Ind. Jn. of Agri. Econ.
Vol.72, No.2, April-June 2017

ARTICLES

Crossbred Cattle Adoption and Its Impact on Income and Household Milk Consumption among Dairy Farmers: Empirical Evidence from Assam

Baban Bayan and Mrinal Kanti Dutta*

ABSTRACT

The paper examines the treatment effects of adopting crossbred cattle on household income from various sources and per capita consumption of self-produced milk. The study has used Propensity Score Matching (PSM) method for impact evaluation based on a cross-sectional data set of 245 dairy farming households (137 crossbred cattle adopters and 108 non-adopters) collected from three districts of Assam, namely Barpeta, Sonitpur and Karbi Anglong. The study shows that adoption of crossbred cattle has statistically significant effect on increasing the dairy income and livestock income, but not on crop/plantation income and off-farm income. The examination of other outcome variable namely, farm milk consumption indicates that there is significant causal relationship between adoption of crossbred cattle and increased per capita consumption of milk. The results strongly recommends that diffusion of crossbreeding programme can play an important role in increasing farm level income and milk consumption supplementing nutritional needs of the smallholder dairy farmers and have the implications on partially meeting United Nation's sustainable development goals of no poverty and zero hunger.

Keywords: Crossbred cattle, Adoption, Propensity score matching, Assam.

JEL: O33, Q12, Q18

I

INTRODUCTION

Dairying has highly favourable consequences on the lives of people in terms of income and employment generation, providing nutritional security, ensuring gender equality etc. While the wellbeing of dairy farmers is highly conditioned by increased farm level milk production, the growth in overall dairy productivity can contribute positively to increased milk production. One of the ways to ensure higher dairy productivity is through adoption of crossbreeding technology- a fact supported by a number of empirical studies across different countries. A study in Gujarat (India) finds that estimates of value added by cattle are 64 per cent higher in households with crossbreds compared to households with local cattle (400 vs 243 US $). In Bhutan, crossbreeding has an even bigger influence on milk production as estimates of value added by cattle are found to be 10 times higher in farms with crossbreds compared to

*Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati - 781039 (Assam).

This paper is drawn from the doctoral dissertation of the first author entitled, "Dairy Productivity and Crossbreeding Technology Adoption in Assam: Impacts and Determinants" prepared for submission to the Department of Humanities and Social Sciences, Indian Institute of Technology, Guwahati.

farms with local cattle (1030 vs 107 US $) (Udo *et al*., 2011). Various cross-country studies have confirmed higher income and nutritional security effect of commercial dairy farming that apparently results from adoption of crossbreeding technology. Studies carried out by Alary *et al*. (2011) in Office du Niger, Mali; Melesse and Jemal (2013) in Ada'a and Lume districts of Central Ethiopia; Quddus (2012) in Bangladesh; Udo and Steenstra (2010) in Indonesia etc. have found a positive impact of crossbreeding technology adoption on income and nutritional security of dairy farm households. Adoption of crossbred cattle can, thus, be a suitable option for improving farmer's welfare through enhancement of farm-level income and higher farm milk consumption due to rise in production leading to household's better nutrition. In view of this, the National Livestock Policy of India, 2013 has also lent support to the existing low input production systems for improving productivity and income so as to improve socio-economic status of a vast majority of our livestock producers (Government of India, 2013).

In Assam, the first organised attempt to improve the indigenous cattle stock for milk production was made during the 1st Five Year Plan (1951-56) with the introduction of Key Village Scheme (KVS) in 1953-54. Adoption of cross-breeding technology was encouraged through a number of subsequent programmes, such as Intensive Cattle Development Project (ICDP), Rashtriya Krishi Vikash Yojana (RKVY), Assam Rural Infrastructural and Agricultural Services project (ARIASP), National Project on Cattle and Buffalo Breeding (NPCBB) etc. However, inspite of these efforts, the proportion of crossbred cattle in total cattle population in the state is abysmally low. According to the 19th Livestock Census, 2012 proportion of crossbred cattle population in the state is only 3.84 per cent against the national average of 20.81 per cent. This implies that there is substantial gap in the penetration level of crossbreeding programme among the dairy farmers in the state. Moreover, there is a lack of impact studies in the state highlighting the role of crossbreeding programme on welfare indicators such as income, consumption, etc., at the household level. To fill this gap, the present study has been taken up to examine the impact of adoption of crossbreeding technology on two major outcome indicators, namely, income and consumption of domestically grown milk in the state. The paper has been organised in four sections including the introduction. The second section presents the materials and methods used in the study followed by presentation of the key results and discussion. The last section summarises the findings and concludes the paper.

II

MATERIALS AND METHODS

Data

The study is based on primary data collected from dairy farmers spread over three districts of Assam, namely, Barpeta, Sonitpur and Karbi Anglong (Table 1). Multistage sampling technique is used for selection of sample households. In the first stage, the sample districts are selected following stratified random sampling method. Using secondary data available from the livestock census of Assam (various issues), districts are grouped into high, medium and low strata depending on the density of crossbred cattle population per hundred hectares of geographical area. This is followed by selection of a district randomly from each group. Accordingly, three districts, namely, Barpeta, Sonitpur and Karbi Anglong are chosen from the high, medium and low strata respectively. In the second stage, two community development blocks (CDBs) are selected purposively from each district considering that one block has higher concentration of crossbred cattle with high artificial insemination (AI) coverage and the other with relatively lesser concentration and low AI coverage. The sample development blocks are selected in consultation with the senior officials of Assam Livestock Development Agency (ALDA), District Veterinary Officer and the Veterinary Doctor of Block Veterinary Dispensary. Before selecting the sample blocks the basic objective of the field study was clearly explained to these personnel. In the third stage 3 villages are selected from each development block. The selection of the villages are based on the understanding that both adopters of high yielding crossbred cattle and non-adopters are sufficiently present in each village. Adopters here are defined as those farmers who rear improved cattle breeds such as Jersey and/or Holstein Friesian (HF) crosses with local cattle while non-adopters are defined as those who rear only the local/nondescript cattle. Care was taken to see that villages in a block are not geographically contiguous to one another. In the last stage, sample farm households are selected in two groups: adopter and non-adopter of crossbred cattle. A total of 137 crossbred cattle adopters and 108 non adopters (total 245) thus selected are interviewed for generating the primary data. The data are collected using a standard and systematically designed structured interview schedule covering various aspects relating to adoption and impacts of cattle crossbreeding. The interview schedule is finalised after a few rounds of pilot surveys in each of the sample districts. The period of data collection is December 2015 to March 2016.

TABLE 1. SAMPLE DISTRICTS WITH NUMBER OF SAMPLE FARMS

Name of districts (1)	Adopter (2)	Non-adopter (3)	Whole sample (4)
Barpeta	54 (39.42)	38 (35.19)	92 (37.55)
Sonitpur	43 (31.39)	39 (36.11)	82 (33.47)
Karbi Anglong	40 (29.20)	31 (28.70)	71 (28.98)
Total	137 (100)	108 (100)	245 (100)

Source: Primary survey, 2015-16.

Note: Figure in parentheses indicates percentage to column total.

Empirical Model

When impact analysis of programme participation is based on counterfactual approach of causality, i.e., what would have been the impact (dairy income and consumption of self-produced milk) had they not adopted high yielding crossbred cattle, then propensity score matching (PSM) is appropriate given the nature of non-randomness (self-selection into treatment) in the adoption of crossbred cattle. PSM is a non-parametric method. As a non-experimental method, it has an advantage over OLS as PSM never relies on linear functional form assumptions and correlations of the error terms (Dehejia and Wahba, 2002; Rosenbaum and Rubin, 1983). The main feature of PSM is to measure the treatment effect by creating the conditions of a randomised experiment that allows comparison between experimental (treated) and control (non-treated) groups (Ito *et al.*, 2012). The idea behind PSM is to identify non-adopters of crossbred cattle that are similar to adopters based on their observable covariates. Rosenbaum and Rubin (1983) suggested the use of balancing score as a single index variable $P(X)$ that summarises the observed covariates. It is the predicted probability for an individual to participate in a treatment and termed as propensity score that can be written as-

$$P(X) = \Pr(z = 1) \mid X \qquad ....(1)$$

where, the propensity score $P(X)$ is estimated by either a logit or a probit model that regresses adoption of crossbred cattle (1 for adopter and 0 for non-adopter) on observed farm and farmer characteristics. Thus if PSM is meant to identify non-adopters that are similar to adopters of crossbred cattle based on observed covariates, then it is also based on propensity scores, i.e., $Y_0 \perp D \mid P(X)$, where $\perp$ indicates independence; Y_0 is the outcome of non-adoption which is independent of adoption D given the propensity score.

Although various matching methods have been proposed in the literature for implementation of PSM, we use the nearest neighbour matching and Kernel based matching (alternatively for the sake of robustness) to pair adopters of crossbred cattle with non-adopters. A good matching method is such that it never allows to lose too many of the original observations from the final analysis and also gives statistically equal covariate means for observations in the treatment and control groups (Caliendo and Kopeinig, 2008).

Following Becker and Ichino (2002) and Abebaw and Haile (2013), the average treatment effect on the treated (ATT), which in our study is the impact of adoption of crossbred cattle on annual dairy income and per capita consumption of self produced milk, can be estimated as follows:

$$\begin{aligned} \text{ATT} &= E\{Y_{1i} - Y_{0i} \mid Z_i = 1\} = E[E\{Y_{1i} - Y_{0i} \mid Z_i = 1, p(X_i)\}] \\ &= E[E\{Y_{1i} \mid Z_i = 1, p(X_i)\} \; E\{Y_{0i} \mid Z_i = 0, p(X_i)\} \mid Z_i = 1] \qquad ....(2) \end{aligned}$$

where, Y_1 and Y_0 are values of the outcome variables of interest for adopters of crossbred cattle and non-adopters; *i* refers to households. The statistical significance of the outcome variables of interest are tested using bootstrapped standard errors that considers variations caused as a result of the matching process. Thus the PSM procedure is grounded in two strong assumptions: (1) Treatment status and potential outcomes are based on conditional independence assumption (CIA), also known as 'un-confoundedness' that states that there exists a set of observables X_i (such as, age and education of household head, family size, farm size and other physical characteristics of the farm etc.) for which Y_0 is independent of the adoption status Z_i conditional on X_i (Smith and Todd, 2005); and (2) A further requirement, besides CIA, is the common support or overlap condition while matching treated and untreated groups. It rules out perfect predictability of Z_i given X_i $(0 < p(z = 1 \mid X) < 1)$ which indicate that household with same values of covariates have positive probability of being either adopter or non-adopter of crossbred cattle.

III

RESULTS AND DISCUSSION

Descriptive Statistics

Table 2 presents the summary statistics and mean and proportion difference tests respectively for continuous and binary variables. The selection of explanatory variables for the adoption of crossbred cattle is drawn from some of the theoretical literatures (Feder *et al*., 1985; Doss, 2006) based on the analysis of socio-economic factors influencing agricultural technology adoption. The outcome variables are the income of the sample households under various heads (crop and/or plantation, dairying, livestock, and off-farm income) and average per capita daily consumption of self produced milk. It is seen that adoption of high yielding crossbred cattle,[1] *ceteris paribus,* may significantly increase average annual dairy income for households rearing crossbred cattle to the extent of Rs. 73,489.1 (p = 0.000) against the non-adopter counterpart. The statistically significant increase in income per milch cattle per day is Rs. 51.61 for adopter of crossbred cattle vis-à-vis non adopter. Adoption of crossbred cattle also directly leads to statistically significant (p = 0.000) increase in livestock income[2] with per annum increase of Rs. 3940.81 for adopters of crossbred cattle. Other outcome variables related to income from different sources of the household such as crop and/or plantation income and off-farm income[3] do not bear a significant difference between the two categories of households. Again, a test of the equality of means between adopters and non-adopters of high yielding crossbred cattle suggests that adopters have significantly higher per capita daily consumption of milk compared to non-adopters (see Table 2). The mean difference test for various farm characteristics that may influence both the outcome variable of interest and adoption of crossbred cattle indicate that non-adopters are likely to be constrained in terms of household head's education, distance to all-weather road, farm size, credit access, information on improved breeding services, co-operative membership, accessing benefit from Government dairy development programme and land ownership.

TABLE 2. DESCRIPTIVE STATISTICS OF SAMPLE HOUSEHOLDS BY ADOPTION OF HIGH YIELDING CROSSBRED CATTLE (MEAN)

Variables (1)	Adopters (N = 137) (2)	Non-adopters (N = 108) (3)	Difference (4)
Outcome variables			
Crop and Plantation Income/annum (Rs.)	27253.28	21061.11	6192.17
Dairy Income/annum(Rs.)	88561.71	15072.71	73489.1***
Net Dairy Income/milch cattle/day	70.63	19.03	51.61***
livestockincome/annum (Rs.)	9120.44	5179.63	3940.81***
Off-farm Income/annum(Rs.)	102949.84	93458.8	9490
Per capita daily milk consumption (gram)	308.69	144.57	164.12***
Explanatory variables			
Age of the HH head (years)	50.67	49.78	0.89
Education of the HH head (in years of schooling)	6.81	4.96	1.85***
Family size (in numbers)	5.72	6.14	-0.42
Off-farm income (1 = yes; 0 otherwise)	0.62	0.56	0.064
Distance to all-weather road (in metre)	350.00	471.77	-121.77**
Herd size (in numbers)	7.16	5.39	1.77**
Access to credit (1 = yes; 0 otherwise)	0.21	0.11	0.10**
Number of years since knowing about artifical insemination (in years)	13.46	7.85	5.61***
Membership to DCS (1 = yes; 0 otherwise)	0.46	0.11	0.35***
Beneficiary of Govt. dairy development programme (1 = yes; 0 otherwise)	0.20	0.13	0.07***
Total land ownership (in hactare)	0.194	0.128	0.067***
Distance to nearest village market (in km)	2.853	3.148	0.296

Source: Primary survey, 2015-16.
Note: *, ** and ***indicate significance at 10 per cent, 5 per cent and 1 per cent probability level respectively.

Estimation of Propensity Score

The logit estimates of the propensity score equation are presented in Table 3. The model is significant with LR Chi^2 value 82.96 per cent and having Pseudo R^2 value of 0.2464. The log likelihood ratio is this is –126.673 and the model correctly predicts 64.96 per cent of adopters and 76.85 per cent of non-adopters. Many of the variables have the expected sign with some of the important variables such as herd size, number of years since knowing about artificial insemination (AI), membership of Dairy Cooperative Society (DCS) and beneficiary of government dairy development programme significantly and positively influencing adoption of high yielding crossbred cattle. With increase in the herd size, the farmers may start adopting more high yielding crossbred cattle as this may help them in two ways: (i) having a capital base (through selling of low productive local cattle) to buy relatively expensive crossbred cattle and/or (ii) through domestically growing of such breeds by impregnating the local female cattle with AI or using bull of high genetic merit (exotic). The variable 'number of years since first knowing about AI' has been taken as a proxy to awareness programmes through better extension services and the social network playing out in the information spread towards adoption of high-yielding crossbred cattle. The study has found a positive and significant relation between farmers' awareness about AI and crossbred cattle adoption emphasising the need for creating better awareness among farmers about the programme. Membership of DCS also positively affects adoption of crossbred cattle. Being in a farmer's group helps in rapid dissemination of knowledge and information about a new technology through better social network which gives an impetus to a non-adopting farmer to adopt the new technology (Ramirez, 2013). Table 3 further shows that government support in terms of providing subsidised concentrate feed distribution and fodder seeds to the farmers through dairy co-operatives has a positive and significant impact on adoption of crossbred cattle. This may be due to the fact that with access to such facilities farmers get incentives and support to rear crossbred cattle. The results of the logit regression are in line with the descriptive statistics presented in Table 2.

TABLE 3. LOGIT ESTIMATES OF THE PROPENSITY TO ADOPT HIGH YIELDING CROSSBRED CATTLE [DEPENDANT VARIABLE=ADOPTION (1/0)]

Variables (1)	Coeficient (Std. error) (2)
Age of the HH head (years)	- 0.003 (0.0129)
Education of the household head (in years of schooling)	- 0.004 (0.0373)
Family size (in numbers)	- 0.074 (0.065)
Off-farm inncome (1 = yes; 0 otherwise)	0.241 (0.349)
Distance to all-weather road (in metre)	- 0.0003 (0.0004)
Herd size (in numbers)	0.103 (0.0400)**
Access to credit (1 = yes; 0 otherwise)	0.267 (0.475)
Number of years since knowing about Artifical Insemination (in years)	0.090 (0.026)***
Membership to DCS (1 = yes; 0 otherwise)	0.874 (0.437)**
Beneficiary of Govt. dairy development programme (1 = yes; 0 otherwise)	1.767 (0.677)**
Total land ownership (in hactare)	2.400 (1.578)
Distance to nearest village market (in km)	- 0.117 (0.098)
Constant	- 1.173 (0.849)
LR Chi2 (12)	82.96***
Pseudo R2	0.2464
Log likelihood	- 126.673
Non-adopters correctly predicted	76.85 per cent
Adopters correctly predicted	64.96 per cent
Number of observation	245

Source: Authors' estimation based on primary survey data.
Note:*, ** and ***indicate significance at 10 per cent, 5 per cent and 1 per cent probability level respectively.

Before going to the causal effect of adoption of high yielding crossbred cattle, we would like to discuss the quality of matching process. Estimating the individual propensity score for the observations in the sample by implementing logit model we checked the common support condition. It was found that there is considerable overlap in common support condition as the predicted propensity scores for adopters of high yielding crossbred cattle ranges from 0.1942 to 0.9471 with a mean of 0.6126 and for non-adopters, it ranges from 0.1216 to 0.9472 with a mean of 0.3968. Thus the common support assumption is satisfied in the region of [0.1942-0.9472] with a loss of 34 (13.88 per cent) observations from the overall sample households. This intersection region for the propensity score is also clear from the common support graph (Figure 1). Figure 1 gives the histogram of estimated propensity scores for both adopters and non-adopters. The bottom half of the graph shows the propensity scores distribution for the non-adopters and upper half for adopters and the densities of the scores are represented in the y-axis. A cursory look of propensity scores density distributions for the two adoption groups indicates that the common support condition is satisfied, i.e., there is substantial overlap in the distribution of the propensity scores for the two groups (adopters and non-adopters).

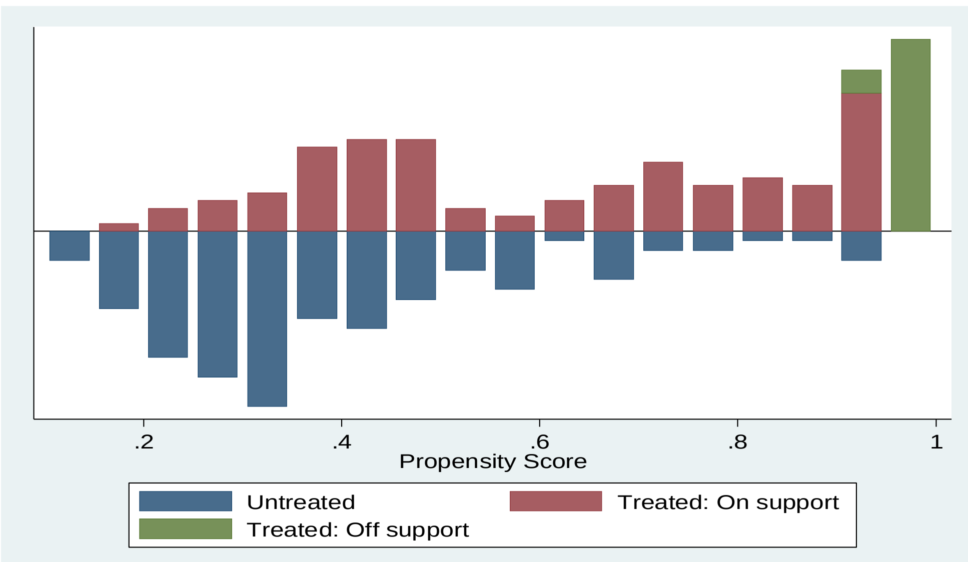

Figure 1. Distribution of Propensity Scores and Estimation of Common Support for Propensity Scores

Note: "Treated: on support" indicates the observation of high yielding crossbred cattle adoption group that have suitable comparison. "Treated: off support" indicates the observation of high yielding crossbred cattle adoption groups that do not have suitable comparisons.

As mentioned above, a major objective of propensity score estimation is to match the distribution of relevant variables between the two adoption groups, i.e., adopters and non-adopters, rather than obtain a precise prediction of selection into treatment. We try to see if individual variables used to match the two adoption groups (adopters and non adopters) are adequately balanced across treated and non-treated (control) groups based on several matching estimators as suggested by different authors (Smith and Todd, 2005; Dehejia and Wahba, 2002; Calendo and Kopening, 2005). Hence, in the present study we implement matching estimators such as nearest neighbour matching and kernel matching using PSM algorithms developed by Leuven and Sianesi (2003) in STATA 14. A preferred matching estimator is one that yields statistically identical covariate means for both groups (Caliendo and Kopeinig, 2005) that provides from a relatively high Pseudo-R^2 value before matching to a low Pseudo-R^2 value after matching (Sianesi, 2004) along with statistically insignificant likelihood ratio test of all regressors after matching (Smith and Todd, 2005). More specifically, rejection of the group means difference test after matching implies a good balancing of the covariates. Additionally, Rosenbaum and Rubin (1983) suggest reduction of mean absolute standardised bias between adopters and non-adopters approach. Reduction of mean standardised bias by a less than 20 per cent indicates good matching of the two distributions based on observable covariates.

Table 4 presents the results of the covariate balancing tests based on the above mentioned indicators using matching estimators such as three and five nearest neighbour matching and kernel based matching with bandwidth 0.06 and 0.03. The Pseudo-R^2 which is 24.7 per cent before matching got reduced to 2.1 – 3.4 per cent after matching. Again, the *p*-values of the likelihood ratio tests (joint significance of covariates) is significant (*p*-0.000) which had never been rejected before matching is always rejected after matching. The standardised mean difference for the covariates used in the propensity score of around 39 per cent before matching is reduced to about 7-10.5 per cent after matching. This reduces total bias substantially in the range of 73.28 – 82.19 per cent. It is further observed that the number of observations retained after matching was 211 from a total of 245 observations and indicates that the matching process did not result in substantial loss of observations (see Table 4).

TABLE 4. PROPENSITY SCORE AND COVARIATE BALANCE BEFORE AND AFTER MATCHING

Matching algorithm (1)	Pseudo R^2 before matching (2)	Pseudo R^2 after matching (3)	LR χ^2 (p-value) before matching (4)	LR χ^2 (p-value) after matching (5)	Mean standardised bias before matching (6)	Mean standardised bias after matching (7)	Total per cent bias reduction (8)	Number of observations retained (9)
NNM[a]	0.247	0.031	82.96 (p=000)***	9.32 (p=0.675)	39.3	8.4	78.63	211
NNM[b]	0.247	0.034	82.96 (p=000)***	10.14 (p=0.604)	39.3	10.5	73.28	211
KBM[c]	0.247	0.021	82.96 (p=000)***	6.31 (p=0.990)	39.3	7.6	80.66	211
KBM[d]	0.247	0.021	82.96 (p=000)***	6.29 (p=0.940)	39.3	7.0	82.19	211

Source: Authors' estimation based on primary survey data.
Notes: ***indicates significant at the 1 per cent probability level.
[a] NNM = three nearest neighbour matching with replacement and on common support.
[b] NNM = five nearest neighbour matching with replacement and on common support.
[c] KBM = kernel based matching with band width 0.06 and on common support.
[d] KBM = kernel based matching with band width 0.03 and on common support.

Estimation of Average Treatment Effects on the Treated

The estimated treatment effects on the treated using NNM and KBM estimators are shown in Table 5. Different bandwidths or calipers of matching estimators such as three and five nearest neighbour matching and Epanechnikov kernel based matching with bandwidth 0.06 and 0.03 have been used for a robust estimation of treatment effects. Common support is implemented for all the matching estimators so that the propensity scores distribution for adopters and non-adopters lies in the same domain. The significance of outcome variables (outcome differences of adopters over non adopters) is based on '*z*' value obtained from bootstrapping of standard errors using 50 replications.

TABLE 5. ESTIMATION OF ATT: IMPACT OF CROSSBRED CATTLE ADOPTION ON INCOME AND CONSUMPTION

Outcome Variable	ATT (Income in Rs.)			
	NNM (3)	NNM (5)	KBM (0.06)	KBM (0.03)
(1)	(2)	(3)	(4)	(5)
Crop and/or plantation income/annum	9655.96	10389.17	11802.20	11287.78
	(1.00)	(1.23)	(1.36)	(1.44)
Net dairy income[#]/annum	49245.37***	49013.59***	49461.53***	49394.09***
	(6.83)	(7.24)	(6.66)	(6.30)
Net dairy income[#]/milch cattle/day	47.04***	47.52***	47.53***	47.89***
	(10.02)	(7.96)	(7.42)	(6.75)
Livestock income[@]	2825.99**	2672.48**	2564.11**	2302.54*
	(2.01)	(2.37)	(1.96)	(1.85)
Off-farm income/annum	4706.85	5748.53	5566.85	8090.95
	(0.17)	(0.23)	(0.21)	(0.34)
Outcome Variables	ATT (Per Capita Daily Consumption in grams)			
Milk and milk products consumption	79.83**	93.46***	89.12***	91.63***
	(2.55)	(2.99)	(3.72)	(3.48)

Source: Authors' estimation based on primary survey data.

Notes: [#]Net Dairy Income is calculated as: gross value from milk and milk product sale + imputed value of domestically consumed milk minus the paid out cost; [@] Livestock income includes the selling of livestock products (other than milk and milk products) such as live animals, cow dung, eggs etc.; ATT estimates of all matching algorithms is obtained by implementing 'psmatch2' command (Leuven and Sianesi, 2003) in STATA 14; Figures in parentheses indicate bootstrapped z value using 50 replications.

*, ** and ***indicate significance at 10 per cent, 5 per cent and 1 per cent probability level respectively.

NNM (3) = three nearest neighbour matching with repalcement and common support.

NNM (5) = five nearest neighbour matching with replacement and common support.

KBM (0.06) = kernel based mathing with bandwidth 0.06 and common support.

KBM (0.03) = kernel based matching with bandwidth 0.03 and common support.

The outcome variables are the household income by different sources of income after adoption of crossbred cattle and per capita consumption of high value commodities. Although the various matching estimators provide slightly different quantitative results but qualitatively crossbreeding adoption effects are same across all the matching estimators. The significant increase (*p*-value = 0.000) in net dairy income per annum after adoption of crossbreeding ranges from Rs. 49013.59 to Rs. 49461.53 (see Table 5) for the different matching estimators. Normalising the net dairy income in terms of per milch cattle per day, the significant increase (*p*-value = 0.000) after adoption of crossbred cattle is estimated in the range of Rs. 47.04 to Rs. 47.89. Another outcome variable of interest in this category is the livestock income that shows the significant increase (5 per cent to 10 per cent probability level) in the range of Rs. 2302.54 to Rs. 2825.99. The increase in average livestock income for adopters is due to higher prices of crossbred heifers that even compensate the low priced crossbred male calves (due to poor drought capacity). However, the remaining two of the income components, namely, crop and/or plantation income and off-farm income do not seem to be affected by the adoption of crossbred cattle. The average treatment effect after adoption of crossbred cattle for average per capita daily consumption of domestically produced milk and milk products indicates a positive and significant increase. Adopter households have higher average per capita daily consumption of milk and milk products by a range of 79.83 to 93.46 grams.

These findings are consistent with some of the recent studies on the impact of adoption of modern agricultural varieties such as studies carried out by Hossain *et al*. (2006) in Bangladesh, Kassie *et al*. (2011) in Uganda, Amare et al. (2012) in Tanzania etc.

IV

CONCLUSIONS

In order to find out the likely benefits of crossbred cattle adoption, the present study made efforts to evaluate income and consumption impact of crossbred cattle adoption in the context of Assam. The impact analysis was based on propensity score matching method using cross-sectional data of 245 sample farmers collected from three districts of Assam (137 adopter of crossbreeding technology and 108 non adopters). It is seen from the study that crossbred cattle adoption has significantly higher potential to generate dairy and livestock income. For better nutritional security, adopter households also have significantly higher consumption of nutritious and protein-rich high value food commodities such as milk compared to non-adopter households. The study has found that since adoption of crossbred cattle has higher income and consumption effect, there is need for greater diffusion of artificial insemination (AI) technology and deployment of exotic bulls in not easily accessible areas to increase the number of crossbred cattle in the state. One important limitation of the present study is that it fails to identify the hindering factors of crossbreeding technology adoption and thus claims that further investigations are needed to identify them. One of the key findings from the study was the role of farmer awareness and institutional support in crossbred cattle adoption. Hence, training and skill development of dairy farmers in farm management and animal husbandry, the role of women dairy farmers and the right institutional support in promoting dairy crossbreeding technology in the state also need further investigation. Nevertheless, the present study is very much highlighting the role of crossbreeding technology for meeting first two sustainable development goals of the United Nations namely no poverty and zero hunger.

Received February 2017. *Revision accepted July 2017.*

NOTES

1. The daily milk yield of crossbred cattle is 6.47 liters/animal/day among the sample farmers against the 1.85 litre/animal/day in case of non-descript cattle with the difference of 4.62 liter/animal/day between the two breeds.

2. Livestock income includes income received (other than milk and milk products) such as income accrued from selling of live animals, cow-dung, eggs etc.

3. Off-farm income includes income accrued for the households from various sources such as salary earned from Govt. or Private job, wage income, business and petty trading and all other sources (other than the heads incorporated in the list of income mentioned in Table 2).

REFERENCES

Abebaw, D. and M.G. Haile (2013), "The Impact of Cooperatives on Agricultural Technology Adoption: Empirical Evidence from Ethiopia", *Food Policy*, Vol.38, pp.82-91.

Alary, V., C. Corniaux and D. Gautier (2011), "Livestock's Contribution to Poverty Alleviation: How to Measure It?", *World Development*, Vol.39, No.9, pp.1638-1648.

Amare, M., S. Asfaw and Shiferaw (2012), "Welfare Impacts of Maize-Pigeonpea Intensification in Tanzania", *Agricultural Economics*, Vol.43, No.1, pp.27-43

Becker, S.O. and A. Ichino (2002), "Estimation of Average Treatment Effects Based on Propensity Scores", *The Stata Journal*, Vol.2, pp.358-377.

Caliendo, M. and S. Kopeinig (2005), *Some Practical Guidance for the Implementation of Propensity Score Matching*, IZA Discussion Paper No. 1588.

Caliendo, M. and S. Kopeinig (2008), "Some Practical Guidance for the Implementation of Propensity Score Matching", *Journal of Economic Survey*, Vol.22, No.1, pp.31-72.

Dehejia, R. and S. Wahba (2002), "Propensity Score Matching Methods for Non-Experimental Causal Studies", *The Review of Economics and Statistics*, Vol.84, No.1.

Doss, C.R. (2006), "Analyzing Technology Adoption using Microstudies: Limitations, Challenges, and Opportunities for Improvement", *Agricultural Economics*, Vol.34, No.3.

Feder, G.L., R.E. Just and D. Zilberman, (1985), "Adoption of Agricultural Innovation in Developing Countries: A Survey", *Economic Development and Cultural Change*, Vol.32, No.2.

Government of India, (2013), *National Livestock Policy 2012*, Department of Animal Husbandry Dairying and Fisheries, Ministry of Agriculture, New Delhi.

Hossain, M., M.L. Bose and B.A.A. Mustafi (2006), "Adoption and Productivity Impact of Modern Rice Varieties in Bangladesh", *Developing Economies*, Vol.64, No.2, pp.149-166.

Ito, J., Z. Bao and Q. Su (2012), Distributional Effects of Agricultural Cooperatives in China: Exclusion of Smallholders and Potential Gains on Participation", *Food Policy*, Vol.37, pp.700-709.

Kassie M., B. Shiferaw and G. Muricho (2011), "Agricultural Technology, Crop Income, and Poverty Alleviation in Uganda", *World Development*, Vol.39, No.10, pp.1784-1795.

Leuven, E. and B. Sianesi (2003), "PSMATCH2: Stata Module to Perform Full Mohalanobis and Propensity Score Matching, Common Support Graphing, and Covariate Imbalance Testing", http://ideas.repec.org/c/boc/bocode/s432001.html.

Melesse K. and J. Jemal (2013), "Dairy Technology Impacts on Livelihoods of Dairy Producers in Central Ethiopia", *International Journal of Food and Agricultural Economics*, Vol.1, No.1, pp.109-118.

Quddus, M.A (2012), "Adoption of Dairy Farming Technologies by Small Holders: Practices and Constraints", *Bangladesh Journal of Animal Science*, Vol.41, No.2.

Ramirez, A. (2013), "The Influence of Social Network on Agricultural Technology Adoption", *Procedia-Social and Behavioral Sciences*, Vol.79, pp.101-116

Rosenbaum, P.R. and D.B. Rubin (1983), "The Central Role of the Propensity Score in Observational Studies for Causal Effects", *Biometrika*, Vol.70, pp.41-55

Sianesi, B. (2004), "An Evaluation of the Active Labour Market Programs in Sweden", *The Review of Economics and Statistics*, Vol.86, No.1.

Smith, J. and P. Todd (2005), "Does Matching Overcome Lalonde's Critique of Non-Experimental Estimators?" *Journal of Econometrics*, Vol.125, Nos.1/2.

Udo, H.M.J and F. Steenstra (2010), "Intensification of Smallholder Livestock Production, is it Sustainable?", The 5th International Seminar on Tropical Animal Production, *Community Empowerment and Tropical Animal Industry*, Yogyakarta, Indonesia.

Udo, H.M.J., H.A. Alkilu, L.T. Phong, R.H. Bosma, I.G.S. Budisatria, B.R. Patil, T. Samdup and B.O. Bebe (2011), "Impact of Intensification of Different Types of Livestock Production in Smallholder Crop-Livestock Systems", *Livestock Science*, Vol.139, pp.22-29.