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Impact of Ghana's Agricultural Mechanization Services Center Program

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ABSTRACT

Use of mechanization in African agriculture has returned strongly to the development agenda, particularly following the recent high food prices crisis. Many developing country governments—including Ghana, the case study of this paper—have resumed support for agricultural mechanization, typically in the form of providing subsidies for tractor purchase and establishment of private-sector-run agricultural mechanization service centers (AMSECs). The aim of this paper is to assess the impact of Ghana's AMSEC program on various outcomes, using data from household surveys that were conducted with 270 farmers, some of them located in areas with the AMSEC program (treatment) and others located in areas without the program (control). A two-stage propensity score matching estimation procedure, with different model specifications and definitions of treatment, is used to estimate the impacts of the program.

The results indicate that the AMSEC program has had a mixed impact on different outcome indicators. For example, whereas the program has contributed to improving availability of mechanization services, reducing drudgery, promoting adoption of good practices, and raising yield, it has had no impact on the change in the prices paid by farmers for the services used and the change in the amount of area plowed. Implications of the results on labor-mechanization substitution and for raising productivity further are drawn.

Keywords: agricultural mechanization, Ghana, propensity score matching

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1. INTRODUCTION

The rationale for mechanization in agricultural development is well known. For example, by increasing power inputs to increase the scale of farming operations and to improve the timeliness, quality, and efficiency of the operations, mechanization can contribute to increasing production, productivity, and profitability of agriculture. With mechanization also seen as a way of relieving drudgery in agriculture, it is not surprising that tractor-based mechanization has historically received popular support among policymakers across Africa and other developing countries. This has led to the establishment of government-run businesses to provide tractor-based mechanization services to farmers. Previous attempts to mechanize agriculture, which took place from the 1950s until the early 1980s, when large quantities of tractors were supplied to developing countries in the form of aid, have been criticized because the programs failed to induce sustained adoption of mechanization. The consensus seems to be that there was lack of real demand from farmers for such tractor-based mechanization services, as agriculture was characterized by high labor-land ratios and low rural wages. Also, the mechanization centers were afflicted with the typical inefficiencies of state-run businesses, which led to heavy fiscal burdens. See, for example, Pingali, Bigot, and Binswanger (1987); Pingali (2007); and Mrema, Baker, and Kahan (2008).

With persistent low agricultural productivity in most parts of Africa, characterized by increasing agricultural labor shortages and high and rising rural wages, agricultural mechanization has returned strongly to the agricultural development agenda in Africa, particularly Africa south of the Sahara, which lags behind other developing regions of the world in mechanization. For example, the proportion of agricultural area that is cultivated by tractors in Africa south of the Sahara is only 10 percent, compared to 20 percent in East Asia, 35 percent in South Asia, 50 percent in Latin America and the Caribbean, and 60 percent in the Near East and North Africa (Takeshima and Salau 2010). Many African governments have resumed their support for agricultural mechanization, typically in the form of providing subsidies for tractor purchase and establishment of private-sector-run agricultural mechanization service centers (AMSECs). In Ghana, the case study of the paper, the government in 2007 introduced an AMSEC program—a credit facility where qualified private-sector companies are given an average machinery package of five tractors and matching implements at a subsidized price and interest rate—with the aim of making mechanization services for farm activities readily available and affordable within each district that has potential for mechanization to increase agricultural output and productivity (MoFA 2013).

The justification for and effects of such interventions (and input subsidies in general) are complex and often controversial. Aside from the potential fiscal burden, providing subsidies on tractors and tractor-related implements can distort the development of the tractor and implement supply chains and crowd out private-sector investments. In Ghana, for example, the government imports all the tractors and implements for the AMSEC program. Therefore, the market could be dominated by government-selected brands of machinery and service providers. As a result, other more-efficient (including lower-cost) machines or mechanization services may not be introduced into the market,[1] competition may be reduced, tractor hire or mechanization service charges may increase, and demand for mechanization may be retarded. Ultimately, this chain of undesirable results may negate achievement of the aims of the AMSEC program to make mechanization services readily available and affordable and to increase agricultural output and productivity.

The aim of this paper is to assess the impact of Ghana's AMSEC program on various outcome indicators (including mechanization services charges, drudgery, agricultural area mechanized, and productivity) using household survey data collected from July to August 2011 from 270 farmers, some located in areas with the AMSEC program and others located in areas without the program. Results from another study that is based on initial analysis of the above survey data (Benin et al. 2013) show that Ghana's AMSEC program has indeed contributed to improving farmers' access to different

[1] For example, since 2003 the majority of tractors imported into Ghana for agricultural use are in the range of 50 to 80 horsepower, which it has been argued is ineffective and inefficient for the small and fragmented landholdings in Ghana (Diao et al 2012).

mechanization services and to increasing the average area mechanized by farmers. The study by Benin et al. (2013) concludes that the program has not crowded out private-sector investments in the market, based on the finding of lack of a statistically significant difference between service providers that benefited from the AMSEC program and those that did not in their respective mechanization market shares and prices charged. However, there are two fundamental methodological issues with that study, which when dealt with appropriately could give different results and, consequently, different policy implications.

The first issue has to do with the estimation of treatment effects, which fundamentally involves identifying a reliable counterfactual or control group (that is, areas or markets that are not contaminated with the AMSEC program) against which to compare the group that has been exposed to the program or treatment group (that is, areas or markets in which AMSEC—or a service provider that has benefited from the AMSEC program—operates). In the Benin et al. (2013) study, treatment is defined by users of AMSEC services only who are then compared with users of non-AMSEC services, without explicit consideration that both users of AMSEC services and users of non-AMSEC services could have accessed the same local market for mechanization, such that they may face the same rental prices and other conditions. The second issue is related to the first one in the sense of identifying a control group that is similar to the treatment group across various variables that affect the treatment as well as the outcomes of the treatment. In the Benin et al. (2013) study, the authors compare their indicators of interest across the two groups (users of AMSEC services and users of non-AMSEC services) without verifying the comparability of the groups in terms of, for example, household labor and farming experience, which are known to affect demand for mechanization (Panin 1995; Pingali 2007) and productivity (Singh, Squire, and Strauss 1986). Therefore, results of the Benin et al. (2013) study could be biased to the extent of the overlap in the covariate distributions or common support between the treated and control observations (Dehejia and Wahba 2002; Imbens and Wooldridge 2009).

To deal with the above issues and to provide more reliable estimates of the treatment effects of Ghana's AMSEC program, we use propensity score matching in a two-stage estimation procedure to first identify a reliable control group against which to compare the treatment group that is consistent with treatment at the local market level and then estimate the impact of the program by testing for statistically significant differences between the two groups in the values of various outcomes indicators. As anticipated with such estimation procedures based on finding common support between the treated and control observations, several of the original 270 observations from the household survey data used (particularly those among the control group) had to be dropped, and then analysis of the treatment effects were conducted with the remaining or legitimate observations. The results obtained indicate that the AMSEC program, which is more likely to be located and used in areas where farmers are more organized, in the transition and guinea savannah zones, or in areas characterized by low market access and low population density, has had mixed impact. For example, whereas the program has contributed to reducing drudgery, promoting adoption of good practices, and raising yield, it has had no impact on the change in the prices paid by farmers for the services used and the change in the amount of area plowed by farmers.

The remainder of the paper is organized as follows. The conceptual framework for evaluating the impacts of the AMSEC program is presented in the next section, followed by the data and evaluation methods in section 3. The results are presented in section 4, followed by conclusions and implications in section 5.

2. CONCEPTUAL FRAMEWORK

The fundamental issue that the AMSEC program seeks to address is the inadequate supply and use of mechanization in agricultural production due to high entry barriers mostly in the form of large initial capital requirement for purchasing tractors and other farm machinery and implements. This in turn places limitations on the amount of land that could be cultivated by a farmer. For example, a farmer using only hand hoes can prepare about 0.5 hectare only for planting in each season (Fonteh 2010), which takes about 93 hours to prepare, compared to 10 hours using draft animals and only a couple of hours using a tractor (Houssou et al. 2013). Furthermore, small-scale farms, compared to larger farms, are usually associated with higher unit costs of operation, lower adoption of modern inputs and technologies, lower average yields, and consequently lower incomes and consumption outcomes to small-scale farmers. Therefore, the pathways of impact of the AMSEC program hinge on easing the entry barriers via some kind of public-private partnership, where the government's credit facility is expected to crowd in private-sector investments in the tractor rental and mechanization services supply chains. The greater supply of services would in turn result in cheaper services, which together would boost the number of farmers purchasing mechanization services as well as the area cultivated. Farmers can now adopt more modern inputs (for example, fertilizer, pesticides) and practices (for example, row planting, specific spacing) that can also be mechanized. Together, the various results are expected to raise labor and land productivity and to reduce the unit cost of production (Rijk 1989), which in turn will affect famers' income, consumption, and food and nutrition security positively.

The expected increase in labor productivity derives from two sources: mechanization as a substitute for labor whereby farm labor is released for employment in other sectors of the economy, thereby cultivating the same area using a smaller amount of farm labor, and mechanization as a facilitator for cultivating a larger area using the same amount of farm labor. The former source of labor productivity growth has been of concern in the sense of mechanization's creating unemployment by displacing labor in similar activities. However, by increasing the scale of operations, mechanization can increase the total demand for farm labor by increasing the scale of complementary farm operations such as fertilizer application, pruning, and harvesting. Regarding increase in land productivity, the notion is that mechanization, being a complementary input in the production process, raises the productivity of all factors used in the production process. The reduction in the unit cost of production is expected because introduction of a machine may lower production costs or offset increased costs of draft animals or labor.

Because provision of mechanization services tends to be localized, that is, limited to the specific geographic area in which the service provider is located, the above chain of outputs and outcomes is expected to occur or to be more pronounced in the area where an AMSEC or a mechanization service provider benefiting from the AMSEC program is located. Furthermore, the fulfillment of the chain of outputs and outcomes will depend on multiple other factors. For example, access to and use of other agricultural inputs like certified seed, fertilizer, and pesticides is important, especially for raising productivity. Farmers' characteristics, including their endowments of human, physical, financial, and social capital, which affect their willingness and ability to purchase mechanization services and other agricultural inputs, are also important (Singh, Squire, and Strauss 1986; Panin 1995). Similarly, adoption decisions as well as the outcomes may be influenced by many community-level factors beyond the farmer's control, such as agricultural potential, access to markets, and population density (Pender, Place, and Ehui 2006). These factors largely determine the comparative advantage of a location by determining the costs and risks of using different inputs and producing different commodities, among other things.

Because the government imports or purchases tractors and implements for the AMSEC program and the government selects service providers benefiting from the program, the mechanization services supply chain could be distorted, as the market could be dominated by government-selected brands of machines and service providers. This could result in reduced competition, lower diversity of services, and higher charges for services. Furthermore, because service providers on their own tend to invest in the same machines and implements over time, and because market failures and liquidity constraints limit

complementarity among different farm implements (Takeshima and Salau 2011), the supply-side substitution effects are likely to be dominant. From the demand side, however, the farmer, who is concerned about getting the needed farm power on a timely basis and at the lowest possible cost, may not care whether the source of mechanization is an AMSEC (service provider that has benefited from the AMSEC program). The farmer's demand for and use of a mechanization service will depend on the extent to which the service provider is able to satisfy his or her mechanization needs timely and at least cost. For example, one of the arguments for mechanization is the reduction in the unit cost of production. In recent past years in Ghana, the cost of plowing an acre of farmland does not seem to be significantly different from using manual labor, draft animals, or a tractor (Houssou et al. 2013),2 which may seem to render moot the reduced cost rationale for mechanization. However, timeliness and other hidden costs associated with the different power sources should be considered in the debate.

[2] The service charge (in Ghanaian Cedi) for plowing an acre of land is GHS 32 for hoeing by hand, GHS 28 for draft animals, and GHS 35 for a tractor (Houssou et al. 2013).

3. DATA AND METHODS

Surveys and Data

The data are from household surveys conducted from July to August of 2011 using a combination of purposive and random stratified sampling of 46 districts and 270 farmers (see Benin et al. 2013 for details). Based on the location of AMSECs or service providers benefiting from the government's AMSEC program within the selected districts, and assuming that mechanization services are provided within the community in which a provider is located,3 the sample was first demarcated into farmers located in communities with an AMSEC (treatment group—180 farmers) and those in communities without an AMSEC but with other mechanization service providers (control group—90 farmers). For the treatment, farmers were differentiated by the source of mechanization services used according to AMSEC only (52 farmers), non-AMSEC only (62 farmers), or both AMSEC and non-AMSEC (66 farmers). The data cover a range of factors hypothesized to affect the ability of farmers to use mechanization and other farm inputs in the production process as well as production and other outcomes. The data were collected to reflect the situation prior to implementation of the program (that is, in 2007/2008, representing the baseline scenario) and any changes that have occurred in the three years following implementation of the program (that is, between 2008 and 2011)—details of the variables used are presented later.

Estimation Approach

The main impact measure of interest here is the average treatment effect on the treated (ATT_j) according to

$$ATT_j = E\left[y_{1j} \middle| AMSEC_j = 1\right] - E\left[y_{0j} \middle| AMSEC_j = 1\right], \tag{1}$$

where y_{1j} is the value of the outcome of farm household j after benefiting from the local market conditions created by introducing an AMSEC into the community and y_{0j} is the income of the same farm household j if the household did not benefit from the program. Unfortunately, we cannot observe the counterfactual or the outcome of the farm household if the farm household had not benefitted from the program or if the farm household had been located elsewhere. In addition, because the location of the program in an area is expected to be based on the potential of the area for mechanization (MoFA 2013) and the characteristics of the location influence farmers' decisions about using mechanization (see conceptual framework), farmers located in areas with the program are likely to be different from those located in other areas. These differences, if they influence outcomes, may invalidate the results from just comparing the outcome (say farm area mechanized) between the two groups and, possibly, even after adjusting for differences in observed covariates (Imbens and Wooldridge 2009).

The underlying estimation problem of equation 1 can be represented as a treatment-effects model of the form

$$y_{jt} = \alpha_j + \tau_t + \boldsymbol{\beta}'\boldsymbol{x}_{jt} + \delta AMSEC_j + \epsilon_{jt} \tag{2}$$

$$AMSEC_j^* = \boldsymbol{\gamma}'\mathbf{w}_j + u_j$$

$$AMSEC_j = \begin{cases} 1, \ if \ AMSEC_j > 0 \\ 0, \ \text{otherwise} \end{cases}, \tag{3}$$

[3] At the time of the fieldwork for collecting the data, there were 84 AMSECs. As at July 2013, there were 89 AMSECs established in 62 districts (MoFA 2013).

where $AMSEC_j^*$ is a latent unobserved variable whose counterpart, $AMSEC_j$, is observed in dichotomous form only; where $AMSEC_j = 1$ represents areas where the program is implemented (that is, treatment) and $AMSEC_j = 0$ represents other areas where the program is not implemented (that is, control); where $\boldsymbol{w}_j$and $\boldsymbol{x}_j$are the vectors of variables determining location and outcome of the AMSEC program, respectively; where α and τ capture the individual and time-specific effect, respectively; where β and γ are the vectors of parameters measuring the relationships between the dependent and independent variables; and where ϵ and u are the random components of the respective equations with joint normal distribution of means (μ, 0) and covariance matrix $\begin{bmatrix} \sigma_\varepsilon^2 & \sigma_{\epsilon u} \\ \sigma_{\epsilon u} & 1 \end{bmatrix}$. A two-stage weighted estimation approach is used wherein equation 3 is first estimated by probit to obtain the propensity scores, which are then used as weights in a second-stage estimation of equation 2 based on matched treatment and control observations identified in the first stage (see Benin et al. 2011).

The *ATT* of the AMSEC program is estimated using three definitions of treatment according to the source of the mechanization services used by the farmer in an area where the AMSEC program is implemented: (1) use of AMSEC providers only, which is labeled $AMSEC_A$; (2) use of other service providers only, which is labeled $AMSEC_N$; or (3) use of both types of service providers only, which is labeled $AMSEC_B$. Different combinations of the definitions were also considered, including: use of either AMSEC providers only or other providers only, which is labeled $AMSEC_{AN}$; use of either AMSEC providers only or both types of providers only, which is labeled $AMSEC_{AB}$; use of either other providers only or both types of providers only, which is labeled $AMSEC_{NB}$; and use of any type of service provider, which is labeled $AMSEC_{ANB}$; to give a total of seven subsamples of treatment. The *ATT*s of the program were obtained by estimating the models using data on each of the seven subsamples ($AMSEC_i$) at a time with the control group (non-AMSEC), represented by ATT_A for the subsample of $AMSEC_A$ and non-*AMSEC*, ATT_N for the subsample of $AMSEC_N$ and non-*AMSEC*, ATT_B for the subsample of $AMSEC_B$ and non-*AMSEC*, and so on.

Assuming that farmers in the same treatment face identical mechanization market conditions, with their choice of service provider used being determined by the farmers' own mechanization requirements and preferences, then there is no a priori expectation of differences between the *ATT*s. That is, there is no reason to expect that, for example, ATT_A would be greater or less than ATT_B. Using the different definitions of treatment, however, helps to generate greater confidence in the results to the extent that the models are correctly specified and estimated. The analyses were carried out using STATA software version 12.1 (StataCorp 2013).

Variables

Various outcome variables are considered in the analysis. These include availability and reliability of mechanization services, number of activities that are mechanized, size of land area that is mechanized, tractor-hire and service charges, reduction in drudgery, adoption of good farm practices (including row planting and recommended planting density and spacing), and yield. Consistent with the conceptual framework, the explanatory variables used capture availability of other farm inputs and technologies (for example, improved seed, fertilizer, irrigation), characteristics of farmers (including gender, age, education, farming experience, and membership in other organizations), and characteristics of the location of farmers (agroecological zones, market access, and population density).

To help generate reliable results of the first-stage estimation in terms of using explanatory variables that give the greatest common support between the matched treatment and control observations, different model specifications involving different measurements of and interactions among the explanatory were tried, as consistent with recommended practices (see, for example, Dehejia and Wahba 2002). Three specifications were used: (1) including only level terms of the explanatory variables—base model or Model 1; (2) adding interaction terms between some of the explanatory variables such as gender, age, and education—base model plus interaction terms or Model 2; and (3) adding squared terms

of continuous explanatory variables—base model plus interaction terms plus squared terms or Model 3. Trying these different specifications also contributes to assessing sensitivity of the results to using different covariates in estimating the impacts of the program. Detailed description of all the variables is given in Table 3.1 and summary statistics are given in Tables 3.2, 3.3, 3.4, and Table A.1 in the appendix.

Table 3.1 Description of outcomes associated with the agricultural mechanization service center program and explanatory variables

Variable Name	Variable Description
Outcome variable	
Availability of mechanization services	Whether service providers are readily available and accessible: 0 = no, 1 = yes
Reliability of mechanization services	Whether service providers are reliable: 0 = no, 1 = yes
Number of activities mechanized	Number of different activities that are mechanized (for example, plowing, harrowing, planting, fertilizer application)
Change between 2008 and 2011 in area plowed and rental charges	
Area plowed (acres)	Change in amount of area plowed (acres)
Rental charge (GHS/acre)	Change in rental charge for plowing services (GHS/acre)
Perception of change between 2008 and 2011 in availability of tractor services and other inputs	
Plowing services (cf. no change)	Plowing (cf. no change)
Deteriorated	Situation has deteriorated by a little or by a lot
Improved	Situation has improved by a little or by a lot
Improved seed (cf. no change)	Seed (cf. no change)
Deteriorated	Situation has deteriorated by a little or by a lot
Improved	Situation has improved by a little or by a lot
Fertilizer (cf. no change)	Fertilizer (cf. no change)
Deteriorated	Situation has deteriorated by a little or by a lot
Improved	Situation has improved by a little or by a lot
Herbicide (cf. no change)	Herbicide (cf. no change)
Deteriorated	Situation has deteriorated by a little or by a lot
Improved	Situation has improved by a little or by a lot
Pesticide (cf. no change)	Pesticide (cf. no change)
Deteriorated	Situation has deteriorated by a little or by a lot
Improved	Situation has improved by a little or by a lot
Irrigation (cf. no change)	Irrigation (cf. no change)
Deteriorated	Situation has deteriorated by a little or by a lot
Improved	Situation has improved by a little or by a lot
Perception of impact of change in mechanization on outcomes	
Reduced drudgery (cf. none)	Reduced drudgery (cf. no impact)
High	The impact is high or very high
Low	The impact is low or very low
Saving labor (cf. none)	Labor saving (cf. no impact)
High	The impact is high or very high
Low	The impact is low or very low
Improved practices (cf. none)	Improved farm practices—for example, row planting, spacing (cf. no impact)
High	The impact is high or very high
Low	The impact is low or very low
High yield (cf. none)	High yield (cf. no impact)
High	The impact is high or very high
Low	The impact is low or very low
Good output price (cf. none)	Good output price (cf. no impact)
High	The impact is high or very high
Low	The impact is low or very low

Table 3.2 Continued

Variable Name	*Variable Description*
Explanatory variable	
Gender	Whether gender of farmer is male: 0 = no, 1 = yes
Age	Age of farmer (years)
Education (cf. none)	Education of farmer (cf. no formal education)
Primary	Attended or completed primary education
Postprimary	Attended or completed some postprimary education
Full-time farmer	Whether farmer is engaged in farming as full-time business: 0 = no, 1 = yes
Membership	Whether farmer is a member of any farmer organization: 0 = no, 1 = yes
Agroecology	Agroecological zone of the community in which the farmer is located: 0 = coastal and forest, 1 = transition and guinea savannah
Population density	Population density of the district in which the farmer is located: 0 = low (that is, less than or equal to 150 persons per square kilometer), 1 = high (that is, greater than 150 persons per square kilometer)
Market access	Access to markets by the community in which the farmer is located: 0 = high (that is, up to two hours of travel time from district to the nearest town with a population of 50,000 or more people), 1 = low (that is, more than two hours)

Source: Household survey (2011).

Note: cf. = compared to. GHS = Ghanaian Cedi. See Tables 3.2, 3.3, and 3.4 for summary statistics on explanatory variables and the appendix for summary statistics on key outcome variables.

Table 3.3 Balancing test on explanatory variables: Model 1

Explanatory variable		Using subsample of non-*AMSEC* and													
		AMSEC$_A$		***AMSEC$_B$***		***AMSEC$_{AB}$***		***AMSEC$_N$***		***AMSEC$_{AN}$***		***AMSEC$_{BN}$***		***AMSEC$_{ABN}$***	
		T	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**
Gender	U	0.61	0.73	0.92	0.73 ***	0.78	0.73	0.70	0.73	0.66	0.73	0.81	0.73	0.75	0.73
	M	0.61	0.54	0.92	0.94	0.78	0.79	0.72	0.85 *	0.66	0.74	0.82	0.73	0.76	0.73
Age	U	45.67	42.79	41.48	42.79	43.33	42.79	45.95	42.79	45.83	42.79 *	43.68	42.79	44.25	42.79
	M	45.76	44.33	42.67	41.14	43.18	43.52	45.95	43.25	45.71	47.18	43.35	43.20	44.01	45.34
Primary	U	0.41	0.47	0.44	0.47	0.43	0.47	0.49	0.47	0.46	0.47	0.47	0.47	0.45	0.47
	M	0.39	0.35	0.47	0.49	0.43	0.40	0.48	0.62	0.43	0.43	0.47	0.50	0.45	0.44
Postprimary	U	0.18	0.19	0.22	0.19	0.20	0.19	0.18	0.19	0.18	0.19	0.20	0.19	0.19	0.19
	M	0.20	0.15	0.25	0.22	0.22	0.14	0.18	0.12	0.19	0.29 *	0.22	0.14	0.20	0.19
Full-time farmer	U	0.57	0.74 **	0.70	0.74	0.64	0.74	0.72	0.74	0.65	0.74	0.71	0.74	0.67	0.74
	M	0.59	0.57	0.67	0.67	0.66	0.68	0.72	0.70	0.66	0.67	0.71	0.69	0.68	0.66
Membership	U	0.53	0.45	0.65	0.45 **	0.60	0.45 **	0.48	0.45	0.50	0.45	0.56	0.45 *	0.55	0.45
	M	0.52	0.43	0.59	0.59	0.60	0.66	0.47	0.48	0.48	0.44	0.54	0.58	0.54	0.47
Agroecology	U	0.67	0.61	0.76	0.61 **	0.72	0.61 *	0.49	0.61	0.57	0.61	0.63	0.61	0.64	0.61
	M	0.67	0.70	0.73	0.76	0.72	0.76	0.50	0.58	0.59	0.60	0.62	0.59	0.64	0.61
Population density	U	0.18	0.33 *	0.32	0.33	0.25	0.33	0.28	0.33	0.23	0.33	0.30	0.33	0.26	0.33
	M	0.20	0.13	0.27	0.20	0.27	0.35	0.28	0.17	0.24	0.20	0.31	0.30	0.27	0.27
Market access	U	0.59	0.47	0.56	0.47	0.57	0.47	0.56	0.47	0.57	0.47	0.56	0.47	0.57	0.47
	M	0.54	0.48	0.47	0.39	0.52	0.49	0.55	0.42	0.55	0.50	0.53	0.56	0.53	0.57

Source: Household survey and first-stage probit selection equation results (2011).

Note: AMSEC = agricultural mechanization service center; T = treated (AMSECj) observations where the AMSEC program is implemented and farmer uses AMSEC service provider only (AMSECA), both types of service providers only (AMSECB), either AMSEC only or both types of providers only (AMSECAB), other service providers only (AMSECN), either AMSEC only or other types of providers only (AMSECAN), either others only or both types of providers only (AMSECNB), and any provider (AMSECANB); C = untreated or control (non-AMSEC) observations where the AMSEC program is not implemented; U = unmatched subsample of treated and control observations; M = matched subsamples of treated and control observations. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Table 3.4 Balancing test on explanatory variables: Model 2

Explanatory variable		Using subsample of non-*AMSEC* and													
		AMSEC$_A$		***AMSEC$_B$***		***AMSEC$_{AB}$***		***AMSEC$_N$***		***AMSEC$_{AN}$***		***AMSEC$_{BN}$***		***AMSEC$_{ABN}$***	
		T	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**
Gender	U	0.61	0.73	0.92	0.73 ***	0.78	0.73	0.70	0.73	0.66	0.73	0.81	0.73	0.75	0.73
	M	0.64	0.52	0.92	0.96	0.80	0.78	0.73	0.76	0.69	0.64	0.81	0.90 *	0.78	0.81
Age	U	45.67	42.79	41.48	42.79	43.33	42.79	45.95	42.79	45.83	42.79 *	43.68	42.79	44.25	42.79
	M	45.66	43.16	42.96	42.21	43.58	45.72	44.77	42.55	45.14	47.49	43.33	42.92	43.99	42.86
Primary	U	0.41	0.47	0.44	0.47	0.43	0.47	0.49	0.47	0.46	0.47	0.47	0.47	0.45	0.47
	M	0.41	0.39	0.46	0.50	0.42	0.49	0.53	0.53	0.44	0.48	0.47	0.43	0.45	0.50
Postprimary	U	0.18	0.19	0.22	0.19	0.20	0.19	0.18	0.19	0.18	0.19	0.20	0.19	0.19	0.19
	M	0.20	0.18	0.25	0.35	0.22	0.25	0.14	0.12	0.19	0.11 *	0.21	0.32 *	0.20	0.22
Full-time farmer	U	0.57	0.74 **	0.70	0.74	0.64	0.74	0.72	0.74	0.65	0.74	0.71	0.74	0.67	0.74
	M	0.57	0.48	0.67	0.65	0.66	0.63	0.78	0.75	0.65	0.70	0.72	0.70	0.68	0.71
Membership	U	0.53	0.45	0.65	0.45 **	0.60	0.45 **	0.48	0.45	0.50	0.45	0.56	0.45 *	0.55	0.45
	M	0.52	0.57	0.60	0.62	0.59	0.65	0.45	0.35	0.47	0.38	0.55	0.44 *	0.53	0.52
Agroecology	U	0.67	0.61	0.76	0.61 **	0.72	0.61 *	0.49	0.61	0.57	0.61	0.63	0.61	0.64	0.61
	M	0.66	0.52	0.73	0.79	0.72	0.75	0.57	0.63	0.58	0.50	0.62	0.68	0.63	0.63
Population density	U	0.18	0.33 *	0.32	0.33	0.25	0.33	0.28	0.33	0.23	0.33	0.30	0.33	0.26	0.33
	M	0.20	0.25	0.27	0.19	0.27	0.23	0.25	0.29	0.25	0.31	0.31	0.26	0.29	0.25
Market access	U	0.59	0.47	0.56	0.47	0.57	0.47	0.56	0.47	0.57	0.47	0.56	0.47	0.57	0.47
	M	0.52	0.50	0.48	0.40	0.53	0.48	0.47	0.41	0.53	0.61	0.54	0.53	0.53	0.53

Source: Household survey and first-stage probit selection equation results (2011).

Note: AMSEC = agricultural mechanization service center; T = treated (*AMSEC$_j$*) observations where the AMSEC program is implemented and farmer uses AMSEC service provider only (*AMSEC$_A$*), both types of service providers only (*AMSEC$_B$*), either AMSEC only or both types of providers only (*AMSEC$_{AB}$*), other service providers only (*AMSEC$_N$*), either AMSEC only or other types of providers only (*AMSEC$_{AN}$*), either others only or both types of providers only (*AMSEC$_{NB}$*), and any provider (*AMSEC$_{ANB}$*); C = untreated or control (non-*AMSEC*) observations where the AMSEC program is not implemented; U = unmatched subsample of treated and control observations; M = matched subsamples of treated and control observations. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Table 3.5 Balancing test on explanatory variables: Model 3

Explanatory variable		Using subsample of non-*AMSEC* and													
		AMSEC$_A$		***AMSEC$_B$***		***AMSEC$_{AB}$***		***AMSEC$_N$***		***AMSEC$_{AN}$***		***AMSEC$_{BN}$***		***AMSEC$_{ABN}$***	
		T	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**
Gender	U	0.61	0.73	0.92	0.73 ***	0.78	0.73	0.70	0.73	0.66	0.73	0.81	0.73	0.75	0.73
	M	0.65	0.54	0.93	0.96	0.81	0.79	0.75	0.69	0.69	0.64	0.81	0.82	0.78	0.80
Age	U	45.67	42.79	41.48	42.79	43.33	42.79	45.95	42.79	45.83	42.79 *	43.68	42.79	44.25	42.79
	M	45.13	44.89	42.75	44.35	43.17	46.73 **	45.38	43.40	45.62	45.41	43.39	45.13	43.94	45.41
Primary	U	0.41	0.47	0.44	0.47	0.43	0.47	0.49	0.47	0.46	0.47	0.47	0.47	0.45	0.47
	M	0.39	0.30	0.45	0.45	0.43	0.42	0.49	0.60	0.44	0.48	0.47	0.43	0.44	0.64 ***
Postprimary	U	0.18	0.19	0.22	0.19	0.20	0.19	0.18	0.19	0.18	0.19	0.20	0.19	0.19	0.19
	M	0.20	0.26	0.24	0.18	0.22	0.30	0.18	0.15	0.19	0.11	0.21	0.21	0.20	0.15
Full-time farmer	U	0.57	0.74 **	0.70	0.74	0.64	0.74	0.72	0.74	0.65	0.74	0.71	0.74	0.67	0.74
	M	0.54	0.52	0.69	0.75	0.66	0.63	0.73	0.87 *	0.65	0.66	0.72	0.76	0.67	0.70
Membership	U	0.53	0.45	0.65	0.45 **	0.60	0.45 **	0.48	0.45	0.50	0.45	0.56	0.45 *	0.55	0.45
	M	0.50	0.46	0.62	0.65	0.60	0.66	0.47	0.42	0.48	0.41	0.54	0.42 *	0.53	0.45
Agroecology	U	0.67	0.61	0.76	0.61 **	0.72	0.61 *	0.49	0.61	0.57	0.61	0.63	0.61	0.64	0.61
	M	0.67	0.67	0.75	0.82	0.72	0.77	0.55	0.58	0.58	0.54	0.61	0.62	0.63	0.61
Population density	U	0.18	0.33 *	0.32	0.33	0.25	0.33	0.28	0.33	0.23	0.33	0.30	0.33	0.26	0.33
	M	0.20	0.20	0.27	0.29	0.27	0.22	0.27	0.22	0.25	0.23	0.32	0.22 *	0.28	0.25
Market access	U	0.59	0.47	0.56	0.47	0.57	0.47	0.56	0.47	0.57	0.47	0.56	0.47	0.57	0.47
	M	0.54	0.50	0.51	0.44	0.52	0.46	0.51	0.51	0.54	0.52	0.53	0.54	0.54	0.57

Source: Household survey and first-stage probit selection equation results (2011).

Note: AMSEC = agricultural mechanization service center; T = treated (*AMSEC$_j$*) observations where the AMSEC program is implemented and farmer uses AMSEC service provider only (*AMSEC$_A$*), both types of service providers only (*AMSEC$_B$*), either AMSEC only or both types of providers only (*AMSEC$_{AB}$*), other service providers only (*AMSEC$_N$*), either AMSEC only or other types of providers only (*AMSEC$_{AN}$*), either others only or both types of providers only (*AMSEC$_{NB}$*), and any provider (*AMSEC$_{ANB}$*); C = untreated or control (non-*AMSEC*) observations where the AMSEC program is not implemented; U = unmatched subsample of treated and control observations; M = matched subsamples of treated and control observations. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

4. RESULTS

Treatment and Model Specification

Results of the first-stage probit selection equation are presented in Tables 4.1, 4.2, and 4.3 for the different definitions of treatment and different model specifications. Looking at the Wald chi-square statistic, which measures the overall statistical significance of the estimated model, the results suggest that using the treatment definitions represented by $AMSEC_A$ (that is, treatment sample of farmers that used an AMSEC only), $AMSEC_B$ (that is, treatment sample that used both AMSECs and non-AMSECs), and $AMSEC_{AB}$ (that is, a combination of $AMSEC_A$ and $AMSEC_B$) give the best results. This is consistent across the three model specifications. Results associated with the model specifications that include interaction terms (that is, Model 2 in Table 4.2) or both interaction and squared terms (that is, Model 3 in Table 4.3) are superior to the results associated with the base model that excludes both interaction and squared terms (that is, Model 1 in Table 4.1). However, the results obtained for models 2 and 3 are not significantly different.

Different aspects of the probit results shown in Tables 4.1, 4.2, and 4.3 and discussed above are reflected by the histograms of the estimated propensity scores (Figures 4.1, 4.2, and 4.3), which show how the treatment and control observations are matched across different classes of propensity scores—see further details in Table 4.4 and balancing tests (Tables 3.2, 3.3, and 3.4), which show how the treatment and control observations compare before and after matching. The histograms show that the treatment definition represented by $AMSEC_{AB}$ gives the best results in terms of having a better distribution of the matched treatment and control observations across the different classes of propensity scores, basically the greatest common support. These results are consistent across the three model specifications.

Table 4.1 First-stage probit selection equation results: Base model or Model 1

Explanatory variable	*AMSEC*$_A$	*AMSEC*$_B$	*AMSEC*$_{AB}$	*AMSEC*$_N$	*AMSEC*$_{AN}$	*AMSEC*$_{BN}$	*AMSEC*$_{ABN}$
	Using subsample of non-*AMSEC* and						
Gender	–0.270	0.836 **	0.225	0.066	–0.133	0.292	0.098
ln age	0.014	–0.006	0.003	0.016 *	0.014 *	0.002	0.006
Education (cf. none)							
Primary	–0.139	–0.122	–0.133	–0.017	–0.050	–0.066	–0.074
Postprimary	–0.075	–0.236	–0.196	–0.059	–0.037	–0.110	–0.104
Full-time farmer	–0.747 ***	–0.299	–0.492 **	–0.078	–0.362 *	–0.112	–0.289
Membership	0.228	0.502 **	0.447 **	–0.015	0.091	0.253	0.270
Agroecology	0.810 **	1.157 ***	1.001 ***	–0.725	0.103	0.451	0.543 *
Population density	–0.770 **	–0.135	–0.358	–0.610 *	–0.708 **	–0.383	–0.451 *
Market access	1.115 ***	1.060 ***	1.086 ***	–0.170	0.577 *	0.735 **	0.818 ***
Intercept	–1.229 *	–1.903 ***	–1.083 **	–0.255	–0.322	–0.661	–0.413
Wald chi-square	25.510 ***	30.050 ***	28.680 ***	8.070	15.370 *	11.350	16.760 *
Pseudo *R*-squared	0.140	0.147	0.100	0.040	0.056	0.040	0.050

Source: Household survey (2011).

Note: AMSEC = agricultural mechanization service center; ln = transformation by natural logarithm. See Table 3.1 for detailed description of variables. The dependent variable is equal to 1 for treated (*AMSEC*$_j$) where the AMSEC program is implemented and farmer uses AMSEC service provider only (*AMSEC*$_A$), both types of service providers only (*AMSEC*$_B$), either AMSEC only or both types of providers only (*AMSEC*$_{AB}$), other service providers only (*AMSEC*$_N$), either AMSEC only or other types of providers only (*AMSEC*$_{AN}$), either others only or both types of providers only (*AMSEC*$_{NB}$), and any provider (*AMSEC*$_{ANB}$); and 0 for untreated (non-*AMSEC*) where the AMSEC program is not implemented. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Table 4.2 First-stage probit selection equation results: Base model plus interaction terms or Model 2

	Using subsample of non-*AMSEC* and						
Explanatory variable	***AMSEC*$_A$**	***AMSEC*$_B$**	***AMSEC*$_{AB}$**	***AMSEC*$_N$**	***AMSEC*$_{AN}$**	***AMSEC*$_{BN}$**	***AMSEC*$_{ABN}$**
Gender	0.520	1.135	0.638	0.983	0.453	0.663	0.461
ln age	0.003	–0.014	–0.003	0.056 *	0.015	0.006	0.005
Education (cf. none)							
Primary	0.297	–0.274	–0.078	–0.127	–0.240	–0.405	–0.276
Postprimary	0.591	–0.621	–0.176	–0.219	–0.457	–0.739	–0.531
Full-time farmer	–1.786	–0.646	–0.961	3.095 **	0.264	0.772	0.105
Membership	1.234 ***	1.070 *	1.192 ***	–0.240	0.494	0.277	0.594 *
Agroecology	0.677	1.183 ***	0.980 ***	–0.880 *	0.046	0.431	0.528 *
Population density	–0.862 **	–0.088	–0.328	–0.708 **	–0.704 **	–0.405	–0.436 *
Market access	1.032 ***	1.067 ***	1.094 ***	–0.183	0.524	0.722 **	0.805 ***
Interaction terms							
Gender × Full-time Farmer	0.022	0.101	0.177	–1.246 *	–0.462	–0.500	–0.246
Gender × Membership	–1.528 ***	–0.683	–0.977 **	0.336	–0.575	–0.006	–0.430
ln Age × Education	–0.008	0.005	0.000	0.001	0.005	0.007	0.005
ln Age × Full-time Farmer	0.023	0.006	0.008	–0.050 *	–0.007	–0.012	–0.005
Intercept	–1.263	–1.880	–1.176	–2.626 *	–0.727	–1.038	–0.638
Wald chi-square	34.970 ***	31.450 ***	33.620 ***	15.620	18.530	13.578	18.650
Pseudo *R*-squared	0.195	0.154	0.122	0.078	0.068	0.047	0.056

Source: Household survey (2011).

Note: AMSEC = agricultural mechanization service center; ln = transformation by natural logarithm. See Table 3.1 for detailed description of variables. The dependent variable is equal to 1 for treated (*AMSEC*$_j$) where the AMSEC program is implemented and farmer uses AMSEC service provider only (*AMSEC*$_A$), both types of service providers only (*AMSEC*$_B$), either AMSEC only or both types of providers only (*AMSEC*$_{AB}$), other service providers only (*AMSEC*$_N$), either AMSEC only or other types of providers only (*AMSEC*$_{AN}$), either others only or both types of providers only (*AMSEC*$_{NB}$), and any provider (*AMSEC*$_{ANB}$); and 0 for untreated (non-*AMSEC*) where the AMSEC program is not implemented. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Table 4.3 First-stage probit selection equation results: Base model plus interaction terms and squared terms or Model 3

	Using subsample of non-*AMSEC* and						
Explanatory variable	***AMSEC*$_A$**	***AMSEC*$_B$**	***AMSEC*$_{AB}$**	***AMSEC*$_N$**	***AMSEC*$_{AN}$**	***AMSEC*$_{BN}$**	***AMSEC*$_{ABN}$**
Gender	0.487	1.227	0.650	0.967	0.413	0.653	0.444
ln age	–0.074	0.047	0.011	–0.062	–0.088	–0.008	–0.023
Education (cf. none)							
Primary	0.446	–0.408	–0.106	–0.032	–0.155	–0.387	–0.239
Postprimary	0.888	–0.943	–0.239	0.080	–0.227	–0.688	–0.436
Full-time farmer	–1.838	–0.717	–0.976	3.188 **	0.229	0.780	0.118
Membership	1.192 ***	1.107 *	1.200 ***	–0.314	0.440	0.273	0.584 *
Agroecology	0.645	1.196 ***	0.983 ***	–0.899 *	0.010	0.430	0.525 *
Population density	–0.876 **	–0.073	–0.326	–0.685 **	–0.688 **	–0.402	–0.432 *
Market access	0.994 **	1.085 ***	1.100 ***	–0.190	0.480	0.718 **	0.795 ***
Interaction terms							
Gender × Full-time Farmer	0.003	0.044	0.176	–1.333 **	–0.503	–0.499	–0.247
Gender × Membership	–1.459 ***	–0.743	–0.992 **	0.458	–0.477	0.005	–0.405
ln Age × Education	–0.011	0.008	0.000	–0.002	0.002	0.007	0.004
ln Age × Full-time Farmer	0.026	0.008	0.009	–0.048 *	–0.005	–0.012	–0.005
Squared terms							
ln Age × ln Age	0.447	–0.362	–0.086	0.675	0.587	0.078	0.159
Intercept	–4.127	0.475	–0.618	–6.987 **	–4.417	–1.542	–1.662
Wald chi-square	35.540 ***	32.240 ***	33.670 ***	17.620	20.490	13.630	18.890
Pseudo *R*-squared	0.198	0.158	0.123	0.088	0.075	0.047	0.057

Source: Household survey (2011).

Note: AMSEC = agricultural mechanization service center; ln means transformation by natural logarithm; cf. = compared to. See Table 3.1 for detailed description of variables. The dependent variable is equal to 1 for treated ($AMSEC_j$) where the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$); and 0 for untreated (non-*AMSEC*) where the AMSEC program is not implemented. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Figure 4.1 Histogram of estimated propensity scores: Model 1

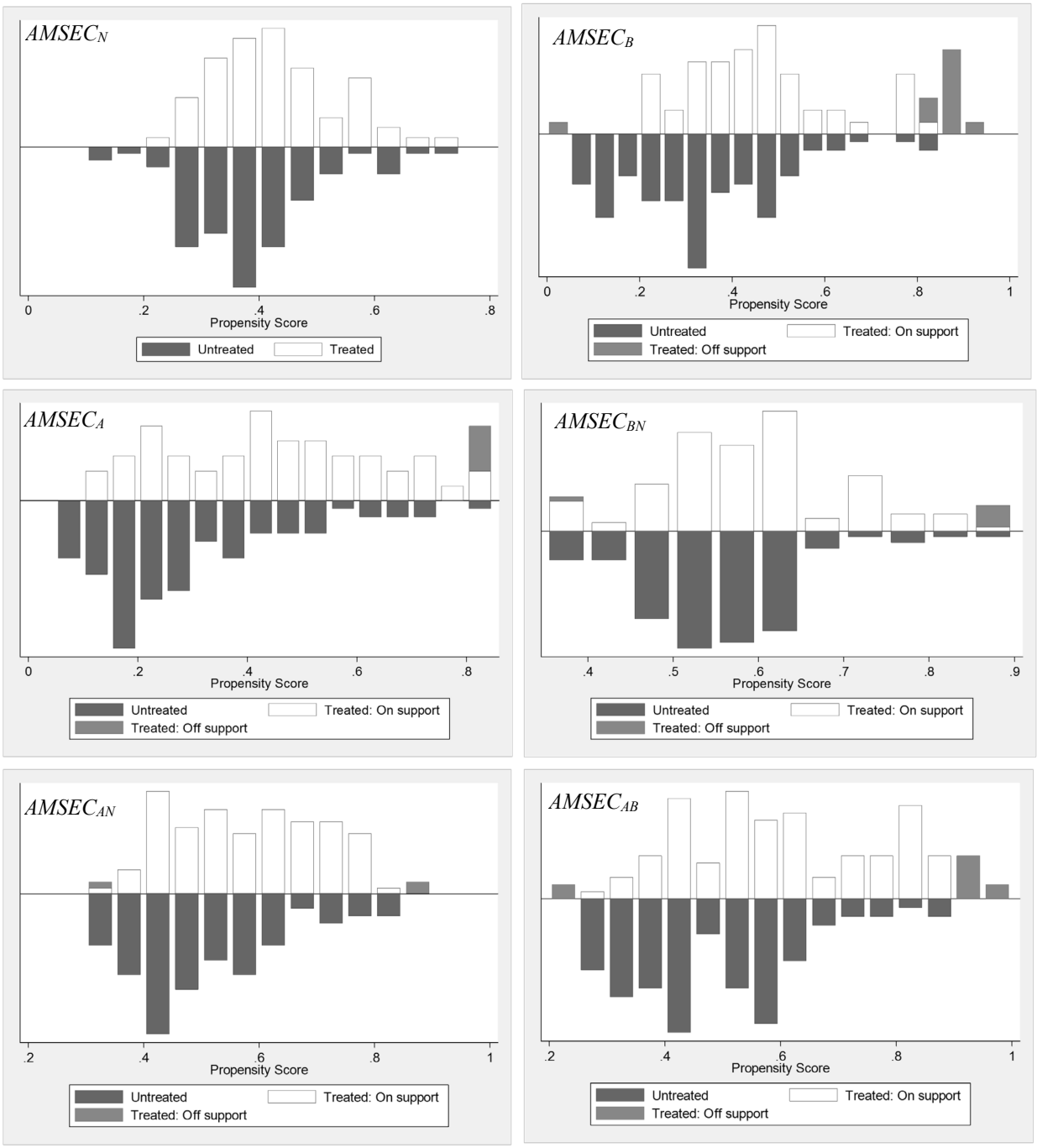
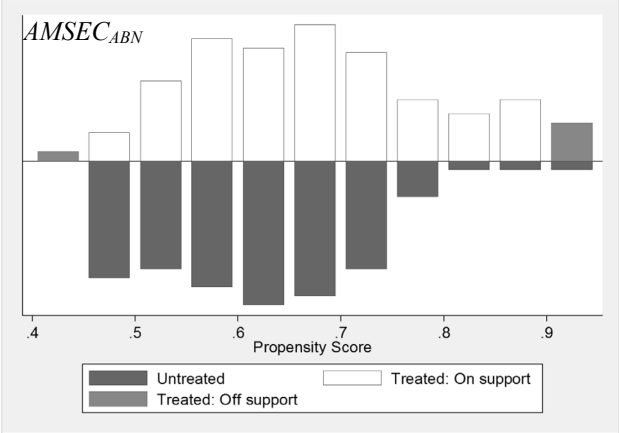


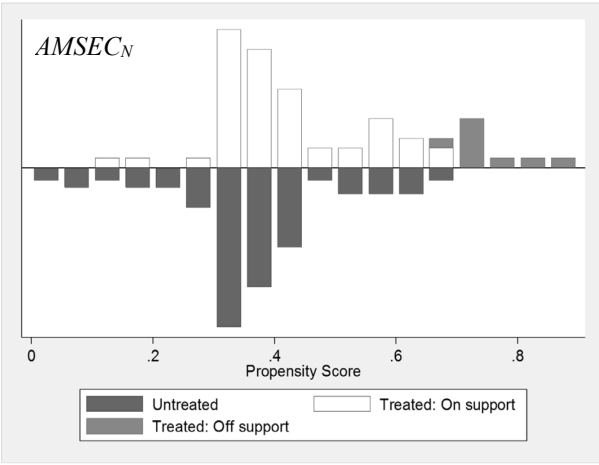
Figure 4.2 Continued

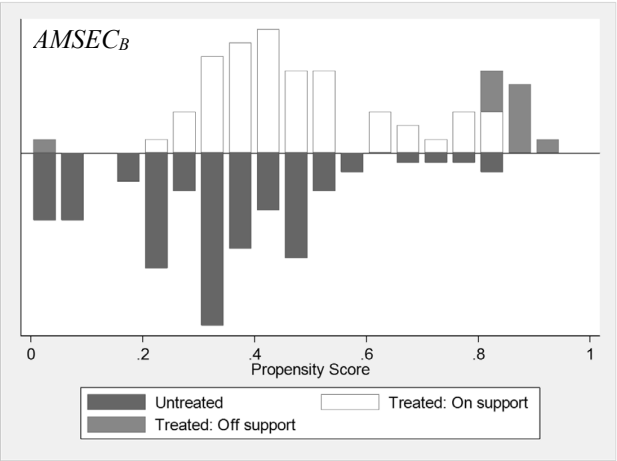


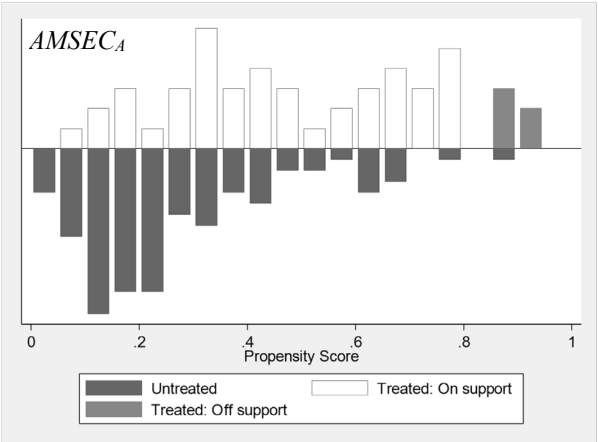
Source: First-stage probit results.

Note: AMSEC = agricultural mechanization service center. The dependent variable is equal to 1 for treated ($AMSEC_j$) where the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$); and 0 for untreated (non-*AMSEC*) where the AMSEC program is not implemented.

Figure 4.3 Histogram of estimated propensity scores: Model 2







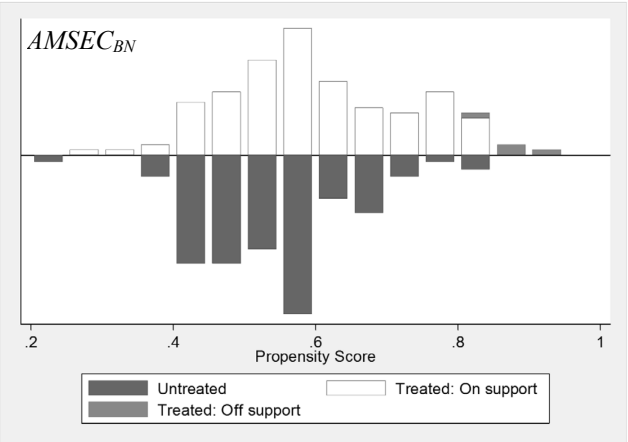
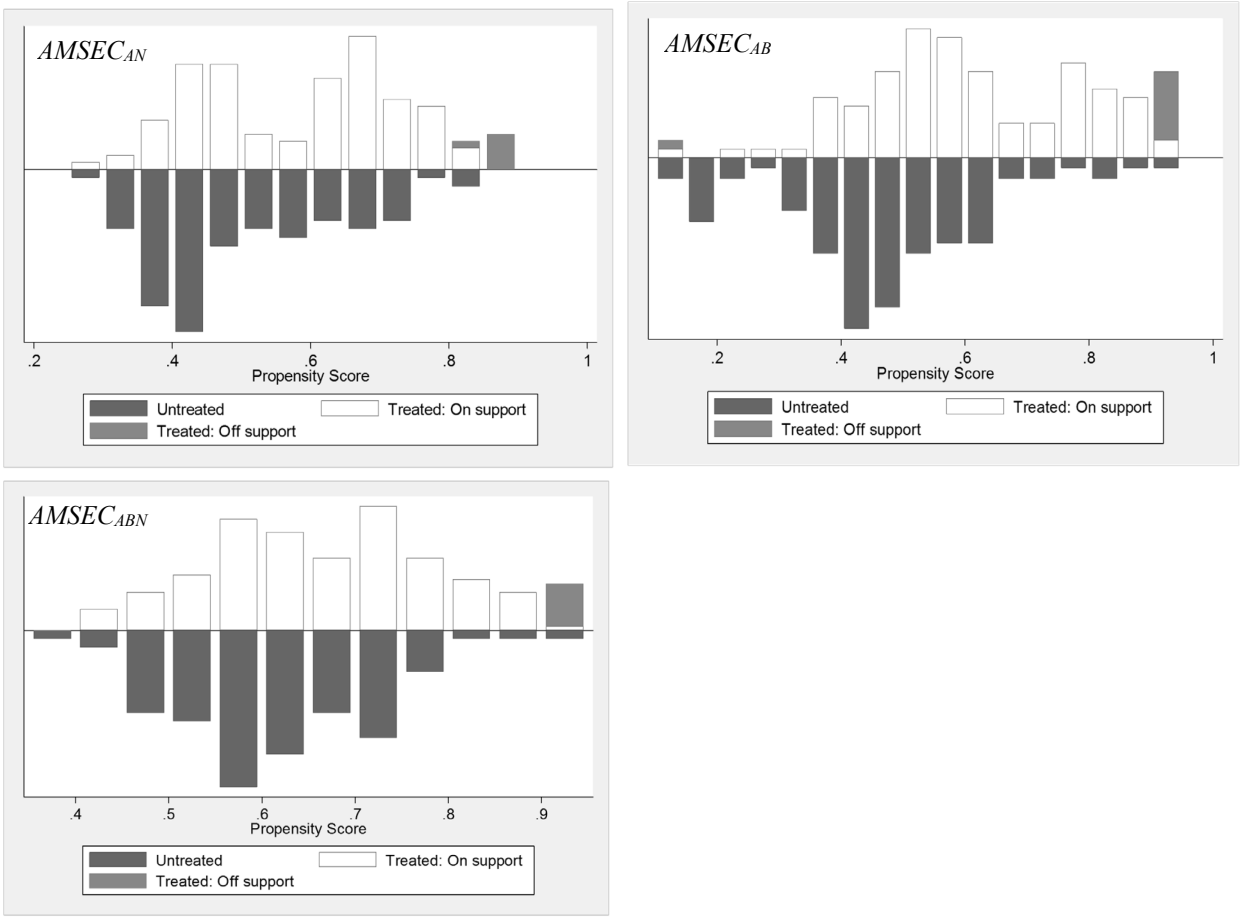


Figure 4.4 Continued



Source: First-stage probit results.

Note: AMSEC = agricultural mechanization service center. The dependent variable is equal to 1 for treated ($AMSEC_j$) where the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$); and 0 for untreated (non-*AMSEC*) where the AMSEC program is not implemented.

Figure 4.5 Histogram of estimated propensity scores: Model 3

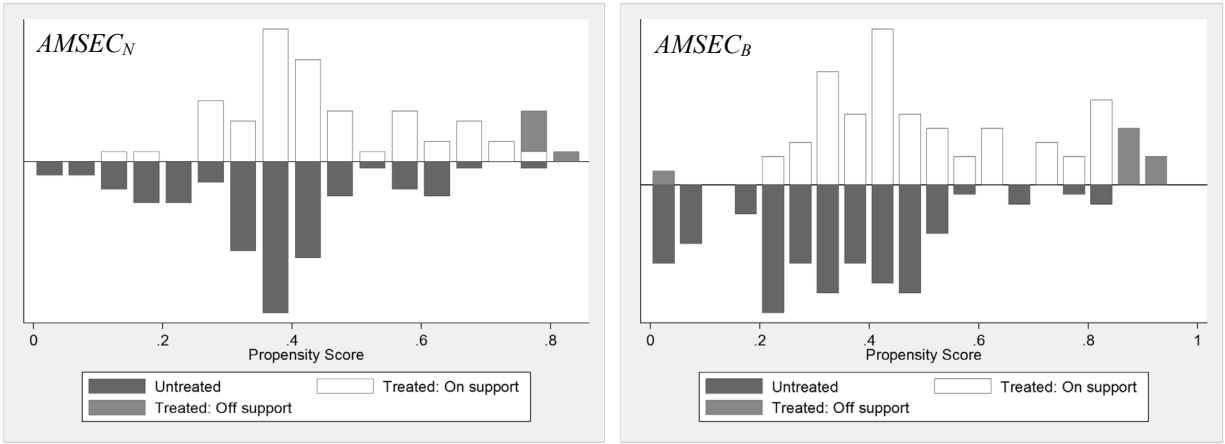
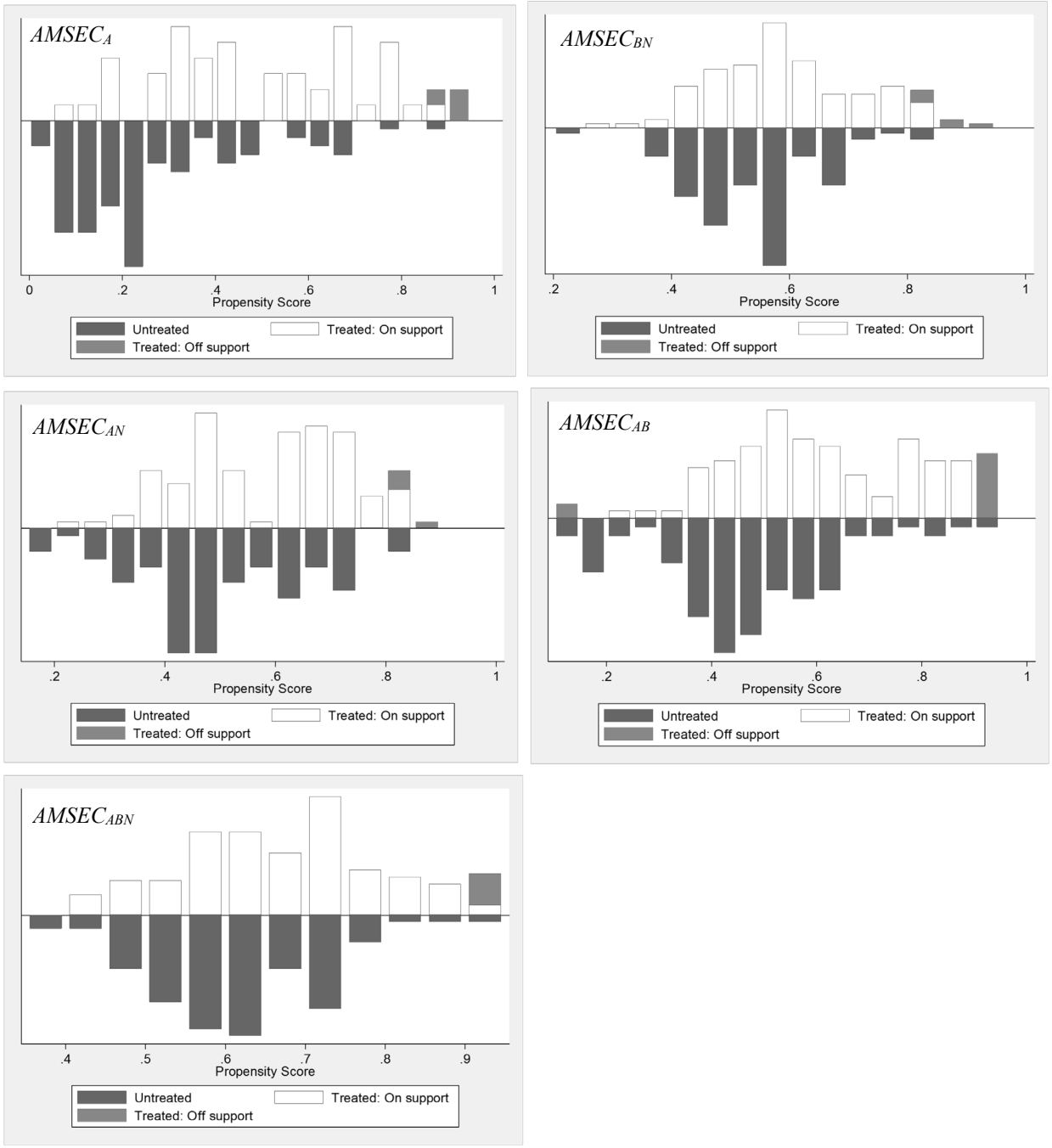


Figure 4.6 Continued



Source: First-stage probit results.

Note: AMSEC = agricultural mechanization service center. The dependent variable is equal to 1 for treated (AMSECj) where the AMSEC program is implemented and farmer uses AMSEC service provider only (AMSECA), both types of service providers only (AMSECB), either AMSEC only or both types of providers only (AMSECAB), other service providers only (AMSECN), either AMSEC only or other types of providers only (AMSECAN), either others only or both types of providers only (AMSECNB), and any provider (AMSECANB); and 0 for untreated (non-AMSEC) where the AMSEC program is not implemented.

Table 4.4 Number of observations associated with the matched and unmatched samples used in estimation of average treatment effects on the treated

	Using subsample of non-*AMSEC* and													
	$AMSEC_A$		$AMSEC_B$		$AMSEC_{AB}$		$AMSEC_N$		$AMSEC_{AN}$		$AMSEC_{BN}$		$AMSEC_{ABN}$	
	C	T	C	T	C	T	C	T	C	T	C	T	C	T
Unmatched sample	90	52	90	66	90	118	90	62	90	114	90	128	90	180
Matched sample	28	44	72	52	89	102	82	51	88	103	88	118	88	161
Matched sample by propensity scores														
Up to 0.2	6	6	n.o.	n.o.	8	1	3	2	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
0.2 to 0.4	4	4	44	19	17	10	51	27	23	10	3	4	n.o.	n.o.
0.4 to 0.6	3	9	23	21	47	45	22	17	43	39	65	64	42	53
0.6 to 0.8	8	10	3	9	13	29	6	5	20	51	18	43	43	86
0.8 to 1.0	7	15	2	3	4	17	n.o.	n.o.	2	3	2	7	3	22
Observations dropped	62	8	18	14	1	16	8	11	2	11	2	10	2	19

Source: Household survey for unmatched sample and first-stage probit selection equation results for matched samples (2011).

Note: AMSEC = agricultural mechanization service center; T = treated ($AMSEC_j$) observations where the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$); C = untreated or control (non-*AMSEC*) observations where the AMSEC program is not implemented; U = unmatched subsample of treated and control observations; M = matched subsamples of treated and control observations. n.o. = no observations.

With respect to the balancing tests results (Tables 3.2, 3.3, and 3.4), the main variables of interest in terms of observing any significant difference between the treatment and control groups are gender, full-time farming status, and membership in a farmer organization as well as the location of the farmer according to the agroecology and population density of the district in which the farmer is located. Statistically significant biases that existed between the treatment and control groups in these variables prior to matching were removed after matching, which includes dropping observations that were dissimilar in these variables (see Table 4.4 for details). Focusing on the balancing test results associated with the treatment definitions represented by $AMSEC_A$, $AMSEC_B$, and $AMSEC_{AB}$, significant bias is introduced after matching when the model is estimated using Model 3 specification and definition of treatment represented by $AMSEC_{AB}$ (Table 3.4).

Together, the above results suggest that estimating the *ATT* of the AMSEC program based on Model 2 specification and definition of treatment represented by $AMSEC_{AB}$ gives the best results. Therefore, results associated with the estimation of ATT_{AB} will be the focus of the presentation and discussion hereafter. Results associated with the other *ATT*s are presented and discussed in relative terms and especially where it is instructional for drawing different implications of the results. They may also be used to provide a range of values (that is, high and low) around the preferred estimates.

Factors Influencing Placement of AMSEC and Use of Mechanization

Because both the treatment and control groups of farmers use mechanization, interpretation of the first-stage probit results is different from interpretation of results from estimating a typical program participation equation. The results obtained here reflect joint program placement and use of mechanization services from a particular source or type of service provider. Focusing on the first-stage probit results obtained from estimating Model 2 and using the definition of treatment represented by $AMSEC_{AB}$ (Table 4.2), the statistically significant variables are membership in a farmers organization, location by agroecology and market access, and interaction between gender and membership. This means that an AMSEC is more likely to be located and used in areas where farmers are organized into associations, in the transition and guinea savannah zones rather than in the coastal and forest zones, or in areas with low market access. These results are not surprising, and they are consistent with the program objectives of establishing AMSECs in areas that have potential for mechanization. The result with respect to market access is not intuitive. However, because low market access areas are also characterized by low population density in the data used here, the results suggest that the program has targeted or been established in areas where labor shortage is likely to be higher. The negative sign of the coefficient on the population density variable (although statistically insignificant) directly reflects this. The results in Table 4.2 also show that areas with male-dominated membership organizations (deriving from the gender-membership interaction term) are associated with a lower likelihood of having an AMSEC there and of farmers' using its services.

These results are generally consistent across the three model specifications and using the three definitions of treatment represented by $AMSEC_A$, $AMSEC_B$, and $AMSEC_{AB}$. The main difference in the results is with $AMSEC_A$, where the population density variable is statistically significant but the agroecology variable is not (Tables 4.2 and 4.3).

Impact of AMSEC on Availability and Use of Mechanization

We assessed the impact of the AMSEC program on availability, reliability, use, and prices of mechanization services. The estimated *ATT*s are presented in Table 4.5. First, focusing on the results obtained from estimating the specification that includes interaction terms (Model 2) and using the definition of treatment represented by $AMSEC_{AB}$, a significantly greater proportion of the farmers in the treatment group compared to those in the control group perceived mechanization services to be readily available (8 percent more) and perceived that service providers were reliable (30 percent more). This suggests that the AMSEC program has led to an increase in the supply of mechanization services. The

number of activities that are mechanized (for example, land preparation, planting, fertilizer and chemical application, irrigation, harvesting) is significantly lower among the treatment group compared to the control group. Because the difference in the number is very small (less than 1), the results reflect the generally low diversity of mechanization services that are supplied or demanded, with land preparation being the dominant activity that is mechanized. Greater availability and reliability of mechanization services, or plowing in particular, does not seem to have translated into a significant increase in the area that is plowed among the treatment group compared to the control group. Between 2008 and 2011, the increase in the average area plowed by farmers in the treatment group was only about 1.2 acres more than the increase in the average area plowed by farmers in the control group. Similarly, greater availability in plowing services has not led to the desired reduction in the prices paid by farmers. The above results are consistent across the other model specifications and definitions of treatment, particularly with the signs of the estimated *ATT*s and especially when they are statistically significant.

Table 4.5 Estimated average treatment effect on the treated (ATT_j) of availability and use of mechanization services: Difference between different treatment groups ($AMSEC_j$) and the control group (non-*AMSEC*)

Model and Outcome Variable	ATT_A	ATT_B	ATT_{AB}	ATT_N	ATT_{AN}	ATT_{BN}	ATT_{ABN}
Model 1							
Availability of mechanization services (%)	17.0 **	4.0	7.0	5.0	7.0	6.0	5.0
Reliability of mechanization services (%)	34.0 ***	23.0 **	40.0 ***	–6.0	17.0 *	4.0	19.0 ***
Number of mechanized activities	–0.6 **	–0.5 *	–0.4 **	–0.7 ***	–0.7 ***	–0.4 **	–0.4 ***
Change in area plowed (acres)	2.7	–0.2	1.1	0.0	1.1	–0.3	0.7
Change in charge for plowing (GHS/acre)	0.2	1.1 **	0.1	0.5	n.e.	0.5	0.5
Model 2							
Availability of mechanization services (%)	19.0 **	8.0	8.0 *	5.0	9.0	1.0	4.0
Reliability of mechanization services (%)	30.0 **	16.0	30.0 ***	2.0	17.0 **	9.0	19.0 ***
Number of mechanized activities	–0.5 *	–0.5 *	–0.4 **	–0.5 **	–0.6 ***	–0.4 **	–0.5 ***
Change in area plowed (acres)	3.1	–0.5	1.2	0.1	1.0	–0.3	0.5
Change in charge for plowing (GHS/acre)	–0.7	1.1 *	0.1	0.3	–0.2	0.9 **	0.4
Model 3							
Availability of mechanization services (%)	15.0 **	2.0	8.0 *	–3.0	11.0 *	2.0	3.0
Reliability of mechanization services (%)	33.0 ***	28.0 **	34.0 ***	–7.0	16.0 *	16.0 *	15.0 **
Number of mechanized activities	–0.7 **	–0.4	–0.4 *	–0.6 ***	–0.6 ***	–0.6 ***	–0.5 ***
Change in area plowed (acres)	2.9	–0.3	1.4	–0.7	1.4	–0.2	0.7
Change in charge for plowing (GHS/acre)	–0.1	0.7	0.1	0.2	0.6	0.8 **	0.5

Source: Matched sample of treated and control observations from household survey.

Note: AMSEC = agricultural mechanization service center; GHS = Ghanaian Cedi. See Table 3.1 for detailed description of the variables. ATT_j is average treatment effect on the treated using matched sample of treated ($AMSEC_j$) and untreated or control (non-*AMSEC*), where ATT_A is obtained from using matched subsample of $AMSEC_A$ and non-*AMSEC*, ATT_B from $AMSEC_B$ and non-*AMSEC*, ATT_{AB} from $AMSEC_{AB}$ and non-*AMSEC*, ATT_N from $AMSEC_N$ and non-*AMSEC*, ATT_{AN} from $AMSEC_{AN}$ and non-*AMSEC*, ATT_{BN} from $AMSEC_{BN}$ and non-*AMSEC*, ATT_{ABN} from $AMSEC_{ABN}$ and non-*AMSEC*. $AMSEC_j$ represents the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$). Change is the difference between the 2008 and 2011 measures of the indicator. Model 1 is base model, Model 2 is base model plus interaction terms, and Model 3 is base model plus interaction and squared terms. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Change in Availability of Other Farm Inputs

An important factor influencing agricultural productivity and other outcomes that was identified in the conceptual framework is access to other agricultural inputs such as certified seed and fertilizer. Table 4.6 presents the estimated *ATT*s on change in availability of improved seed, fertilizer, pesticides and other chemicals, and irrigation. Focusing on the preferred estimator (ATT_{AB}), the results show that whereas availability of irrigation improved between 2008 and 2011, availability of the other farm inputs has not. Basically, the estimates show that a larger proportion of the farmers in the treatment group compared to those in the control group perceived that the availability of irrigation has improved (18 percent more), whereas a smaller proportion of the farmers in the treatment group compared to those in the control group perceived that the availability of the other farm inputs has improved (3 to 24 percent less). Similarly, a smaller proportion of the farmers in the treatment group compared to those in the control group perceived that the availability of irrigation has deteriorated (12 percent less), whereas a larger proportion of the farmers in the treatment group compared to those in the control group perceived that the availability of other farm inputs has deteriorated (2 to 5 percent more). Here too, the results are consistent across the other model specifications and definitions of treatment. Together, the results suggest that improvement in availability of plowing services is accompanied by improvement in availability of irrigation, but the supply and availability of other farm inputs (improved seed, fertilizer, and other chemicals) has yet to catch up. Impact of AMSEC on Drudgery and Productivity

Tables 4.7 and 4.8 present estimated *ATT*s on labor, adoption of improved farm practices (involving row planting, recommended planting density and spacing, and so forth), yield, and output prices. They are based on farmers' perception of how change between 2008 and 2011 in availability and use of mechanization have affected these outcomes, using a rating of no impact, low impact, and high impact. Focusing on the preferred estimator (ATT_{AB}), the results show that change in the availability and use of mechanization has had positive impact on the various outcomes. The estimates show that a statistically significantly larger proportion of the farmers in the treatment group compared to those in the control group perceived the impact to be high on reducing drudgery or saving labor in land preparation (15 to 18 percent more), on promoting good farm practices (16 percent more), and on achieving high yield (16 percent more). The impact on output prices was moderate. Here too, the results are consistent across the other model specifications and definitions of treatment.

Table 4.6 Estimated average treatment effect on the treated (ATT_j) of change between 2008 and 2011 in availability of tractor plowing services and inputs: Percentage points difference between different treatment groups ($AMSEC_j$) and control group (non-$AMSEC$)

Outcome Variable	ATT_A	ATT_B	ATT_{AB}	ATT_N	ATT_{AN}	ATT_{BN}	ATT_{ABN}
Model 1							
Plowing services (cf. no change)							
Deteriorated	–1.0	n.e.	1.0	3.0	0.0	7.0	1.0
Improved	40.0 ***	n.e.	26.0 ***	–20.0 *	4.0	3.0	7.0
Improved seed (cf. no change)							
Deteriorated	–1.0	n.e.	8.0 **	–7.0	–1.0	0.0	0.0
Improved	3.0	n.e.	4.0	21.0 *	11.0	18.0 **	11.0
Fertilizer (cf. no change)							
Deteriorated	–4.0	n.e.	0.0	5.0	0.0	1.0	1.0
Improved	–3.0	n.e.	–22.0 ***	–7.0	–9.0	–7.0	–8.0
Herbicide (cf. no change)							
Deteriorated	–4.0	n.e.	2.0	0.0	–2.0	4.0	3.0
Improved	–15.0	n.e.	–22.0 ***	–2.0	–8.0	–1.0	–12.0 *
Pesticide (cf. no change)							
Deteriorated	–7.0	n.e.	4.0	–1.0	–3.0	3.0	1.0
Improved	–46.0	n.e.	–33.0 ***	2.0	–12.0	–9.0	–20.0 ***
Irrigation (cf. no change)							
Deteriorated	n.e.	–10.0	–11.0	–7.0	10.0 **	n.e.	–8.0
Improved	n.e.	31.0 **	15.0 **	3.0	2.0	n.e.	11.0 **
Model 2							
Plowing services (cf. no change)							
Deteriorated	7.0	4.0	6.0	7.0	–1.0	7.0	0.0
Improved	35.0 ***	14.0	18.0	–13.0	8.0	1.0	5.0
Improved seed (cf. no change)							
Deteriorated	5.0	–2.0	5.0	–3.0	1.0	0.0	–1.0
Improved	–3.0	10.0	–3.0	12.0	10.0	17.0 *	13.0
Fertilizer (cf. no change)							
Deteriorated	–3.0	–3.0	2.0	6.0	67.0	–2.0	2.0
Improved	–3.0	–8.0	–11.0	–4.0	–3.0	–13.0 *	–13.0 *
Herbicide (cf. no change)							
Deteriorated	–6.0	8.0	5.0	1.0	–2.0	4.0	3.0
Improved	–5.0	–16.0 *	–9.0	–3.0	–9.0	–7.0	–14.0 **
Pesticide (cf. no change)							
Deteriorated	–12.0	3.0	4.0	–1.0	0.0	0.0	0.0
Improved	–3.8	–17.0	–24.0	1.0	–13.0	–9.0	–16.0 **
Irrigation (cf. no change)							
Deteriorated	–4.0	n.e.	–12.0	6.0	–7.0	–1.0	–1.0
Improved	0.0	n.e.	16.0 **	5.0	1.0	15.0	11.0 **

Table 4.7 Continued

Outcome Variable	ATT_A	ATT_B	ATT_{AB}	ATT_N	ATT_{AN}	ATT_{BN}	ATT_{ABN}
Model 3							
Plowing services (cf. no change)							
Deteriorated	5.0	4.0	4.0	–5.0	–3.0	4.0	–1.0
Improved	41.0 ***	12.0	20.0 **	–8.0	15.0	–1.0	13.0
Improved seed (cf. no change)							
Deteriorated	6.0	–2.0	5.0	–1.0	0.0	2.0	–1.0
Improved	3.0	1.0	5.0	16.0	15.0	11.0	16.0 *
Fertilizer (cf. no change)							
Deteriorated	–2.0	–3.0	0.0	1.0	1.0	0.0	4.0
Improved	–10.0	–8.0	–8.0	–6.0	–1.0	–10.0	–9.0
Herbicide (cf. no change)							
Deteriorated	–8.0	8.0	3.0	–1.0	–2.0	3.0	3.0
Improved	–10.0	–16.0 *	–6.0	–10.0	–7.0	–8.0	–9.0
Pesticide (cf. no change)							
Deteriorated	–17.0	5.0	3.0	–3.0	–5.0	–3.0	0.0
Improved	–22.0	–23.0 **	–26.0 ***	–11.0	–12.0	–7.0	–16.0 **
Irrigation (cf. no change)							
Deteriorated	10.0	8.0	–9.0	2.0	–7.0	4.0	4.0
Improved	0.0	27.0	16.0 **	5.0	2.0	15.0 **	11.0 **

Source: Matched sample of treated and control observations from 2011 household survey.

Note: AMSEC = agricultural mechanization service center; cf. = compared to; n.e. = not estimated. See Table 3.1 for detailed description of the variables. ATT_j is average treatment effect on the treated using matched sample of treated ($AMSEC_j$) and untreated or control (non-*AMSEC*), where ATT_A is obtained from using matched subsample of $AMSEC_A$ and non-*AMSEC*, ATT_B from $AMSEC_B$ and non-*AMSEC*, ATT_{AB} from $AMSEC_{AB}$ and non-*AMSEC*, ATT_N from $AMSEC_N$ and non-*AMSEC*, ATT_{AN} from $AMSEC_{AN}$ and non-*AMSEC*, ATT_{BN} from $AMSEC_{BN}$ and non-*AMSEC*, ATT_{ABN} from $AMSEC_{ABN}$ and non-*AMSEC*. $AMSEC_j$ represents the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$). Model 1 is base model, Model 2 is base model plus interaction terms, and Model 3 is base model plus interaction and squared terms. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Table 4.8 Estimated average treatment effect on the treated (ATT_j) of impact of change between 2008 and 2011 in use of mechanization services on labor and farm practices: Percentage points difference between different treatment groups ($AMSEC_j$) and control group (non-*AMSEC*)

Outcome Variable	ATT_A	ATT_B	ATT_{AB}	ATT_N	ATT_{AN}	ATT_{BN}	ATT_{ABN}
Model 1							
Reduced drudgery (cf. no impact)							
High	–77.0 ***	20.0 **	24.0 ***	–18.0 *	6.0	–2.0	10.0 *
Low	–4.0	0.0	1.0	–3.0	–1.0	0.0	–2.0
Saving labor (cf. none)							
High	13.0 **	16.0 **	23.0 ***	–22.0 **	7.0	–3.0	8.0
Low	0.0	23.0	1.0	0.0	0.0	1.0	1.0
Improved practices (cf. no impact)							
High	5.0	32.0 ***	15.0 *	–7.0	7.0	7.0	10.0
Low	12.0	2.0	6.0	0.0	5.0	0.0	4.0 *
Model 2							
Reduced drudgery (cf. no impact)							
High	20.0 **	14.0 **	18.0 ***	–2.0	4.0	0.0	8.0
Low	–5.0	–2.0	–1.0	–4.0	–4.0	2.0	–1.0
Saving labor (cf. none)							
High	15.0 **	8.0	15.0 ***	–6.0	2.0	1.0	7.0
Low		2.0	1.0	0.0	0.0	1.0	1.0
Improved practices (cf. no impact)							
High	8.0	25.0 **	16.0 *	2.0	2.0	12.0	16.0 *
Low	14.0	2.0	6.0	0.0	3.0	0.0	3.0
Model 3							
Reduced drudgery (cf. no impact)							
High	11.0	15.0 **	19.0 ***	–2.0	8.0	0.0	11.0 *
Low	0.0	–1.0	1.0	2.0	–4.0	–3.0	–1.0
Saving labor (cf. none)							
High	12.0	9.0	19.0 ***	–2.0	4.0	–4.0	10.0
Low	0.0	2.0	1.0	0.0	0.0	1.0	1.0
Improved practices (cf. no impact)							
High	13.0	25.0 **	15.0 *	2.0	7.0	17.0 *	16.0 **
Low	13.0	1.0	6.0	–4.0	7.0 **	–1.0	3.0

Source: Matched sample of treated and control observations from 2011 household survey.

Note: AMSEC = agricultural mechanization service center; cf. = compared to. See Table 3.1 for detailed description of the variables. ATT_j is average treatment effect on the treated using matched sample of treated ($AMSEC_j$) and untreated or control (non-*AMSEC*), where ATT_A is obtained from using matched subsample of $AMSEC_A$ and non-*AMSEC*, ATT_B from $AMSEC_B$ and non-*AMSEC*, ATT_{AB} from $AMSEC_{AB}$ and non-*AMSEC*, ATT_N from $AMSEC_N$ and non-*AMSEC*, ATT_{AN} from $AMSEC_{AN}$ and non-*AMSEC*, ATT_{BN} from $AMSEC_{BN}$ and non-*AMSEC*, ATT_{ABN} from $AMSEC_{ABN}$ and non-*AMSEC*. $AMSEC_j$ represents the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$). Model 1 is base model, Model 2 is base model plus interaction terms, and Model 3 is base model plus interaction and squared terms. *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level. ***Statistical significance at the 1 percent level.

Table 4.9 Estimated average treatment effect on the treated (ATT_j) of impact of change between 2008 and 2011 in use of mechanization services on yield and output prices: Percentage points difference between different treatment groups ($AMSEC_j$) and control group (non-*AMSEC*)

Outcome Variable	ATT_A	ATT_B	ATT_{AB}	ATT_N	ATT_{AN}	ATT_{BN}	ATT_{ABN}
Model 1							
High yield (cf. none)							
High	4.0	14.0 **	18.0 **	–20.0	–3.0	–5.0	4.0
Low	3.0	2.0	5.0 **	1.0	4.0 **	2.0	2.0
Good output price (cf. no impact)							
High	13.0	15.0	11.0	0.0	6.0	–3.0	5.0
Low	12.0 **	2.0	6.0 **	–4.0	7.0 **	2.0	3.0
Model 2							
High yield (cf. none)							
High	9.0	9.0	16.0 **	–9.0	–5.0	–1.0	4.0
Low	0.0	0.0	–1.0	–1.0	0.0	2.0	2.0 *
Good output price (cf. no impact)							
High	–10.0	17.0	9.0	–8.0	3.0	1.0	6.0
Low	9.0 *	1.0	4.0 **	0.0	6.0 **	2.0	4.0 **
Model 3							
High yield (cf. none)							
High	0.0	10.0	15.0 **	–6.0	–2.0	–3.0	7.0
Low	5.0	2.0	1.0	1.0	2.0	0.0	2.0 *
Good output price (cf. no impact)							
High	12.0	23.0 **	11.0	3.0	2.0	10.0	12.0
Low	12.0 **	0.0	5.0 **	–3.0	5.0 *	2.0	1.0

Source: Matched sample of treated and control observations from 2011 household survey.

Note: AMSEC = agricultural mechanization service center; cf. = compared to. See Table 3.1 for detailed description of the variables. ATT_j is average treatment effect on the treated using matched sample of treated ($AMSEC_j$) and untreated or control (non-*AMSEC*), where ATT_A is obtained from using matched subsample of $AMSEC_A$ and non-*AMSEC*, ATT_B from $AMSEC_B$ and non-*AMSEC*, ATT_{AB} from $AMSEC_{AB}$ and non-*AMSEC*, ATT_N from $AMSEC_N$ and non-*AMSEC*, ATT_{AN} from $AMSEC_{AN}$ and non-*AMSEC*, ATT_{BN} from $AMSEC_{BN}$ and non-*AMSEC*, ATT_{ABN} from $AMSEC_{ABN}$ and non-*AMSEC*. $AMSEC_j$ represents the AMSEC program is implemented and farmer uses AMSEC service provider only ($AMSEC_A$), both types of service providers only ($AMSEC_B$), either AMSEC only or both types of providers only ($AMSEC_{AB}$), other service providers only ($AMSEC_N$), either AMSEC only or other types of providers only ($AMSEC_{AN}$), either others only or both types of providers only ($AMSEC_{NB}$), and any provider ($AMSEC_{ANB}$). Model 1 is base model, Model 2 is base model plus interaction terms, and Model 3 is base model plus interaction and squared terms *Statistical significance at the 10 percent level. **Statistical significance at the 5 percent level.

Given the shortage of farm labor and high and rising rural wages in Ghana, the finding that the AMSEC program has had a positive impact on reducing drudgery or saving labor in land preparation is an important one. About one-half of the power employed in farming in Ghana is provided by human labor, with the remaining deriving from draft animal power (34 to 42 percent) and mechanical power (8 to 16 percent) (Josiah, Bani, and Mahama 2008; Fonteh 2010). The finding that the program has had a positive impact in promoting adoption of farm practices that could require large amounts of farm labor is also important as it complements the previous one. Basically, these results together suggest that farm labor that may be displaced by mechanization in land preparation could be used in other labor-intensive farm operations without necessarily causing unemployment. However, given the labor shortage to begin with, it is not clear how labor demands for the other operations could be met. Several studies, for example, Panin (1995) and Rahman et al. (2011), have shown that the reduction in drudgery and the gain in time and cost from using tractors in land preparation may not spill over to the entire farm profitability when successive farming operations are not mechanized (including using draft animal power), because of the excessive labor requirements for weeding, fertilization, pruning, harvesting, and so forth. Recall that the results obtained here show that the number of different activities that are mechanized is significantly lower among the treatment group compared to the control group (Table 4.5).

The estimated positive impact of the program on yield seems somewhat surprising given the finding of the relatively low improvement in the availability of modern inputs (improved seeds, fertilizers, other chemicals) in the treatment compared to the control group (Table 4.6). However, the improvement in availability of irrigation and the positive impact of the program on adoption of improved farm practices could explain the increase in yield. The effect of tractorization on yield within traditional small-scale farming systems as examined here does not seem to be favorable. In the studies by Panin (1995) on sorghum and maize production in Botswana and Rahman et al. (2011) on wheat production in northern Bangladesh, for example, the average yield was only 3 percent more for farm households that used tractors or power tillers in some operations compared to those that did not use any mechanical power. Without transforming the entire farming system accompanied by increasing the scale of operations, using modern inputs and technologies, and mechanizing the chain of farm operations, it is difficult to see how yields can be sustainably increased by introducing tractors merely for land preparation.

5. CONCLUSIONS

The aim of this paper is to assess the impact of Ghana's AMSEC program on various performance indicators (including tractor hire charges, drudgery, agricultural area mechanized, and productivity). The data used are from household surveys that were conducted from July to August 2011 and collected from 270 farmers, some of them located in areas *with* the AMSEC program (treatment) and others located in areas *without* the program (control). Propensity score matching is used in a two-stage estimation procedure to first identify a reliable control group against which to compare the treatment group and then test for statistical differences between the two groups in the values of various outcomes indicators. Different model specifications and definitions of treatment were used to assess the sensitivity of the results and to generate greater confidence in the findings.

The results indicate that the AMSEC program is more likely to be located and used in areas where farmers are more organized, in the transition and guinea savannah zones, or in areas characterized by low market access and low population density. The results also indicate that availability of mechanization services has improved, with a significantly greater proportion of farmers in the treatment compared to those in the control group perceiving mechanization services to be readily available (8 percent more) and perceiving that service providers were reliable (30 percent more). The improvement in the availability and reliability of mechanization services, particularly plowing, has not translated into a significant increase in the size of the area that is plowed by farmers. Between 2008 and 2011, the increase in the average area plowed by farmers in the treatment group was only about 1.2 acres more than the increase in the average area plowed by farmers in the control group. Similarly, greater availability of plowing services has not led to the desired reduction in prices paid by farmers for the services purchased.

Regarding change in availability of other farm inputs, with the exception of irrigation—the results show there was a significant improvement in its availability between 2008 and 2011—the availability of other farm inputs (improved seed, fertilizer, pesticides and other chemicals) has not improved.

The impact of the AMSEC program on different outcomes (drudgery, farm practices, and yield) was more positive. A statistically significantly larger proportion of the farmers in the treatment group compared to those in the control group perceived the impact to be high on reducing drudgery or saving labor in land preparation (15 to 18 percent more), on adopting good farm practices such as row planting and recommended planting density and spacing (16 percent more), and on achieving high yield (16 percent more).

Given the shortage of farm labor and high and rising farm wages in Ghana, the finding of a positive impact of the program on reducing drudgery or saving labor in land preparation is an important one. Together with the finding of the positive impact on promoting adoption of labor-intensive farm practices, the results suggest that farm labor that may be displaced by mechanization in land preparation could be used in other labor-intensive farm operations. Therefore, the notion that mechanization could create unemployment by displacing farm labor, which has been an argument against mechanization, may not be relevant here. However, the gains from reducing drudgery and saving labor in land preparation may not spill over to the profitability of the entire farm if successive farming operations are not mechanized.

The finding of the positive impact of the program on yield seems somewhat surprising because of the finding of the relatively low improvement in the availability of modern inputs (improved seeds, fertilizers, and other chemicals), although it could be explained by the improvement in irrigation and greater adoption of improved farm practices (row planting and recommended planting density and spacing). These suggest that there is room for raising yields further by improving availability and access by farmers to modern inputs. However, transforming the entire farming system that is accompanied by increasing the scale of operations, using modern inputs and technologies, and mechanizing other farm operations will be important for sustainably raising yield.

APPENDIX: SUPPLEMENTARY TABLE

Table A.1 Summary statistics of selected outcome variables

Outcome Variable	Mean Value	
	Treatment	Control
Whether services are available and accessible: 0 = no, 1 = yes (percentage of farmers)		
Mechanization services are available	93.6	88.6
Mechanization services are reliable	73.1	55.1
Number of activities that are mechanized (for example, plowing, planting, harvesting)[a]	1.9	2.4
Area plowed (acres)[b]		
2008	6.1	5.9
2011	8.9	8.0
Tractor rental charge for plowing (GHS/acre)		
2008	24.8	22.5
2011	31.5	29.7
Perception of impact of change in mechanization on outcomes (percentage of farmers)		
Reduced drudgery (cf. no impact)		
High	83.5	70.8
Low	1.2	2.2
Saving labor (cf. no impact)		
High	82.5	70.8
Low	0.6	0.0
Improved practices (cf. no impact)		
High	60.6	44.3
Low	4.7	1.1
High yield (cf. no impact)		
High	78.4	70.5
Low	2.9	1.1
Good output price (cf. no impact)		
High	39.4	31.8
Low	4.1	2.3
Number of observations	180	90

Source: Unmatched sample of treated and control observations from household survey data (2011).

Note: GHS = Ghanaian Cedi; cf. = compared to. See Table 3.1 for detailed description of the variables. [a] Total number of activities considered is nine. [b] 1 acre = 0.4 hectares.

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