Indian Journal of Agricultural Sciences **94** (3-S1): 063–071, March-S1 2024/Article
https://doi.org/10.56093/ijas.v94i3.148771

Impact of India's farm science centers (Krishi Vigyan Kendras) on farm households' economic welfare: An evidence from a national farmers' survey

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Received: 12 March 2024; Accepted: 9 April 2024

ABSTRACT

This study examines the impact of access to India's farm science centers (Krishi Vigyan Kendras, or KVKs) on agricultural households' welfare using household data from the nationally representative Situation Assessment Survey of Agricultural Households conducted by India's National Sample Survey Office in 2013. Employing different matching techniques and endogenous switching regression models, it was observed that the KVKs have a positive and statistically significant impact on agricultural households' economic welfare, although, that impact is heterogeneous. Further, the investments made in expansion of India's network of KVKs have been quite remunerative, as the benefit-to-cost ratio of expenditure on KVKs ranges from 8–12. Moreover, present findings suggest that expanding rural formal credit markets and promoting literacy can maximize the potential impact of KVKs on agricultural households' economic welfare.

Keywords: Agricultural households, Benefit-cost ratio, Economic welfare, Farm science centers (Krishi Vigyan Kendras), Farmers

Agricultural extension has been recognized as a vital element in improving agricultural development. It builds the knowledge base and the capabilities of farmers for the adoption of improved agricultural technologies and innovations developed in public and private research systems. Similar to agricultural research, with which it is closely interwoven, agricultural extension attracts substantial public resources, although more could be invested. Agricultural extension and rural service institutions and approaches continue to evolve in India and worldwide. Yet, these approaches have not been fully assessed for their contribution to farmer's welfare (Babu and Joshi 2019). In India, the model of Krishi Vigyan Kendras (KVKs) has emerged as one of the pivotal district-level extension institutions to translate innovations from the laboratory to farmers' fields through location-specific trials and applications.

Since the establishment of the first KVK in Puducherry in 1974, KVKs have evolved to meet the technological needs of the Indian farming community. Besides transfer of technology and knowledge, KVKs engage in other rural service activities including, quality seed production and distribution, identifying and documenting farm innovations, and facilitating convergence with ongoing rural intervention schemes and programmes dictated by national policies. In addition, KVKs have been a primary channel for communication of national policy makers, programme managers and researchers to share their innovations that aim at increasing farmer's welfare. Despite their widespread presence and multifaceted contribution to farmers' knowledge base, empirical evidence on their relevance, efficacy, and effectiveness of India's KVKs is lacking. However, there is hardly any study that shed light on the impact of KVKs on the Indian farming community in general and, on how much change in the economic welfare of the farming community can be attributed to KVKs. Although considerable evidence exists that the returns to agricultural research investments are high, evidence of the rate of return to investments in agricultural extension approaches are grossly lacking at the global level (Fan *et al*. 2008, Joshi *et al*. 2015, Bathla *et al.* 2017). Impact assessment of KVKs is typical. The rates of return to investments in extension activities in India have not been well documented. Estimation of the economic benefits of extension faces several difficulties, the most serious of which has been an inability to separate the effects of extension contributions to farm income from other sources, notably from research

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and human capital (Wossen *et al*. 2017, Cawley *et al.* 2018). Additionally, there are difficulties associated with assessing both extension expenditure and the outputs resulting from those expenditures. The quantification of the impact of KVKs is even more challenging as farmers receive extension services from many public and private extension agencies.

In this backdrop, this study assesses the impact of KVKs in India using net farm income and annual per capita household income as measures of agricultural households' welfare collected through a nationally representative agricultural household survey. The paper contributes to the literature as follows. Evaluating the impact of KVKs, or of any other extension or development programme is a challenge because of endogeneity. In our study, we employ alternative econometric techniques, namely propensity score matching and endogenous switching regression, to address the endogeneity bias problem. The present study provides empirical evidence on the impact of KVKs on farm households' economic welfare and in estimating the heterogeneous treatment effects of these interventions. To the best of our knowledge, this paper is the first to provide a comprehensive assessment of India's KVK initiative on agricultural households' welfare outcomes. Hopefully, our findings will help policymakers make informed decisions in prioritizing investments in India's agricultural sector.

Functioning of KVKs in India: Krishi Vigyan Kendra (KVKs), is a multidisciplinary agricultural extension education and knowledge center situated at the district level, funded and technically supervised by the Indian Council of Agricultural Research (ICAR). There are currently 731 KVKs in India, almost one in each district, testifying to the growth of the KVK network. State agricultural universities, central agricultural universities, non-governmental organizations, ICAR research institutes, state governments, and the private sector all play a hand in hosting and administering the KVKs. Activities of the KVKs include on-farm testing to assess the location specificity of agricultural technologies, the scaling of farm innovations through frontline demonstration, capacity development of farmers and extension personnel, working as knowledge and resource centers, conducting frontline extension programmes, providing farm advisories, data documentation, and characterization and strategic planning of farming practices. Each KVK is headed by a chief scientist known as the Programme Coordinator who is supported by 6 scientists known as subject matter specialists (SMS) and 9 other staffs (administrative and technical).

At the national level, the KVKs fall under the jurisdiction of the Agricultural Extension (AE), Division of the Indian Council for Agricultural Research (ICAR), and the Deputy Director General (AE) is responsible for the overall functioning of the KVKs. At the zonal level, the KVK programmes are planned, monitored, and evaluated by 11 Agricultural Technology Application Research Institutes (ATARIs; previously known as the Zonal Project Directorate) located in 11 different agro-ecological zones in India. The KVKs are designed to have expertise in three core areas, technology adaptation; capacity development; and acting as a knowledge and resource center. A scientific advisory committee, constituted for each KVK, meets once a year, with the attendance of the heads of the various district level government line departments, progressive farmers, and the zonal coordinator, to discuss the KVK action plan for the following year. The action plan is undertaken based on a Participatory Rural Appraisal (PRA), carried out by each KVK; accordingly, the needs of the farmers are incorporated into the KVK's action plan.

The expenditure on KVKs has consistently risen both in absolute and proportionate terms. The percentage share for KVKs in the overall ICAR budget has increased from 7% in 2002–2003 to 12.5% in 2016–2017 and remained almost same till 2022–23, implying growing importance accorded to the KVKs in the Indian Agricultural Research and Extension System.

MATERIALS AND METHODS

Data: The data pertaining to this study were obtained from the nationally representative Situation Assessment Survey of Agricultural Households conducted by India's National Sample Survey Office in 2013, which was designed to assess the status of farming and farmers in India. The survey followed a stratified multistage design wherein the first-stage units were the census villages (panchayat wards in the case of Kerala), and the ultimate-stage units were households. The survey covered 4,529 villages across the country and elicited information from 35,200 farming households. The information was collected primarily for the agricultural year 2012–13. The same households were visited twice during the survey period, the first time between January and July 2013 and the second time between August and December 2013. For crops, information on expenses and receipts of cultivation were collected for the period July–December 2012 on the first visit and for January–June 2013 on the second visit. The survey collected data on landholding sizes, land use patterns, types of crop production and animal farming activities, seasonal variation in household farm activities, and livestock ownership. The survey also gathered information on social, economic, institutional, and organizational aspects of farming, production, farming expenses, and marketing patterns of crops, livestock, and fisheries.

Empirical Strategy: The main aim of this study was to estimate the impact of KVKs on the economic welfare of farming households. The net returns from farming (net farm income, or NFI) and household income (HI) was used as indicators of farmers' economic welfare. Income has been widely used as a proxy for household welfare in a number of previous studies (Li *et al* 2011, Arouri *et al*. 2015, Kumar *et al.* 2017). Identification of the causal effects of access to a KVK on potential outcome indicators such as farmers' economic welfare is complex for several reasons. For example, since we cannot observe the counterfactual, that is, outcome indicators of a farm household in the event the farm household had not accessed a KVK, this may introduce an endogeneity bias. Further, individual farm households may choose whether to access a KVK or not, and those who access KVKs are likely to be different in certain characteristics from those who choose not to. Therefore, the precise estimation of impacts will require controlling for both observable and unobservable characteristics through random selection of individuals or households for treatment. In the absence of random experiments, selection bias may persist as observed and unobserved characteristics of individual farm households may affect the probability of access to a KVK (treatments) as well as NFI and annual per capita household income (outcome indicators). Several methods have been proposed and used in the literature to deal with these issues, ranging from instrumental variable methods to experimental and quasi-experimental methods (Davis *et al.* 2012, O'Donoghue and Hennessy 2015, Cawley *et al.* 2018).

Propensity score matching (PSM), inverse probability weighted regression adjustment (IPWRA), and endogenous switching regression (ESR) was applied to control sample selection and endogeneity bias. The impact of access to KVK on farmers' welfare can be measured by the difference between the expected values of outcome indicators of the two groups of farming households; the one who access to KVK and the ones who do not (herein after called KVK and non-KVK households). Following Imbens and Wooldridge (2009), this difference, referred to as the average treatment effects on the treated (ATT) can be defined as follows:

$$ATT = E(Y_1 - Y_0/T_i = 1), \quad (1)$$

where Y_1 and Y_0, Outcome indicators (NFI and HI) of KVK and non-KVK farmers, respectively, and T, Indicator of access to a KVK. However, we can observe only $E(Y_1)/T = 1$ in our dataset; $E(Y_0)/T = 1$ is absent. We cannot observe the welfare level of treated households had they not been treated, once they are treated. Simple comparison of welfare levels of farmers with and without treatment will produce biased estimates due to self-selection bias. The magnitude of self-selection bias is formally given as:

$$E(Y_1 - Y_0/T_i = 1) = ATT + E(Y_0/T_i = 1 - Y_0/T_i = 0) \quad (2)$$

By generating comparable counterfactual households for treated households, PSM takes care of the bias due to observables. Once households are matched with observables, PSM assumes that there are no systematic differences in unobservable characteristics between treated and untreated households. Given this assumption of conditional independence and the overlap conditions, ATT is computed as follows:

$$ATT = E(Y_1)/T_i = 1, p(x) - E[Y_0/T_i = 0, 0, p(x)] \quad (3)$$

However, ATT from PSM can still be biased in the presence of misspecification in the propensity score models (Wooldridge 2007, Wooldridge 2010, Wossen *et al.* 2017).

The use of inverse probability weighted regression adjustment (IPWRA) can be a potential solution (Wooldridge 2007, Wooldridge 2010) as its estimates will be consistent in the presence of misspecification in the treatment/outcome model. Following Imbens and Wooldridge (2009), we can estimate ATT in IPWRA models in two steps. Assume that the outcome model is represented by a linear regression function of the form $Y_i = \alpha_i + \delta_i X_i + \in_i$ for i = [0,1] and the propensity scores are given by $p(x; \gamma)$. In the first step, we estimate the propensity scores as $p(x; \tilde{\gamma})$. In the second step, we then employ linear regression to estimate (α_0, δ_0) and (α_1, δ_1) using inverse probability weighted least square as:

$$\min_{\alpha_0,\gamma_0} \sum_i^N (Y_i - \alpha_0 - \gamma_0 X_i)/p(x;\hat{\gamma}) \text{ if } T_i = 0 \quad (4)$$

$$\min_{\alpha_1,1} \sum_i^N (Y_i - \alpha_1 - \gamma_1 X_i)/p(x;\hat{\gamma}) \text{ if } T_i = 1 \quad (5)$$

We can then estimate ATT as the difference between equations 4 and 5:

$$ATT = \frac{1}{N_w}\sum_i^{N_w}[(\widehat{\alpha_1} - \widehat{\alpha_0}) - (\widehat{\gamma_1} - \widehat{\gamma_0})X_i], \quad (6)$$

where (α_1, δ_1), Estimated inverse probability weighted parameters for treated households; (α_0, δ_0), Estimated inverse probability weighted parameters for untreated households;. N_w, Total number of treated households. However, matching techniques- regardless of adjustments for misspecification bias can overcome only the selection bias caused by observables. When the endogeneity bias is due to unobservable heterogeneity, the results based on matching techniques will be biased. Therefore, to account for both observed and unobserved sources of bias, we employ an endogenous switching regression (ESR) framework to estimate the parameters. The ESR approach addresses this endogeneity problem by estimating the selection and outcome equations simultaneously using the full information maximum likelihood (Wossen *et al.* 2017, Kumar *et al.* 2018).

We specify the selection equation for association with a KVK as:

$$T_i^* = X_i\,\alpha + \delta_i \text{ with } \begin{cases} 1 \text{if } T_i^* > 0 \\ 0 \text{ otherwise} \end{cases}. \quad (7)$$

That is, a farmer will opt to access a KVK (T_i–1), if $Y^*>0$, where Y^* represents the expected benefits of accessing the KVK compared to not accessing the same.

Here, X is a vector of variables that determine a farmer's association with a KVK. The relationship between a vector of explanatory variables X and the outcome Y can be represented by Y = f(X). Specifically, the outcome function conditional on treatment can be represented as follows:

$$\text{Regime 1: } Y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \text{ if } T_i = 1$$

$$\text{Regime 2: } Y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i} \text{ if } T_i = 0, \quad (8)$$

where Y_i, Outcome of interest i.e. net farm income (₹/ha) (and annual per capita household income (₹) in regimes 1 and 2 of equation 8 and X_i represents a vector of the explanatory variables; ε_{2i}, Error term of the outcome variable. Finally, the error terms are assumed to have a trivariate normal distribution, with zero mean and covariance matrix. If the estimated co-variances between δ and ε's (ρ_1 and ρ_2, respectively) are statistically significant, then the farmers' association with KVK and the farmers' welfare are correlated. The ρ_1 and ρ_2 are the transformation of the correlation between the errors from equation 8. Using this method, we found evidence of endogenous switching and rejected the null hypothesis that sample selectivity bias was absent. This model is defined as a "switching regression model with endogenous switching" (Maddala and Nelson 1975), which can be used to estimate ATT and ATU (average treatment effects on untreated households).

Identification of the ESR model requires at least one additional variable as an instrument. The selection of instrumental variables should directly affect the selection variable but not the outcome variable. In this study, we use caste as a selection instrumental variable. We established the admissibility of the instruments by performing a simple falsification test: if a variable is a valid selection instrument, it will affect the households of farmers that are associated with a KVK but will not affect the outcome variable of the households of farmers that are not associated with a KVK.

In addition to using the ESR model, we calculate the farmers' conditional expectations for farm income and annual per capita household income for the four following cases:

$$E(Y_{1i}|T_i = 1) = [\Sigma_{Ti=1}(X_{1i}\beta_1 + \sigma_{1n}\gamma_{1i})]/N_1 \quad (9)$$

$$E(Y_{2i}|T_i = 0) = [\Sigma_{Ti=1}(X_{2i}\beta_2 + \sigma_{2n}\gamma_{2i})]/N_0 \quad (10)$$

$$E(Y_{2i}|T_i = 1) = [\Sigma_{Ti=1}(X_{1i}\beta_2 + \sigma_{2n}\gamma_{1i})]/N_1 \quad (11)$$

$$E(Y_{1i}|T_i = 0) = [\Sigma_{Ti=0}(X_{2i}\beta_1 + \sigma_{1n}\gamma_{2i})]/N_0 \quad (12)$$

N_1 and N_0, Number of observations with $T_i = 1$ and $T_i = 0$, respectively.

Cases (a) and (b) (Table 1) represent the actual expectations observed in the sample. Cases (c) and (d) represent the counterfactual expected outcomes. However, following Heckman, Tobias, and Vytlacil (2001), we calculate the effect of the treatment "KVK farmers" on the treated (TT) as the difference between (a) and (c), which represents the impact of KVK on the outcome variable of the farm households that are KVK farmers. Similarly, we calculate the difference between (d) and (b) as the effect of the treatment on the untreated (TU) for the farm households that did not access a KVK.

We also defined the "effect of base heterogeneity" for the group of farm households that decided to access a KVK as the difference between (a) and (d). For the group of farm households that decided not to access a KVK, the effect of base heterogeneity was defined as the difference between (c) and (b) (Carter and Milon 2005).

Finally, we examine the transitional heterogeneity (TH) namely, whether the effect of a KVK on the outcome variable is larger or smaller for the farm households that are associated with a KVK than for those that are not associated with a KVK in the counterfactual case (that is, the difference between TT and TU).

Descriptive statistics

Characteristics of KVK and non-KVK Farmers: Table 4 presents the descriptive statistics of the key and

Table 1 Decision stage treatment and heterogeneity effect

Transitional heterogeneity	Decision stage		Treatment effects
	KVK	Non-KVK	
KVK	(a) $E(Y_{1i}|T_i = 1)$	(c) $E(Y_{2i}|T_i = 1)$	TT
Non-KVK	(d) $E(Y_{1i}|T_i = 0)$	(b) $E(Y_{2i}|T_i = 0)$	TU
Heterogeneity effects	BH^1	BH^2	TH

Source: Carter and Milon (2005).

(a) and (b), Observed expected outcome indicators; (c) and (d), Counterfactual expected outcome indicators; T_i, 1 if farm households are associated with a KVK; T_i, 0 if farm households are not associated with a KVK; Y_{1i}, Outcome indicators if farm households are associated with KVK; Y_{2i}, Outcome indicators if farm households are not associated with a KVK; TT, Effect of the treatment (that is, KVK farmers) on the treated; TU, Effect of the treatment (that is, KVK) on the untreated (that is, not KVK) BH^i, Effect of base heterogeneity for farm households that are associated with KVK (i = 1), and not associated with KVK (i = 2); TH, (TT − TU) (that is, transitional heterogeneity).

Table 2 presents the descriptive statistics of the key variables of interest. The average household size is about 5 members and the average household head is 48.24 years old. About 92% of the households are male headed and the majority of the respondents are literate (59.19%). In terms of caste classification of the sample households, the category "Other backward caste" accounts for 45.07% of the agricultural households followed by "general caste" (25.47%), "scheduled caste" (15.48%), and "scheduled tribe" (13.98%). In terms of land holding sizes, a majority of the sample farmers are classified as marginal (67.25%) and smallholder farmers (18.35%). Moreover, 72.19% of the sample households reported agriculture as the principal source of income. About 87.71% of the households hold a ration card and 44.2% had a MGNREGA job card. The cropping pattern is dominated by food crops with a 72.63% share in gross cropped area, although 10.83% of gross cropped area is devoted to the cultivation of high-value crops. The agricultural households have a mean annual net farm income of ₹34,200 per hectare and a mean annual per capita household income of ₹16,522.

In terms of characteristics, the KVK farmers are relatively older and better educated, and have larger landholdings (Table 2). The difference in education between KVK and non-KVK farmers is more pronounced at higher levels of education. There appears to be a scale bias in access to the KVKs, as the proportions of medium-size and large-size farm households are higher among the KVK farmers. Caste is an important indicator of social hierarchy in India, with scheduled castes and scheduled tribes at the bottom most layer, followed by other backward castes while the upper castes stacked up at the top. Social bias is visible in access to KVKs. The proportion of general caste is significantly higher among KVK beneficiaries. Further, more than 77% of the KVK farmers list agriculture as their main occupation.

The mean differences are statistically significant for outcome indicators analyzed in this paper. For instance, KVK

Table 2 Selected characteristics of KVK and non-KVK farmers

Variable	All	KVK	Non-KVK	Mean diff
Socio-demographic characteristic				
Age (years)	48.24	51.79	48.11	3.68***
Household size (no.)	5.13	5.54	5.11	0.43
Male-headed households (%)	91.96	94.27	91.88	2.39
Formal training in agriculture (%)	2.62	12.2	2.26	9.94***
Social structure by caste (%)				
Scheduled tribe	13.98	9.41	14.12	-4.71***
Scheduled caste	15.48	9.12	15.72	-6.6***
Other backward caste	45.07	43.64	45.14	-1.5
General caste	25.47	37.84	25.02	12.82***
Education level of the household head (%)				
Illiterate	40.81	22.78	41.48	-18.7***
Primary	13.27	13.81	13.25	0.56***
Middle	27.17	36.99	26.81	10.18***
Secondary	14.94	20.09	14.75	5.34***
Higher secondary and above	3.81	6.32	3.72	2.6***
Land size (in hectares)	1.10	1.61	1.08	0.53***
Structure of households by farm size (%)				
Marginal (< 1 ha)	67.25	55.4	67.7	-12.3***
Small (1–2 ha)	18.35	20.08	18.29	1.79
Medium (2–4 ha)	10.04	15.78	9.82	5.96***
Large (> 4 ha)	4.36	8.74	4.19	4.55***
Principal source of income (%)				
Agriculture	72.19	77.32	72	5.32
Non-agriculture	23.12	17.87	23.32	-5.45
Pension	1.00	2.2	0.96	1.24***
Remittance	3.08	2.45	3.1	-0.65
Access to social safety nets (%)				
MGNREGA job card	44.2	41.15	44.3	-3.15***
PDS ration card	87.71	92.77	87.53	5.24***
Access to institutional credit (%)	36.48	55.04	35.41	19.63***
Source of seeds (%)				
Own farm	35.07	39.18	34.91	4.28***
Local trader and input dealer	60.05	50.80	60.41	-9.61***
Cooperative and government agency	4.89	10.01	4.69	5.33***
Cropping pattern (% share in GCA)				
Food crop	72.63	63.27	72.97	-9.7***
High-value crops	10.83	18.49	10.55	7.94***
Oilseeds	8.84	11.4	8.75	2.65***
Other crops (nonfood)	7.69	6.83	7.72	-0.89*
Simpson index of diversity (%)	39.37	47.03	39.1	7.93***
Net farm income per hectare (₹/ha)	34,200.30	46,035.89	33,748.05	12,287.84***
Annual per capita expenditure (₹/person)	16,066.12	19,889.56	15,923.73	3,965.83***
Per capita annual household income (₹)	16,522.39	26,289.60	16,145.48	10,144.12***

Source: Authors calculation

MGNREGA, Mahatma Gandhi National Rural Employment Guarantee Act; PDS, Public Distribution System; GCA, Gross Cropped Area.

farmers are realizing significantly higher net farm income compared to non-KVK farmers a difference of ₹12,288/ha. Similarly, the annual per capita household income of KVK farmers is also significantly higher than that of non-KVK farmers. However, the results in Table 2 cannot be used to make inferences about the impact of KVKs on farmers' income without controlling for other confounding factors.

RESULTS AND DISCUSSION

Determinants of access to KVK: The results showed that access to a KVK is strongly associated with the socio-economic and demographic characteristics of farm households (Table 3). In particular, older, larger, and more educated households are more likely to seek advice from the KVKs. There appears to be a gender bias with the probability of male-headed households accessing a KVK is higher than the female-headed households. Farmland holding size has a positive and statistically significant effect on the probability of accessing a KVK. Larger farm owners are more likely to search for innovations and scientific methods. With greater financial backing, they are also more likely to adopt new technologies and thus are more likely to search for new innovations and scientific methods through KVKs (NILERD 2015). The positive relationship between farm size and KVK access implies that the KVKs should revisit their strategies for targeting more smallholders and marginal landholders through their outreach programmes. Similarly, households with access to formal credit are more likely to seek information from a KVK.

Impact of KVK on farm income and annual per capita household income: Table 4 reports treatment effect estimates for KVK access on net farm income (NFI) and annual per capita household income. Rows one and two present treatment effects of KVK access based on the PSM and IPWRA specifications. The third row, which is our preferred specification, presents the ESR results. The reported effects of access to KVK are robust on both of our outcome indicators, showing that the KVKs are playing an important role in farmers' lives. We find that KVK access increases net farm income by ₹3,457/hectare (an increase of about 10%) under the PSM specification and by ₹3,674/hectare (~11%) under the IPWRA specification. Similarly, access to a KVK increases per capita annual household income by ₹419 and ₹404 under PRM and IPWRA, respectively (a 2.5% increase). The endogenous switching regression estimates are given in Supplementary Table 1 and 2. In the ESR model, the net farm income function, σ_i, is positive and statistically significant when comparisons are made with reference to the non-KVK. This indicates that access to a KVK has an absolute advantage over non-KVK access. However, the annual per capita household income function, ρ_i, is negative and significant. This indicates that those who have access to a KVK are having a higher income compared with others irrespective of whether they access or not but are relatively better off when they access the KVK services. Nevertheless, we found a difference between the coefficient of the NFI function and HI function in KVK and non-KVK farmers, indicating the presence of heterogeneity in the sample. In the ESR model, where we account for both observable and unobservable sources of bias, the effect of KVK access is an additional increase in NFI of ₹5,752/hectare (~17%). Similarly, the per capita annual income is likely to increase by ₹758 (4.6%). The results suggest that KVKs have a positive and significant impact on household welfare

Table 3 Determinants of access to KVK services

Dependent variable: Access to KVK services (yes = 1, otherwise = 0)	Linear probability model		Logit model			
	Coefficient	SE	Coefficient	SE	Marginal effect (dy/dx)	SE
Age in years (ln)	0.007	(0.006)	0.241*	(0.143)	0.011*	(0.007)
Household size (ln)	0.004	(0.003)	0.137*	(0.075)	0.006*	(0.004)
Male-headed household^	0.011*	(0.006)	0.260*	(0.155)	0.012*	(0.007)
Education in years (ln)	0.011***	(0.002)	0.298***	(0.049)	0.014***	(0.002)
Principal source of income (base: agriculture)						
Non-agriculture	-0.010**	(0.005)	-0.227**	(0.104)	-0.011**	(0.005)
Pension	-0.015	(0.013)	-0.243	(0.170)	-0.011	(0.008)
Remittances	-0.011	(0.010)	-0.134	(0.188)	-0.006	(0.009)
Landholdings in hectares (ln)	0.013***	(0.002)	0.293***	(0.039)	0.014***	(0.002)
Social safety net	0.003	(0.005)	0.148	(0.163)	0.007	(0.008)
Access to institutional credit	0.017***	(0.004)	0.356***	(0.077)	0.017***	(0.004)
Constant						
Observations	30,938		30,228		30,228	
R^2	0.096					

Source: Authors calculation

Note: Robust standard errors (SE) in parentheses. ^ denotes binary variable.

*** *P*<0.01; ** *P*<0.05; * *P*<0.1

indicators (Table 4). These findings underscore the crucial role that investment in the KVK network may play in improving the welfare of rural poor farm households. These findings are in line with the previous findings in the literature. Cawley *et al.* (2018) reported an increase of 35 in family farm income with participation in extension services in Ireland. We find evidence of increase in family farm income in other countries too, 26% in Virginia (Akobundu *et al.* 2012); 61% in East Africa (Davis e*t al.* 2004); 55% in Ireland (O'Donoghue and Hennessy 2015). Feder, Lau, and Slade (1987) reported a return of at least 15% to the incremental investment in extension (Training & Visit system in north-west India). Wossen *et al*. (2017) attributed 47% and 26% increase in farmers' assets value and consumption expenditure, respectively due to access to extension services in Nigeria.

To better understand how KVK access effects different groups of farmers, we examined the impact of KVK access on large and small farmers separately. The detailed estimates obtained from ESR and PSM model of outcome variables are given in Supplementary Table 3 and 4. The large farmers accrue a greater benefit from KVKs than do the smallholder and marginal landholding farmers (Table 4). This has important policy implications for the functioning of the KVKs and calls for developing a mechanism to better target the smallholder and marginal land holding farmers instead of relying on a one-size-fits-all approach.

Since the reliability of PSM results depends on the quality of our matching, we present the extent of overall covariate balancing and the overlap over the common support. The overall covariate balancing test shows that the standardized mean difference for all covariates used in the PSM reduces from 16.7% pre-matching to about 1% in post-matching (Table 5). The balancing test of each covariate is presented in Supplementary Table 5 and Supplementary Fig. 1 reflects the standardized percentage bias across covariates of matched and unmatched sample. Moreover, the joint significance of all covariates was never rejected before matching ($P > \chi 2 = 0.000$). However, the likelihood ratio tests indicate that the joint significance of the covariates can be rejected after matching ($P > \chi 2 = 0.999$). The low mean standardized bias and joint insignificance of the covariates are indicative of successful balancing of the distribution of covariates between treated and untreated households. In addition, a visual perusal of the estimated propensity scores for households with and without treatment indicates that the common support condition for access of KVKs is satisfied (Fig. 1).

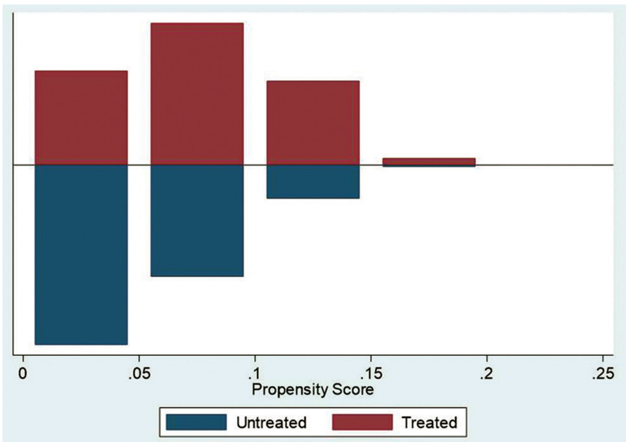
Table 4 Effect of access to a KVK on net farm income and annual per capita household income

Method	Net farm income (₹/ha)	Annual per capita household income (₹)	N
Full model			
PSM	3,457	419	30,938
IPWRA	3,674	404	30,938
ESR	5,752	758	30,938
Large farmers			
PSM	6,748	418	9,380
IPWRA	7,256	508	9,380
ESR	7,825	969	9,380
Small farmers			
PSM	594	346	21,558
IPWRA	1,633	326	21,558
ESR	4,435	624	21,558

Source: Authors calculation.

PSM, Propensity score matching; IPWRA, Inverse probability weighted regression adjustment; ESR, Endogenous switching regression. N = Number of observations.

Heterogeneous treatment effects: The previous results for the ATT of KVK access on outcome indicators depicted the important role the KVK network plays. The estimates reported in Table 6 assume a heterogeneous impact of KVK access on all farmers. However, the estimated ATTs of KVK access on welfare outcome indicators can vary among different sets of farm households. Capturing the differential impact of KVK access is therefore important for targeting individual farm households as well as designing the best-fit approach instead of a one-size-and-one-method-fits-all approach. Following Verhofstadt and Maertens (2014) and Wossen *et al*. (2017), we use the ATT of individual outcome indicators as a dependent variable in an OLS regression and examine how the estimated ATT varies with the socio-economic characteristics of farmers, with the results shown in Table 6. The estimated results showed that receiving information from a KVK has heterogeneous effects on farm households. There was a statistically significant differential impact of KVK access with respect to age, household size, gender, education, farm size, occupation, and access to formal credit. These results emphasize that households with large landholdings, with better access to credit, headed by a male, and where the heads are more educated, benefit most from KVK



Source: Authors calculation.

Fig. 1 Common support region for access to KVK.

Table 5 Propensity score matching quality test for net farm income and household income

Quality test	Matching	Full model		Large farmers		Small farmers	
		NFI (₹/ha)	Annual per capita household income (₹)	NFI (₹/ha)	Annual per capita household income (₹)	NFI (₹/ha)	Annual per capita household income (₹)
Pseudo R^2	Before	0.049	0.047	0.039	0.039	0.051	0.049
	After	0.000	0.000	0.000	0.000	0.000	0.000
LRχ^2 (*P*-value)	Before	639.720 (0.000)	570.280 (0.000)	187.260 (0.000)	170.750 (0.000)	424.420 (0.000)	375.88 (0.000)
	After	1.190 (0.999)	1.180 (0.999)	0.650 (1.000)	0.460 (1.000)	1.040 (1.000)	1.010 (1.000)
Mean standardized bias	Before	16.70	18.00	13.60	14.60	17.80	19.2
	After	1.00	1.10	1.10	1.00	1.20	1.30

Source: Authors calculation.
NFI, Net farm income.

Table 6 Heterogeneity treatment effects of KVK

Variable	Net farm income (ln)	Annual per capita household income (ln)
Age in years (ln)	0.092**	-0.096*
	(0.041)	(0.052)
Household size (ln)	0.491***	
	(0.029)	
Male-headed household^	0.640***	-0.505***
	(0.119)	(0.023)
Education in years (ln)	0.234***	0.369***
	(0.014)	(0.016)
Principal source of income (base: agriculture)		
Non-agriculture^	-0.850***	1.508***
	(0.027)	(0.032)
Pension^	-1.333***	0.596***
	(0.164)	(0.058)
Remittances^	-0.652***	-0.430***
	(0.192)	(0.039)
Landholdings in hectares (ln)	0.133***	0.486***
	(0.017)	(0.011)
Access to institutional credit^	0.241***	0.495***
	(0.022)	(0.022)
Social safety nets^	0.021	0.115
	(0.055)	(0.125)
Constant	6.491***	5.679***
	(0.214)	(0.286)
Observations	1,684	1,684
R^2	0.645	0.816

Source: Authors calculation.

Robust standard errors in parentheses. ln, Log values and ^ denotes binary variable. *** $P<0.01$; ** $P<0.05$; *$P<0.1$

services. Nevertheless, special attention needs to be given to marginal and small landholding households.

Additional robustness checks

OLS of matched cases: After the PSM, we ran an OLS regression for only those cases that are matched based on the PSM scores. The details of the estimated coefficients are given in Supplementary Table 6 and 7. The results from the regression of matched cases corroborate the findings based on the PSM and ESR models.

Estimated net benefit of KVKs: We calculated a benefit-to-cost ratio to gain an understanding of the returns to expenditures made on KVKs. The expenditure on the KVKs was taken from the ICAR budget book. We estimated the gross direct benefit of the KVKs by multiplying the estimated per unit incremental NFI accrued due to KVK access, and the gross cropped area operated by the direct beneficiaries of KVKs. Recall that 3.6% of farm households were observed to be reported as direct beneficiaries of the KVKs, and they together cultivate 4.9% of the gross cropped area. The total direct net benefits due to KVKs are estimated to range from ₹43 billion to ₹64 billion. The benefit-to-cost ratio ranges from 8–12 (Table 7). This was in agreement with Benin *et al*. (2011) who found that the estimated benefit-to-cost ratio for spending on agricultural extension ranged from 3–6 in Uganda. The additional surplus generated from KVK was learned to be ~ ₹6,414 crore (ESR method) and the major benefit goes to large farmers (74%).

Table 7 Net benefit and benefit-to-cost ratio

Method	Additional surplus (in crore)	Cost (in crore)	Net benefit (in crore)	Benefit-to-cost ratio
PSM	4,338	544	3795	7.98
IPWRA	5,032	544	4488	9.26
ESR	6,414	544	5871	11.80

Source: Authors calculation.

PSM, Propensity score matching; IPWRA, Inverse probability weighted regression adjustment; ESR, Endogenous switching regression.

Conclusion and policy implications

It has been about 50 years since the inception of farm science center (Krishi Vigyan Kendra, KVK) initiative. All agricultural stakeholders have witnessed the growth of the KVK network, but not much attention has been given to empirical evidence of its impact on famers' welfare. In this study, using a national representative sample, the impact and returns to investments in KVKs were estimated. The net farm income and household income were used as the households' economic welfare indicators. The key findings suggest a significant positive impact of KVK access on farmers' economic welfare; however, the benefits of KVKs were heterogeneous and non-neutral to scale. Such anomaly needs rectification, and efforts should be made to focus more on small and marginal landholding farmers. The ratio of return to expenditure on the KVK system was found very high. The success of KVKs in India could also be noted with the positive impacts in terms of return on expenditure. The treatment effect of access to a KVK also depended on specific household characteristics such as formal credit access, education level, household size, age, and land size. The consistent positive and significant impact of formal credit access on these outcome indicators implies that expanding rural financial markets can maximize the potential impact of KVK access on agricultural household welfare. The beneficial impact of KVK access was stronger for better educated agricultural households. These differential impacts suggest a significant policy implication: expansion of rural financial markets and literacy would reinforce the positive impacts of KVK services. Given that ICAR is spending a substantial share of its resources of the KVK model of extension, the need for continuous refinement of its outreach strategies cannot be overlooked.

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