. Results of estimating the effect of the program are presented in Section 5. All the analyses were carried out using STATA software (version 11, StataCorp, 2008), which calculates the correct standard errors of the estimated parameters based on the stratified sampling features of data—corrects for stratification, clustering, and weighting of sample.[14]

4.2.8. *Interpretation of results*

As we utilize different approaches that have different underlying assumptions to evaluate the impacts of the program, naturally we do not expect to obtain identical point estimates. The main assumptions underlying the DID and matching methods, for example, involve (observable) behavior of the treatment and control groups prior to the treatment as well as their (unobservable) behavior following treatment. These assumptions are not testable with the data at hand to *a priori* determine the direction or magnitude of any expected differences among the different estimates.

Based on the design features of the NAADS program also, we acknowledge that the participation decision (i.e., determinants) could be different for the direct and indirect participants. However, we use the same explanatory variables across the board to simplify the analysis and to also examine how they are indeed different. Furthermore, we expect the characteristics of the two groups to be different to the extent that the principles of the program are indeed implemented. For example, we expect the direct participants to be poorer, to be less educated, and to have lower physical and financial assets than the indirect participants. These are testable and are indeed verified (see Table 2). The issue is how these differences affect the estimates of the direct and indirect impacts of the program. Since indirect participants are better endowed to acquire the enterprises and technologies being promoted by the program on their own, then it is possible for the indirect impacts to be greater than the direct impacts, especially in the early years of the program (until direct participants catch up) and where availability of the enterprises and technologies is not limited to the direct participants only.

Adoption of improved technologies and practices (*TECH*) and marketed output (*MKT*) may be treated as outcomes of the program, which introduces the issue of simultaneity for estimating the structural models for each outcome variable. We address this by estimating Eqs. (7) and (8) with and without these potentially endogenous explanatory variables. Estimating the models without them eliminates the potential for endogeneity bias altogether, allowing estimation of the total effect of the included explanatory variables on *INC,* which is the direct effect of the included explanatory variable plus the indirect effect via the excluded endogenous variables. The results will help shed light on the likely impact pathways of the program.

Given the above concerns and issues, there is more confidence in our findings to the extent that the results are similar across the different approaches, especially regarding the sign and statistical significance associated with the relevant variables. Furthermore, there is credibility to our findings to the extent that the results conform to other literature.

5. Results

5.1. *Determinants of participation in the program*

The results presented in Table 3 show that the longer the NAADS program had been in the sub-county the more likely farmers are to participate either directly or indirectly in the program. Membership in other organizations is also strongly associated with greater likelihood of direct or indirect participation in the NAADS program, which is consistent with the NAADS program's approach in terms of targeting existing farmer groups to maximize the payoffs from efforts to build farmers' capacity to demand advisory services. Age, education, and value of productive assets were important for indirect participation but not for direct participation. The statistical insignificance of the coefficients associated with these and other variables on direct participation suggests that the NAADS program may have been successful so far in targeting all socioeconomic groups. It also reflects the strategy of the NAADS program in targeting the economically active poor (i.e., those with limited physical and financial assets, skills, and knowledge). As indirect participants do not have access to the program's grants to finance purchase of relevant technologies, the significant and positive association between the value of productive assets and indirect participation are intuitive. Farmers in the Northern Region were the most likely to participate either directly or indirectly in the program, followed by those in the Western Region, as compared to their counterparts in the Central and Eastern Regions.

The probit results were used to estimate the propensity scores that were used to match the program participants (treatment group) and nonparticipants (control group) for the DID method

[14] Continuous variables were transformed by natural logarithm so that the estimated parameters in the regressions, particularly the 2SWR method, are interpretable directly as elasticities.

Table 2
Description of variables and summary statistics for participants and nonparticipants of the NAADS program

Variable name	Variable description	Nonparticipants ($NAADS_{NON}$)				Indirect participants ($NAADS_{IND}$)				Direct participants ($NAADS_{DIR}$)			
		2004 Mean	S.E.	2007 Mean	S.E.	2004 Mean	S.E.	2007 Mean	S.E.	2004 Mean	S.E.	2007 Mean	S.E.
Income (***INC***)													
Agricultural revenue	Value of total agricultural output per AE ('000 UGX, 2000 value)	193.05	20.59	296.57	42.49	247.48	20.62	382.19	51.78	186.21	30.88	303.91	44.63
*Adoption of technologies (**TECH**)*, proportion of households that:													
Improved seeds	Used improved crop varieties	0.29	0.03	0.56	0.03	0.55	0.03	0.69	0.03	0.28	0.06	0.67	0.06
Spacing	Used recommended spacing/planting practices	0.37	0.03	0.45	0.03	0.67	0.03	0.63	0.03	0.40	0.06	0.63	0.06
Inorganic fertilizer	Used inorganic fertilizers	0.11	0.02	0.06	0.02	0.15	0.02	0.08	0.02	0.12	0.05	0.10	0.04
Pesticides	Used pesticides	0.19	0.03	0.21	0.03	0.36	0.03	0.25	0.03	0.19	0.05	0.21	0.05
Improved breeds	Used improved livestock breeds	0.06	0.02	0.20	0.03	0.22	0.03	0.29	0.03	0.12	0.05	0.29	0.06
*Market participation (**MKT**)*													
Market share	Percent of total agricultural (crop, livestock, apiary, aquaculture) output sold	29.72	2.34	17.79	1.98	32.51	1.83	19.30	1.67	33.14	4.37	21.03	3.59
*Household assets (**ASSETS**)*													
Land owned	Total farmland area owned (acres)	1.79	0.35	1.45	0.29	2.41	0.57	3.34	1.56	1.06	0.12	1.35	0.22
Crop area	Total farmland area under cultivation (acres)	1.54	0.35	1.02	0.11	1.31	0.17	2.65	1.50	1.01	0.20	1.32	0.25
Productive assets	Value of total agricultural productive assets—equipment and livestock ('000 UGX, 2000 value)	121.64	17.91	200.19	22.44	201.74	36.86	301.48	38.72	135.32	32.49	200.32	33.47
*Other factors (OT**H**)*													
Gender of head	Proportion of female-headed households	0.19	0.03	0.23	0.03	0.12	0.02	0.16	0.02	0.19	0.05	0.19	0.05
Age of head	Age of household head (years)	42.99	1.01	46.26	0.98	45.05	0.83	46.48	0.77	43.70	1.88	45.15	1.70
Education	Education of household head (cf: no formal education), proportion												
Primary	Attended or completed primary education	0.64	0.03	0.62	0.03	0.59	0.03	0.61	0.03	0.63	0.06	0.73	0.06
Post-primary	Attended of completed some post-primary education	0.21	0.03	0.20	0.03	0.31	0.03	0.31	0.03	0.24	0.06	0.21	0.06
Size	Number of adult equivalents (AE)	5.14	0.17	5.38	0.16	5.28	0.13	5.77	0.16	4.46	0.30	5.08	0.29
Membership	Proportion of households with a member in any other socioeconomic group	0.36	0.03	0.40	0.03	0.78	0.03	0.69	0.03	0.37	0.06	0.77	0.06
Income strategy	Primary source of income of household (cf: crops), proportion												
Livestock	Livestock is primary source	0.05	0.01	0.04	0.01	0.02	0.01	0.04	0.01	0.07	0.03	0.03	0.03
Other agriculture	Other agriculture is primary source	0.05	0.02	0.04	0.01	0.02	0.01	0.05	0.01	0.11	0.05	0.01	0.01
Nonfarm	Nonfarm is primary source	0.19	0.03	0.30	0.03	0.17	0.02	0.26	0.03	0.10	0.04	0.30	0.06
Access to services	Average distance (km) to nearest:												
Credit	Bank or credit association	20.68	1.14	19.93	1.17	16.78	0.75	15.42	0.70	14.14	1.65	13.63	1.55
All-weather road	All-weather road	2.54	0.19	2.51	0.19	2.71	0.36	2.70	0.36	2.31	0.42	2.35	0.42
Markets	Crop or livestock market and services (input supply, veterinary, etc.)	7.40	0.40	7.46	0.41	8.99	0.56	8.71	0.48	6.09	0.49	6.14	0.51

Source: NAADS-IFPRI 2004 and 2007 household surveys (panel data).

Table 3
First-stage probit results of participation in the NAADS program

	Treated = $NAADS_{TOT}$ Control = $NAADS_{NON}$	Treated = $NAADS_{DIR}$ Control = $NAADS_{NON}$	Treated = $NAADS_{IND}$ Control = $NAADS_{NON}$
NAADS_years			
NAADS_year02/03	1.74***	0.79***	7.58***
NAADS_year01/02	2.07***	0.81***	8.01***
Gender of head	0.07	0.13	0.11
Ln age of head	0.33***	0.25	0.36***
Education			
Primary education	0.26	0.17	0.42***
Post-primary education	0.48**	0.33	0.62***
Ln size	−0.02	−0.27	0.11
Membership	0.98***	0.37**	1.34***
Income strategy (cf: crops)			
Livestock	−0.11	0.09	−0.37
Other agriculture	−0.21	0.30	−0.51
Nonfarm	−0.06	−0.25	−0.04
Ln assets:			
Land owned	−0.01	−0.11	0.05
Crop area	0.07	−0.01	0.12
Productive assets	0.04	0.02	0.06**
Ln distance to service:			
Credit	−0.07	−0.12	−0.04
All-weather road	0.05	0.04	0.03
Markets	0.02	−0.05	0.06
Region (cf: Central)			
Eastern	−0.05	0.32	−0.11
Northern	1.08***	1.23***	1.00***
Western	0.63***	0.81***	0.42**
Intercept	−3.91***	−2.62**	−10.83
Likelihood ratio test	359.65***	58.91***	432.35***
Pseudo R-squared	0.38	0.16	0.50
Number of households			
Total	703	349	627
Treated	430	76	354
Control	273	273	273

See Tables 1 and 2 for detail description of variables. Dependent variables are 2007 values while the explanatory variables are 2004 values. Ln means transformation by natural logarithm. *, **, and *** means statistical significance at the 10%, 5%, and 1% level, respectively.

and weights for the 2SWR method. Households for which there were no matches were dropped from the sample for subsequent estimation of Eq. (2). Among the 719 households, 74 participants did not match any of the nonparticipants and so they were dropped.[15] The relatively large number of dropped indirect participants is intuitive given the program's targeting of the economically active poor (i.e., those with limited physical and financial assets, skills, and knowledge)—indirect participants are realistically outside this basic characterization. The balancing test (Dehejia and Wahba, 2002) results (see Appendix) show that any significant differences in the observable characteristics between the direct participants and controls in the unmatched sub-samples were eliminated after the matching. With respect to the indirect participants, however, several of the existing biases prior to matching remained after matching, particularly regarding gender, education, income source, land, and access to markets. This again reflects the targeting principle of the program, which renders indirect participants further apart from the others, suggesting that estimated indirect effects may not be solely attributed to the program to the extent that those characteristics affect income differently across the different groups.

5.2. *Impact of the program on agricultural income (INC)*

Table 4 summarizes the estimated average total, direct and indirect impacts of the program on agricultural income (*INC*), which is measured by agricultural revenue per AE, using the

[15] The number dropped out of the total number of treatment households for the respective sub-samples associated with the results in Table 3 were 76 of 430 overall participants, 2 of 76 direct participants, and 72 of 354 indirect participants.

Table 4
Impact of the NAADS program on change between 2004 and 2007 in agricultural revenue per adult equivalent and distribution of impact across selected socioeconomic and development indicators (percent difference between program participants and nonparticipants)

	DID			2SWR		
	ATT_{TOT}	ATT_{DIR}	ATT_{IND}	ATT_{TOT}	ATT_{DIR}	ATT_{IND}
Average impact	63.4***	94.8***	55.4***	32.18*	39.20**	26.97
Distribution						
Gender of head						
Male	48.0**	63.9**	42.7**	35.0*	38.1	31.3
Female	33.6	70.1	23.7	2.4	14.1	−3.1
Age of head						
>40 years	42.6*	64.4*	36.8	27.6	30.1	17.1
≤ 40 years	53.1**	58.8*	50.6**	49.9*	56.7*	45.1*
Education of head						
No formal	110.9**	65.3	117.3**	52.9	−53.8	76.0
Primary	35.6	56.1*	30.1	22.8	46.4**	17.5
Post-primary	21.0	32.6	16.3	18.6	−14.1	7.1
Household size						
>5 AE	70.5***	79.5**	68.7***	56.0**	48.2*	49.6**
≤5 AE	22.6	45.7	14.6	6.6	22.0	1.3
Land owned						
>1 acre	77.3**	50.3	84.0**	92.0***	29.4	95.7***
≤1 acre	29.4	65.2**	20.4	2.6	51.4**	−2.2
Cultivated land						
>1 acre	60.0*	53.9	61.1*	69.2**	63.0*	64.0**
≤1 acre	35.8*	58.8**	29.2	16.9	55.3**	17.4
Productive assets						
Tercile 1	31.0	3.9	36.6*	44.2**	49.1	31.2
Tercile 2	67.2**	82.7**	63.4**	55.8*	−8.0	57.2**
Tercile 3	40.5	83.6*	27.0	−18.9	−24.1	−21.5
Distance to credit						
>10 km	81.6***	81.3***	80.3***	53.1**	35.2	53.4**
≤10 km	−0.6	33.1	−9.3	−16.6	27.3	−15.5
Distance to road						
>0.5 km	44.6**	65.8**	37.8*	36.9*	30.7	31.8
≤0.5 km	52.1*	60.4	50.4*	17.7	−8.4	16.5
Distance to markets						
>5 km	83.1***	101.2***	77.3***	66.5***	72.2***	62.2***
≤5 km	4.0	20.7	−0.1	−12.6	−11.8	−11.6
Region						
Central	−0.8	48.7	−11.1	−6.3	−15.3	−11.7
Eastern	63.9*	88.8**	53.0	54.6*	38.5	37.1
Northern	6.1	66.1	−8.5	−55.4	41.7	−20.4
Western	−2.4	−11.8	0.5	−21.3	−6.5	−22.4

The control group in each case is those not exposed to the program ($NAADS_{NON}$). *, **, and *** mean statistical significance at the 10%, 5%, and 1% level, respectively. The distributions of sub-samples across each category are different (see Appendix Table 3).
Source of data: Matched sample of treatment and nontreatment households from NAADS-IFPRI 2004 and 2007 household survey (panel data).

DID and 2SWR methods.[16] Results of factors enhancing or mitigating the estimated impacts are also shown in Table 4.

As Table 4 shows, the NAADS program has had significant positive impact on agricultural revenue per AE. Any form of participation is associated with an average increase of 32–63% in agricultural revenue per AE between 2004 and 2007. As expected, the estimated average impact associated with direct participation is greater than the estimated average impact associated with indirect participation. These are 39–95% and 27–55%, respectively. The detailed regression results presented in the Appendix suggest that the impact of the program on agricultural revenue was significantly via its effect on increased adoption of pesticides for direct participants and increased commercialization (likely due to higher market prices obtained by farmers) for indirect participants. The greater average direct

[16] Detailed 2SWR results are shown in the Appendix, which shows the estimated parameters (and their statistical significance) with respect to change in the other explanatory variables on change in income.

than indirect impact is also reflected in the descriptive statistics (Table 2) in terms of the dynamics between 2004 and 2007 in the adoption of improved technologies and practices. Although the proportion of indirect participants adopting these technologies was significantly higher than the proportion of direct participants adopting in 2004, the proportion of direct participants caught up with those participating indirectly in the year 2007.

These findings are supportive of those of the initial evaluation studies (Benin et al., 2007; Nkonya et al. 2005; OPM, 2005; Scanagri, 2005) that show the program as having had positive impact on increasing use of improved technologies and wealth status of farmers receiving services from the program. The concern regarding the NAADS program in having little success in improving soil fertility management (Benin et al., 2007) is also reflected by the descriptive statistics presented in Table 2, which shows that the adoption of inorganic fertilizers is much lower than the adoption of the other technologies and practices. For example, the proportion of direct participants adopting improved seeds increased substantially from 28% in 2004 to 67% in 2007, compared to only 12% and 10% for those adopting inorganic fertilizers in the respective years.

5.2.1. Distribution of program impacts and factors enhancing the impacts

Gender, age, education, and household size: The estimated average program impact associated with male-headed households was generally greater compared to female-headed households, suggesting that the NAADS program has so far not been as effective for women. This could be explained by the fact that the majority of the extension providers in Uganda are men (about 88%), as research shows that gender similarity between provider and receiver plays a major role in its effectiveness (Lahai et al., 2000). Gender imbalance in service providers in Uganda is consistent with the general knowledge that women experience limited access to agricultural extension (e.g., Doss, 2001; Adesina et al., 2000; Staudt, 1986). The estimated average impact of the program was greater among relatively younger (less than 40 years) household heads, suggesting that the program's strategy of targeting the younger population, which is consistent with the notion that younger people are more willing to adopt riskier and more expensive agricultural technologies, is being effective. The effect of education as a conditioning factor was mixed. Regarding household size, the estimated average impact of the program was greater for larger households, suggesting that labor constraints have hindered adoption of labor-intensive technologies and practices promoted by the program. Thus, providing technologies with different labor requirements for farmers to choose will be critical in maintaining the gains achieved especially among smaller households, where the estimated average impact was greater for those participating directly in the program that may have had assistance with labor-saving technologies such as pesticides.

Land and nonland assets: The estimated direct impact was greater among households that owned or cultivated less than one acre of land while the estimated indirect impact was greater among those that owned or cultivated at least one acre of land. By nonland asset terciles, the estimated average impact was greater among the poorest households and those in the middle category compared to those in the richest tercile. Together, these results suggest that the NAADS program has been more successful at raising average agricultural revenue per AE among those taking on noncrop high-value enterprises as well as among poorer households. It seems that the NAADS program is achieving its objective of promoting those enterprises and targeting the economically active poor including those with limited physical and financial assets.

Access to services and infrastructure and regional location: Households living relatively further away from financial services, all-weather roads, and markets were associated with greater impacts. Looking across regions, the largest and most significant impacts of the program have so far occurred among households located in the Eastern Region. Those located in the Northern Region and participating directly in the program were also associated with greater average agricultural revenue per AE. These results are consistent with each other and may seem counterintuitive. However, the NAADS program, by bringing advisory services and grants for acquiring necessary technologies in addition to creating market linkages, has been more effective in areas with poor access to services and infrastructure needed to support technology adoption and increased commercialization of agricultural production. It seems that farmers in more well-off areas or regions are in a better position to acquire the improved technologies and related advisory services on their own.

5.3. Estimated net benefit of the program

To estimate the net benefit of the program, we used the benefits and costs associated with the surveyed sub-counties only. For the benefit, we used the range of estimated average direct impact (ATT_{DIR}) of 39–95% and average indirect impact (ATT_{IND}) of 27–55%. First, we estimated the annual average direct and indirect benefits, which were obtained by dividing the estimated values by three.[17] These were then converted into per capita values using a scaling factor of 0.7, which is the mean number of adult equivalents (5.3) divided by the mean number of household members (7.1) from the survey. The total benefits for each year was calculated as the sum of the products of the annual average direct and indirect impact by the respective total number of farmers that were expected to benefit directly

[17] Applying the estimated benefits from 2004 to 2007 retroactively to previous years assumes that the gains from the NAADS program are immediate because there are enough off-the-shelf technologies available that are easily procured and implemented by farmers if provided with the right financial resources. This is not unrealistic as the results presented earlier show that the program has been more effective among the poor, including those with limited physical and financial assets as well as those in areas with poor access to services and infrastructure needed to support technology adoption and increased commercialization of agricultural production.

Table 5
Total benefits and costs of the NAADS program in surveyed sub-counties (2000 UGX, millions)

	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	Total
Benefits							
ATT_{DIR} & ATT_{IND}							
Low	4,605	7,374	7,632	7,900	8,417	9,209	45,137
High	9,848	15,772	16,324	16,895	18,001	19,696	96,536
ATT_{TOT}							
Low	5,175	8,287	8,577	8,877	9,458	10,349	50,724
High	10,188	16,315	16,886	17,477	18,621	20,374	99,862
Costs							
Imputed Secretariat/District	2,864.8	1,687.4	1,619.8	621.8	1,139.5	939.4	8,872.7
Sub-counties	242.3	774.0	710.0	1,025.9	1,243.2	1,556.7	5,551.9
CBFs	0.8	1.5	1.9	2.4	2.9	3.7	13.2
Total	3,107.9	2,462.9	2,331.7	1,650.0	2,385.6	2,499.8	14,437.8

Source: Benefits are authors' calculation based on estimated average direct and indirect impacts of the NAADS program on agricultural revenue per AE (Table 4), expected number of direct and indirect participants of the NAADS program (Table 1), and 2002/03 population census data (UBOS, 2003); costs are authors' calculation based on data from the NAADS Secretariat and sub-county offices.

Table 6
Benefit–cost ratio of the NAADS program in surveyed sub-counties

Discount rate (%)	Based on estimated impact on gross revenue		Accounting for cost of farmers and of loan (I)		Accounting for cost of farmers and of loan (II)	
	Low *ATT*	High *ATT*	Low *ATT*	High *ATT*	Low *ATT*	High *ATT*
5.0	3.1	6.5	1.7	3.5	1.3	2.7
8.5	3.0	6.4	1.6	3.5	1.3	2.7
14.0	2.9	6.3	1.6	3.5	1.3	2.7

Source: Authors' calculation based on estimated benefits and costs of the program (Table 5). Assume farmers' cost associated with participation is 35 and 50% in I and II, respectively, while the cost of loan is 0.125% of the total amount spent.

and indirectly from the NAADS program in that year. The respective total number of farmers were obtained by multiplying the percentage of survey respondents that benefited directly ($NAADS_{DIR}$) and indirectly ($NAADS_{IND}$) from the program by the total population of farmers in the sub-county.[18] The total benefit of the NAADS program in the 37 surveyed sub-counties between 2001/02 and 2006/07 was estimated at UGX 45.1–96.5 billion (Table 5). This is close to the estimated amount of UGX 50.7–99.9 billion based on the estimated average total impact (ATT_{TOT}) of 32–63%.

The total cost of the NAADS program was estimated based on transfers from the NAADS Secretariat to the sub-counties (including contributions made by the districts and sub-counties), imputed amounts spent at the Secretariat and district levels, and the opportunity cost of the time of the CBFs in providing advisory services.[19] The resulting estimated total cost of the NAADS program from 2001/02 to 2006/07 in the 37 surveyed sub-counties is UGX 14.4 billion (Table 5).

Based on the total benefits and costs presented above and using the 5, 8.5, and 14% discount rates, the benefit–cost ratio is in the range of 2.9–6.3 and 3.1–6.5 for the highest and lowest discount rates, respectively; where the low- and high-end values of each range of ratios correspond to the low- and high-end values of the range of estimated benefits, respectively (Table 6).

The benefits of the NAADS program as presented above were based on the estimated gross agricultural revenue per AE, which did not account for the cost of farm inputs and operations incurred by farmers to participate in the program as well as the cost of raising public funds to finance the NAADS program. Regarding the farm production costs, we estimated that they

[18] The percentage of farmers benefiting directly and indirectly from the program in each year was assumed constant at 9 and 52, respectively (see Table 1). The total number of farmers in the surveyed sub-counties was obtained by using data from the 2002/03 population census (UBOS, 2003). First, we used the average of 5305 households per sub-county and 4.9 persons per household, and then we applied the average annual population growth rate of 3.5% to get the annual population for each sub-county.

[19] The amounts spent at the Secretariat and at the district levels were divided proportionally for each sub-county according to the total number of sub-counties where the program was implemented at the time. The opportunity cost of time of the CBFs in year t ($C_{CBF,t}$) was calculated as follows: $C_{CBF,t} = EXT_{CBF,t} * h_t * w_t * n_t$; where: EXT_{CBF} is the average number of CBF visits received by a farmer each year, which was obtained from the household survey panel data and was 0.4 in 2004 and 0.5 in 2007; h is the average number of hours spent by a CBF in a farmer visitation, which was assumed at 1.5 hours; w is the hourly wage rate, which was estimated at UGX 300 in 2000 value terms (based on Barambah et al., 2007); and n is the number of farmers visited by a CBF, which was obtained by the percentage of the surveyed farmers visited by a CBF multiplied by the population of farmers. The proportion of farmers visited by a CBF each year was obtained by a linear extrapolation of estimates from the household survey data in 2004 and 2007, which were 6 and 7%, respectively. The number of farmers in each sub-county was obtained as discussed earlier.

account for about 35% of the gross revenue, based on data from the 2007 survey, which reduces the discounted total benefits to UGX 24.7–52.0 billion, UGX 21.6–46.2 billion, and UGX 18.2–38.8 billion for the 4, 8.5, and 15% discount rates, respectively. For sensitivity purposes, we also use a higher value of 50% of the gross revenue to represent the cost by farmers.

Increased public spending necessarily implies raising taxes, now or in the future. And it is common knowledge that taxation alters the consumption and production decisions of society, which results in a deadweight loss–the marginal cost of public funds. Basically, the shadow price of a dollar of public revenue is higher than one because, in addition to the deadweight loss, the government incurs administrative costs to collect taxes. The deadweight loss (i.e., negative effect on production and consumption) has been estimated to range from 1.1 to 1.4% of GDP for several African countries, while the administrative cost of governments to collect taxes has been estimated to range from 1 to 4% of total tax collections (Warlters et al., 2005, cited in Herrera, 2008). For the NAADS program, the Government of Uganda obtained a development credit from the International Development Association in the amount thirty five million three hundred thousand Special Drawing Rights (SDR 35,300,000) at the cost of up to 0.075% per annum of amount withdrawn (i.e., service charge) and up to 0.05% per annum of amount not withdrawn (i.e., commitment charge) (ROU/IDA, 2001). Taking account of the interest payments only (i.e., not accounting for the deadweight loss and administrative cost associated with raising and collecting taxes, respectively), we estimated an additional discounted cost of UGX 2.4 billion.

These together bring down the benefit–cost ratio to 1.6–3.5 or 1.3–2.7, assuming that the cost to farmers in participating in the program is about 35 or 50% of the estimated average impact on gross agricultural revenue per AE, respectively (Table 6). This means an internal rate of return of 16–49 or 8–36% assuming cost to farmers is 35 and 50% of the estimated average impact on gross agricultural revenue per AE, respectively. These are lower than the average rate of return of 85% and 48% estimated for agricultural extension and combined agricultural research and extension, respectively, based on a meta-study of several case studies by Alston et al. (2000). The range of values identified by Alston et al. (2000) is very large though: zero to 636% for agricultural extension only, and −100 to 430% for combined agricultural research and extension.

6. Conclusions and implications

The NAADS program of Uganda, which started in 2001, is an innovative public–private extension service delivery approach, with the goal of increasing market-oriented agricultural production by empowering farmers to demand and control agricultural advisory services. While the importance of agricultural advisory services in agricultural and rural development is widely known, due to competing uses of public resources for promoting overall growth and equitable distribution, careful reflection of the impacts of and returns to spending on the NAADS program is necessary. This is the aim of the study, whose overall objective was to assess the direct and indirect impacts of the program on household agricultural income and returns to spending on the program.

Due to methodological challenges arising from the complex ways that many factors influence the relationship between extension inputs and outcomes, as well as data quality issues, we used data from the two rounds of household surveys conducted in 2004 and 2007, as well as different evaluation methods and model specifications, to deal with the above concerns and to generate greater confidence in the policy implications of the estimated impact and rate of return.

The results show that direct participation in the program was associated with a larger positive impact on overall agricultural revenue per adult equivalent. Overall participation was associated with an average increase of 32–63% in gross agricultural revenue per adult equivalent, while direct and indirect participation were associated with average increases of 37–95% and 27–55%, respectively. Based on these and assuming that farmers incur an average cost of 35–50% of the estimated gross revenue to participate in the program, the internal rate of return on expenditures made on the program until the end of the 2006/07 financial year is estimated at 8–49%.

Assessment of the distributional effects of the program across several socioeconomic and demographic groups suggests that the NAADS program has so far not been as effective for women as for men. While the effect of education as a conditioning factor was mixed, the estimated average impact was greater for larger households, suggesting that labor constraints have hindered adoption of labor-intensive technologies and practices promoted by the program.

The results also suggest that the program has been more successful at raising average agricultural revenue per adult equivalent among poorer households, suggesting that the program is achieving its objective of targeting the economically active poor including those with limited physical and financial assets. Households living relatively further away from financial services, all-weather roads, and markets or located in the Eastern and Northern Regions were associated with greater impacts. By bringing advisory services and grants for acquiring necessary technologies in addition to creating market linkages, the NAADS program has been more effective in areas with poor access to services and infrastructure needed to support technology adoption and increased commercialization of agricultural production. Farmers in the more well-off areas or regions are in better position to acquire the improved technologies and related advisory services being on their own.

Although the study tried to capture many important issues regarding the benefits and costs of the program to assess the economic returns, a few issues remain that future research can improve upon. These relate to general equilibrium effects and accounting for other costs and benefits. For example, the scaling out of the NAADS program to all parts of the country is likely to affect relative prices and may require additional taxes to pay back the loan obtained to finance the program. From the production point of view, both effects mitigate the impact of the program, potentially leading to an overestimation of benefits based on partial equilibrium analysis. However, reduced food prices, which benefit consumers and farmers that are net-buyers of food, may cancel or outweigh the negative effect on producer surplus, leading to overall welfare gain. Similarly, strengthening the capacity of farmers and service providers also will affect the skill composition of the rural labor force and service providers, which in turn will likely affect the wage structure and cost of advisory services. An increase in aggregate demand by farmers for advisory services would also have similar effect on wage and cost effects. Thus, including economic modeling techniques in future analysis will prove useful.

The NAADS program can be expected to generate a range of other benefits, including improved human resource skills associated with training and strengthening of local institutional capacity. For example, training will develop improved skills that could contribute to productivity improvements not only on the farm but off it. Training of village groups, CBFs, farmer contact groups, and farmer forums at the local level will strengthen local institutional capacities and empower farmers to effectively demand advisory services. The improvements in both the human resource skills and institutional capacity will generate benefits when also used in nonagricultural economic and noneconomic activities.

Appendix Table 1. Balancing test on initial values (2004) of observable characteristics between NAADS participants and nonparticipants for alternative definitions of treatment and control

Variable	Sample	Treated = $NAADS_{TOT}$ Control = $NAADS_{NON}$			Treated = $NAADS_{DIR}$ Control = $NAADS_{NON}$			Treated = $NAADS_{IND}$ Control = $NAADS_{NON}$		
		Treated	Control	*t*-test	Treated	Control	*t*-test	Treated	Control	*t*-test
Gender of head	Unmatched	0.15	0.20	***	0.21	0.20		0.13	0.20	***
	Matched	0.16	0.15		0.22	0.22		0.14	0.25	***
Ln age of head	Unmatched	3.75	3.70	***	3.71	3.70		3.76	3.70	***
	Matched	3.73	3.79	***	3.70	3.75		3.74	3.74	
Education										
Primary	Unmatched	0.60	0.64		0.64	0.64		0.59	0.64	***
	Matched	0.62	0.64		0.62	0.55		0.61	0.62	
Post primary	Unmatched	0.28	0.20	***	0.21	0.20		0.29	0.20	***
	Matched	0.25	0.19	***	0.22	0.27		0.25	0.17	***
Ln size	Unmatched	1.55	1.49	**	1.39	1.49	**	1.58	1.49	***
	Matched	1.53	1.52		1.41	1.41		1.56	1.62	
Membership	Unmatched	0.71	0.36	***	0.38	0.36		0.78	0.36	***
	Matched	0.68	0.67		0.39	0.47		0.74	0.73	
Income strategy										
Livestock	Unmatched	0.04	0.06		0.06	0.06		0.04	0.06	***
	Matched	0.05	0.05		0.05	0.09		0.05	0.08	***
Other agriculture	Unmatched	0.03	0.05	**	0.08	0.05		0.02	0.05	***
	Matched	0.03	0.04		0.08	0.05		0.02	0.00	**
Nonfarm	Unmatched	0.14	0.16		0.10	0.16	***	0.15	0.16	
	Matched	0.16	0.14		0.11	0.11		0.18	0.13	
Ln land owned	Unmatched	0.04	−0.21	***	−0.23	−0.21		0.09	−0.21	***
	Matched	−0.02	0.15	**	−0.29	−0.22		−0.02	0.39	***
Ln crop area	Unmatched	−0.29	−0.44	***	−0.45	−0.44		−0.25	−0.44	***
	Matched	−0.32	−0.50	***	−0.51	−0.40		−0.32	−0.27	
Ln productive assets	Unmatched	10.34	9.64	***	9.82	9.64		10.45	9.64	***
	Matched	10.34	10.14		9.86	9.79		10.40	10.48	
Ln distance to service:										
Credit	Unmatched	2.51	2.69	***	2.31	2.69	***	2.55	2.69	***
	Matched	2.48	2.32	***	2.41	2.33		2.44	2.44	
All-weather road	Unmatched	0.15	0.27	***	0.14	0.27		0.15	0.27	
	Matched	0.15	0.20		0.18	0.35		0.19	0.53	***
Markets	Unmatched	1.89	1.83		1.76	1.83		1.92	1.83	***
	Matched	1.85	1.83		1.76	1.80		1.80	1.94	**

See Tables 1 and 2 for detail description of variables. The variables are 2004 values. Ln means transformation by natural logarithm. **, and *** mean statistical significance at the 5% and 1% level, respectively, of the difference in the means between treated and control group.

Appendix Table 2. Second-stage weighted regression results of change between 2004 and 2007 in logarithm of agricultural revenue per adult equivalent (AE)

	Without change in adoption and marketed output			With change in adoption and marketed output		
	$NAADS_{TOT}$	$NAADS_{DIR}$	$NAADS_{IND}$	$NAADS_{TOT}$	$NAADS_{DIR}$	$NAADS_{IND}$
NAADS						
$NAADS_{TOT}$	0.32*			0.12		
$NAADS_{DIR}$		0.39**			0.24	
$NAADS_{IND}$			0.27			0.11
Δ Use of technologies						
Improved seeds				0.19	0.22	0.15
Spacing				−0.17*	−0.03	−0.11
Pesticides				0.18	0.24*	0.15
Inorganic fertilizer				0.17	−0.23	0.17
Livestock breeds				0.18	0.20	0.24
Δ Market share				0.01***	0.00	0.01***
Δ Gender of head	−0.11	0.00	−0.09	−0.24	−0.19	−0.25
Δ Age of head	−0.41	−0.86**	−0.12	0.10	−0.07	0.35
Δ Education (cf: no change)						
Reduction	−0.13	−0.20	−0.04	0.05	0.12	0.12
Improvement	0.06	−0.06	0.08	0.13	−0.08	0.15
Δ Size	0.36	0.35	0.30	0.05	0.02	0.01
Δ Income strategy						
To crops	−0.18	−0.42	−0.13	−0.26	−0.54**	−0.13
To livestock	0.88***	1.73***	0.62*	0.79***	1.37***	0.52
To other agriculture	0.58*	0.54	0.50*	0.44	0.21	0.34
To nonfarm	0.02	0.22	−0.10	−0.17	0.09	−0.27
Δ Land owned	0.12	0.13	0.18**	0.06	0.07	0.11
Δ Crop area	0.32***	0.39***	0.29***	0.37***	0.42***	0.33***
Δ Productive assets	0.12**	0.10*	0.11***	0.02	0.00	0.03
Δ Distance to service:						
Credit	0.05	−0.28	0.01	0.05	−0.47	0.01
All-weather road	−0.06	−0.06	0.19	−0.07	−0.14	0.20
Markets	−0.02	−0.32	−0.03	−0.10	−0.25	−0.04
Ln agricultural revenue per AE_2004	−0.76***	−0.81***	−0.75***	−0.61***	−0.71***	−0.59***
Intercept	8.81***	9.43***	8.72***	7.37***	8.41***	7.14***
Fisher's *F*-test	27.10***	39.06***	27.42***	12.76***	13.65***	11.57***
R-squared	0.53	0.67	0.52	0.35	M	0.36

See Tables 1 and 2 for detail description of variables. The control group in each case is those not exposed to the program ($NAADS_{NON}$). Ln means transformation by natural logarithm. Δ means change between 2004 and 2007 values. *, **, and *** mean statistical significance at the 10%, 5%, and 1% level, respectively.
Source of data: Matched sample of treatment and nontreatment households from NAADS-IFPRI 2004 and 2007 household survey panel data.

Appendix Table 3. Distribution of sub-samples across categories

	Nonparticipants	Indirect participants	Direct participants
Gender of head			
Male	211	228	55
Female	71	50	14
Age of head			
>40 years	171	157	36
≤40 years	124	122	33
Education of head			
No formal	57	37	6
Primary	179	174	52
Post-primary	57	68	11
Household size			
>5 AE	140	140	31
≤5 AE	155	139	38
Land owned			
>1 acre	77	86	27
≤1 acre	218	193	42

(*Continued*)

Appendix Table 3. ***Continued***

	Nonparticipants	Indirect participants	Direct participants
Cultivated land			
>1 acre	72	80	27
≤1 acre	223	199	42
Productive assets			
Tercile 1	118	81	19
Tercile 2	94	102	25
Tercile 3	83	96	25
Distance to credit			
>10 km	183	135	40
≤10 km	112	144	29
Distance to road			
>0.5 km	216	203	49
≤0.5 km	79	76	20
Distance to markets			
>5 km	184	166	41
≤5 km	111	113	28
Region			
Central	71	56	10
Eastern	131	57	18
Northern	17	38	12
Western	76	128	29

Source of data: Matched sample of treatment and nontreatment households from NAADS-IFPRI 2004 and 2007 household survey (panel data).

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