

Does Access to Agricultural Credit Affect the Performance of Sugarcane Production in India

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Abstract

Sugarcane is a commercial crop that demands substantial external inputs to maximize yield and income. However, the capital availability for marginal and small farmers continues to be insufficient. Successive governments in India have introduced a number of credit policies to overcome capital constraints in agricultural production. However, literature indicates a larger level of inefficient production. This study aims to assess the impact of agricultural credit on the productivity and income of sugarcane producers in India. Based on national sample survey data pertaining to the year 2018-2019, an endogenous switching regression model was employed to determine the true effect of credit access. Our findings reveal that the productivity and income of farmers who grow sugarcane have significantly increased due to credit access. The study also found that if these farmers had access to credit, they could potentially experience an increase of 1,172 kg per acre in yield, and their farm income could increase by Rs. 10,221 per farm. Thus, it is suggested that efforts to extend credit supply to all farmers and strengthen financial literacy regarding access to institutional credit may help achieve additional yield per unit area and income per farm.

Categories: Banking and financial services, Social systems (economies, governments, industry), Sustainable Economic Development

Keywords: credit access, institutional source, productivity, income, esr, sample selection bias

JEL Classifications: D13, Q12, Q15

Introduction

India's agricultural landscape has undergone substantial transformations over the past few decades, driven by a combination of demographic pressures, environmental challenges, and market dynamics. One of the most significant shifts has been the transition from subsistence-oriented farming systems to more commercially focused agricultural production. This evolution has been necessitated by the growing need to manage challenges such as population growth, climate change, declining groundwater levels, changing consumer preferences and labor shortages. As these factors increasingly strain traditional farming methods, farmers have been compelled to adopt more modern, capital-intensive agricultural practices to sustain productivity and income levels. The shift to commercial agriculture has considerable implications for the livelihoods of millions of smallholders and marginal farmers in India, many of whom operate with limited financial resources. Commercial agriculture, while offering opportunities for increased productivity and income, requires substantial investments in inputs such as high-yielding seed varieties, fertilizers, irrigation systems and machinery. Farmers must also adapt to the growing demands for precision agriculture and sustainability, which often necessitate access to newer, more efficient technologies. For these farmers, access to capital is a significant constraint. Without adequate financial resources, they struggle to make the necessary investments, leading to suboptimal production outcomes.

Sugarcane and its products contribute about 1.1% to the national gross domestic product in India [1]. The sugarcane sector directly supports the livelihoods of around 50 million farmers and offers employment to around 0.5 million skilled and semi-skilled workers in sugar firms and its associated industries [2]. Beyond its economic importance, sugarcane is central to India's sugar industry, which also supplies key by-products like ethanol, bio-energy and molasses, all of which play a vital role in the country's energy security and rural development. However, sugarcane cultivation requires substantial financial investments. The high costs connected with inputs like seeds, pesticides, fertilizers, precision irrigation systems and machinery (such as sugarcane harvesters) can be prohibitive for many farmers, particularly those with limited access to capital. The high input costs mean that sugarcane farmers face a greater level of financial risk, especially in the event of crop failure or market fluctuations. Therefore, access to timely and reasonable credit is crucial for sugarcane farmers to meet their input needs, adopt new technologies and maintain productivity levels. Agricultural credit plays a pivotal role in enabling farmers to finance their production activities, invest in modern farming technologies and manage the risks associated with agricultural production.

In India, the importance of agricultural credit has been recognized since the Green Revolution era, when

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the government introduced various policies aimed at increasing credit availability to farmers. Over the years, these efforts have expanded, with the introduction of numerous schemes and programs designed to address the credit constraints faced by farmers, particularly smallholders and marginal farmers. One of the key government initiatives in this regard is the Kisan Credit Card (KCC) scheme, which was introduced in 1998-99 to provide farmers with easy access to credit for their production needs. The KCC scheme allows farmers to obtain short-term loans at subsidized interest rates, enabling them to purchase essential inputs such as seeds, fertilizers and irrigation equipment. Another significant initiative is the Interest Subvention Scheme, which was introduced in 2010-11. The Interest Subvention Scheme offers farmers an interest rate subsidy on loans taken for crop production, making credit more affordable and easing the financial burden on farmers. In addition, programs such as the Doubling Agricultural Credit initiative (2004), Agricultural Debt Waiver and Debt Relief Scheme (2008) and extension of the KCC to cover livestock and fish farmers (2018) have further expanded the reach and scope of institutional credit for agriculture.

These efforts have yielded positive results in terms of increasing the availability of institutional credit to farmers. Evidently, the share of formal institutional credit in agricultural lending increased from 7% in 1951 to 69% by 2018, with a substantial portion of this credit directed towards small and marginal farmers [3]. Furthermore, the subsidized interest rates offered by institutional lenders have made credit more accessible to resource-poor farmers, covering nearly 50% of marginal and small farmers [4]. These developments have allowed farmers to finance their operating expenses, invest in new technologies and improve their overall productivity and income levels. Despite the substantial progress made in expanding access to agricultural credit in India, there remain significant challenges for sugarcane farmers, particularly smallholder and marginal farmers, in accessing timely and adequate credit. Sugarcane is a highly capital-intensive crop that requires significant investments in inputs and technologies. However, many farmers lack the financial resources to make these investments, and they often face difficulties in obtaining credit from formal financial institutions due to factors such as insufficient collateral, high transaction costs and bureaucratic hurdles. As a result, these farmers may be forced to rely on informal sources of credit, which often come with high-interest rates and unfavorable terms, leading to a cycle of indebtedness.

The issue of indebtedness is particularly concerning in the context of sugarcane farming, where input costs are high, and the risk of crop failure is significant. According to the National Sample Survey Office 70th round report (2012-13), more than half of farm households (52%) in India are in debt. For sugarcane farmers, who face high input costs and long crop cycles, indebtedness can prevent them from investing in the necessary inputs and adopting modern technologies, leading to lower productivity and income. The inability to repay loans can also result in further indebtedness, pushing farmers deeper into poverty.

Furthermore, while access to credit has been shown to have a positive impact on agricultural productivity, the evidence is mixed when it comes to sugarcane farming specifically. Some studies have found that access to institutional credit can lead to significant improvements in crop productivity and income by enabling farmers to purchase inputs on time and adopt modern farming practices [5-8]. However, other studies have reported mixed or insignificant effects, with some suggesting that the impact of credit may vary depending on the crop and the socio-economic conditions of the farmers [9,10]. This variation in findings highlights the need for a more focused investigation into the relationship between credit access and sugarcane productivity in India. Hence, this study seeks to address the following research questions: How does access to institutional agricultural credit influence the productivity of sugarcane farmers in India? And what are the major determinants of accessing institutional credit? The findings of this study will contribute to the existing body of literature on agricultural credit and its impact on farm productivity, with a particular focus on sugarcane cultivation in India. By exploring the specific challenges and opportunities associated with credit access in the sugarcane sector, the study aims to provide insights into how institutional credit can be leveraged to improve sugarcane farm productivity and farm income. This research will also inform policymakers and financial institutions about the barriers to credit access faced by farmers at farm household level to promote sustainable and inclusive agricultural development in India.

Research Method

Theoretical framework

Theoretically, effective utilization of inputs and appropriate inter-cultural operations hold the potential to increase the crop productivity. However, increased cost of farm inputs, labour wage, machinery rentals and limited availability of capital among farmers, particularly small and marginal farmers in developing countries, often hinder the optimal use of input combination at the critical stages of crop growth. Consequently, this leads to crop failures and income loss. In order to avoid such situation, farmers commonly seek credit from both formal and informal financial sources. This financial assistance enables them to implement timely farm management practices during key crop growth phases as part of maximizing output. As a result, access to credit is expected to impact significantly crop productivity and overall income of farm households. In this context, a farmer assesses the expected utility of crop production with and without credit. Thus, the potential impact of access to credit on productivity of crops

and income of the farmers can be modelled using random utility model [11,12].

Assuming that U_{i1}^* is a latent variable representing the expected utility obtained by i th farm household through credit access, whereas U_{i0}^* represents the expected utility of the same household with no access to credit. Considering the cost of availing credit, a household decides to access credit if the net benefit exceeds the cost, i.e., $C_i^* = U_{i1}^* - U_{i0}^* > 0$. The net benefit C_i^* is a function of latent variables determined by observable and unobservable (stochastic error term) characteristics. Functionally, it is expressed as follows:

$$C_i^* = aZ_i' + e \quad \dots (1)$$

Then, the observed decision variable for access to credit is:

$$C_i = \begin{cases} 1, & \text{if } C_i^* > 0 \text{ (if access to credit)} \\ 0, & \text{otherwise} \end{cases} \quad \dots (2)$$

where Z_i' represents major factors determining the expected benefit or access to credit, a represents the unknown parameters to be assessed, and e denotes the independent and identically distributed normal random variable with $e \sim N(0, \sigma^2)$.

Now let Y_i^* represent the productivity of sugarcane crop at farm households, which is influenced by a set of exogenous variables as well as access to credit as an endogenous variable. Then, the impact of access to credit on crop productivity can be presented as follows:

$$Y_i^* = bX_i' + cC_i + u_i \quad \dots (3)$$

where X_i' represents exogenous factors determining the productivity of crop; C_i is an endogenous binary variable for credit accessing as demarcated above; b and c are a vector of parameters to be estimated; and u represents the error term. The effect of access to credit on the productivity and income is measured by the parameter c . However, estimating c in the aforementioned equation will result in biased results, as farmers who are with access to credit and those without access to credit are not randomly assigned to the corresponding sub-samples [13] - this causes sample selection bias [14-16].

To estimate the effect of credit access, it is important to establish a counterfactual condition to address the problem of causal inferences, i.e., data on output variables must be available for both the situations - accessing credit and not accessing credit. However, we can practically observe no information regarding output variables for credit holders in case they did not accessing credit. In other words, we do not observe data for outcome variables for credit holders who had not adopted (or the converse) as farmers with credit and without credit are mutually exclusive, and, hence, they cannot be observed simultaneously for the same farmers. In experimental research, such counterfactual problem is observed by randomly assigning access to credit to treatment and control status, which assures that outcome variables observed with respect to control households without access to credit are statistically representative of what would have occurred without access to credit. Nevertheless, the distribution of credit access is not random in real-world scenarios; farmers decide to access credit based on available information. Consequently, credit holders and non-credit holders may exhibit systematic differences [17]. Addressing this non-random distribution is imperative for an accurate impact assessment in the context of credit access among farmers. Fortunately, non-experimental data, such as farm household survey data, provides an avenue for creating a counterfactual scenario with the satisfaction of certain statistical properties [18,19]. This enables the experiment or evaluation of the impact of agricultural credit on crop productivity and farm income at the farm household level. A substantial body of literature leverages such quasi-experimental data to assess the effects of technological, institutional and policy interventions on output, income and welfare of farmers [20-25]. Specifically, the endogenous switching regression (ESR) and propensity score model (PSM) are two largely applied methods in impact assessment research [26]. However, the ESR model is assumed to be better to the PSM model as ESR technique minimizes the consequence of unobserved confounding variables in the functional equation by including a stochastic or random error term in the model, whereas PSM model employ only the noticeable confounding variables [27].

Estimation procedure - ESR model

The ESR model has found widespread application in estimating the impact of agricultural intervention schemes, with a specific focus on estimating the effect of access to agricultural credit on production, income and welfare of farmers across world [11,12,28-32]. Employing the ESR framework to estimate the impact of credit accessing on productivity and income of farm households involves two-stages. In the first stage, probit regression function given in Equation (2) was used for estimating farmers' decisions related to accessing agricultural credit. Subsequently, ordinary least squares (OLS) regression, along with

selectivity correction, is employed to study the association between productivity and income variables and a set of independent variables conditional on access to credit. The two outcome regression equations, conditional on credit accessing, can be stated as:

$$\text{Regime 1 (accessing credit): } y_{1i} = b_1 x_{1i} + w_{1i} \quad \text{if } C_i = 1 \quad \dots (4)$$

$$\text{Regime 2 (not accessing credit): } y_{2i} = b_2 x_{2i} + w_{2i} \quad \text{if } C_i = 0 \quad \dots (5)$$

where x_{1i} and x_{2i} are vectors of exogenous covariates; b_1 and b_2 are vectors of parameters to be estimated; and w_{1i} and w_{2i} are error terms. Error terms are assumed to have a trivariate normal distribution with mean zero and covariance matrix of the form:

$$\text{Cov}(\mu_i, \epsilon_{1i}, \epsilon_{2i}) = \begin{bmatrix} \sigma_\mu^2 & \sigma_{1\mu} & \sigma_{2\mu} \\ \sigma_{1\mu} & \sigma_1^2 & 0 \\ \sigma_{2\mu} & 0 & \sigma_2^2 \end{bmatrix} \quad \dots (6)$$

where σ_μ^2 is a variance of error term in the selection equation, and σ_1^2 and σ_2^2 are variances of error terms in the continuous equations. $\sigma_{1\mu}$ is a covariance of μ_i and ϵ_{1i} , and $\sigma_{2\mu}$ is a covariance of μ_i and ϵ_{2i} . The covariance between ϵ_{1i} and ϵ_{2i} is not defined, as y_{1i} and y_{2i} are never observed simultaneously. We can assume that $\sigma_{1\mu} = 1$ since γ is estimable only up to a scalar factor [33]. The model is identified via construction through nonlinearities. Assuming the distribution of disturbance terms, the logarithmic likelihood function for the system of Equations (4) and (5) is:

$$\begin{aligned} \ln L = \sum_i \left(C_i w_i \left[\ln(F(\eta_{1i})) + \ln\left(\frac{f(\epsilon_{1i})}{\sigma_1}\right) \right] \right) \\ + (1 - C_i) w_i \left[\ln(1 - F(\eta_{2i})) + \ln\left(\frac{f(\epsilon_{2i})}{\sigma_2}\right) \right] \quad \dots (7) \end{aligned}$$

where F is a cumulative normal distribution function; f is a normal density distribution function; w_i is an optional weight for observation i and

$$\eta_{ji} = \frac{\gamma Z_i + \frac{\rho_j \epsilon_{ji}}{\sigma_j}}{\sqrt{1 - \rho_j^2}} \quad j = 1, 2 \quad \dots (8)$$

The “movestay” command in Stata is used to estimate the full information maximum likelihood (FIML) simultaneous estimation of Equations (4)-(6), which yields consistent standard errors [33]. This method offers a distinct advantage over single estimation techniques by effectively addressing selectivity bias in productivity assessment.

The ESR model can be applied to compare the expected productivity and income levels of farmers accessing credit for the production of sugarcane crops with those of farm households with no access to credit. It also examines the expected productivity and income levels in counterfactual hypothetical cases, i.e., farmers accessing credit not accessing credit and farmers without accessing credit accessing credit. The conditional expectations with respect to productivity in the four cases are defined as follows:

$$E(y_{1i} | C_i = 1, X_{1i}) = X_{1i}\beta_1 + \sigma_1\rho_1 \frac{f(\gamma Z_i)}{F(\gamma Z_i)} \quad \dots (9)$$

$$E(y_{1i} | C_i = 0, X_{1i}) = X_{1i}\beta_1 - \sigma_1\rho_1 \frac{f(\gamma Z_i)}{1 - F(\gamma Z_i)} \quad \dots (10)$$

$$E(y_{2i} | C_i = 1, X_{2i}) = X_{2i}\beta_2 + \sigma_2\rho_2 \frac{f(\gamma Z_i)}{F(\gamma Z_i)} \quad \dots (11)$$

$$E(y_{2i} | C_i = 0, X_{2i}) = X_{2i}\beta_2 - \sigma_2\rho_2 \frac{f(\gamma Z_i)}{1 - F(\gamma Z_i)} \quad \dots (12)$$

where (9) is the predicted productivity level of farmers who actually access credit, (10) is the predicted productivity level of farmers accessing credit when they had not accessed credit, (11) is the predicted

productivity level of farmers without access when they had accessed credit and (12) is the predicted productivity level of farmers without access when they did not have access to credit. Equations (9)-(12) assess the expected average treatment effect on the treated (ATT) and the expected average treatment effect on the untreated (ATU) as follows:

$$ATT = X_{1i}(\beta_1 - \beta_2) + \sigma_1\rho_1(\lambda_1 - \lambda_2) \quad \dots (13)$$

$$ATU = X_{2i}(\beta_2 - \beta_2) + \sigma_2\rho_2(\lambda_1 - \lambda_2) \quad \dots (14)$$

where $\lambda_1 = \frac{f(\gamma Z_i)}{F(\gamma Z_i)}$ and $\lambda_2 = \frac{f(\gamma Z_i)}{1 - F(\gamma Z_i)}$. Estimates from Equations (13) and (14) are used to show the effect of access to informal credit on productivity.

Data

The study used farm household survey information collected by the National Sample Survey Office (NSS), a governmental body in India, specifically focusing on the 2018-19 period (77th round), to examine variations in farm household characteristics across the country. This survey encompassed 58,040 farm households and offered comprehensive insights into cropping patterns, crop and livestock production, input costs, yields, sales along with characteristics of farmer and farms, institutional variables such as credit, insurance, extension services and training attended. After excluding landless farm households and outliers, 790 farmers who cultivated only sugarcane were chosen for analysis. Out of which, 53% of the total farmers are observed as the credit holders.

Distribution of yield and income under credit holders and non-credit holders

Table 1 provides a comprehensive comparison of productivity and income of farm households accessing credit and non-credit holders of sugarcane farmers. It is evident that farmers accessing credit for sugarcane exhibit lower levels of productivity per acre and consequently earn less income per farm, as compared to their counterparts of non-credit holders.

	Outputs	Credit holders	Non-credit holders	Difference
1	Productivity in kilograms per acre	25,717.75	26,027.84	-310.096
2	Income in rupees	51,342.070	51,627.080	-285.019

TABLE 1: Productivity and income of sugarcane in India

Distribution of farmers by major household characteristics

Figure 1 provides a comprehensive overview of the distribution of farmers by different household characteristics across credit-accessing and non-credit-accessing farmers. The comparison reveals notable differences in household characteristics. Both groups have a similar gender distribution, with the majority being male, and a very low proportion of households reporting female involvement in decision-making. In terms of age, credit holders tend to be older, with a higher percentage of elders, while non-credit holders have a younger demographic profile. Education levels also differ, with credit holders generally being more educated, as seen by their higher representation in high school, collegiate, and postgraduate categories, whereas non-credit holders have a higher proportion of illiterate individuals and those with primary education. Regarding caste, non-credit holders are more likely to belong to disadvantaged groups such as scheduled tribes (ST) and scheduled castes (SC), while credit holders are more represented in the 'Others' caste category.

Access to financial products and extension services also varies between the two groups. Credit holders are more likely to have Prime Minister's insurance and are better served by extension services, including face-to-face interactions, media, and progressive farmers. Membership in farmer organizations is more common among credit holders. However, non-credit holders show a slightly higher participation in formal training programs. Both groups exhibit similar involvement in non-farm employment. Lastly, farm size is a distinguishing factor; non-credit holders are predominantly small farmers, while credit holders have a more balanced distribution, with a significant portion being medium farmers. Overall, credit holders appear to have more favorable socioeconomic conditions, with better access to education, services, and resources compared to non-credit holders.

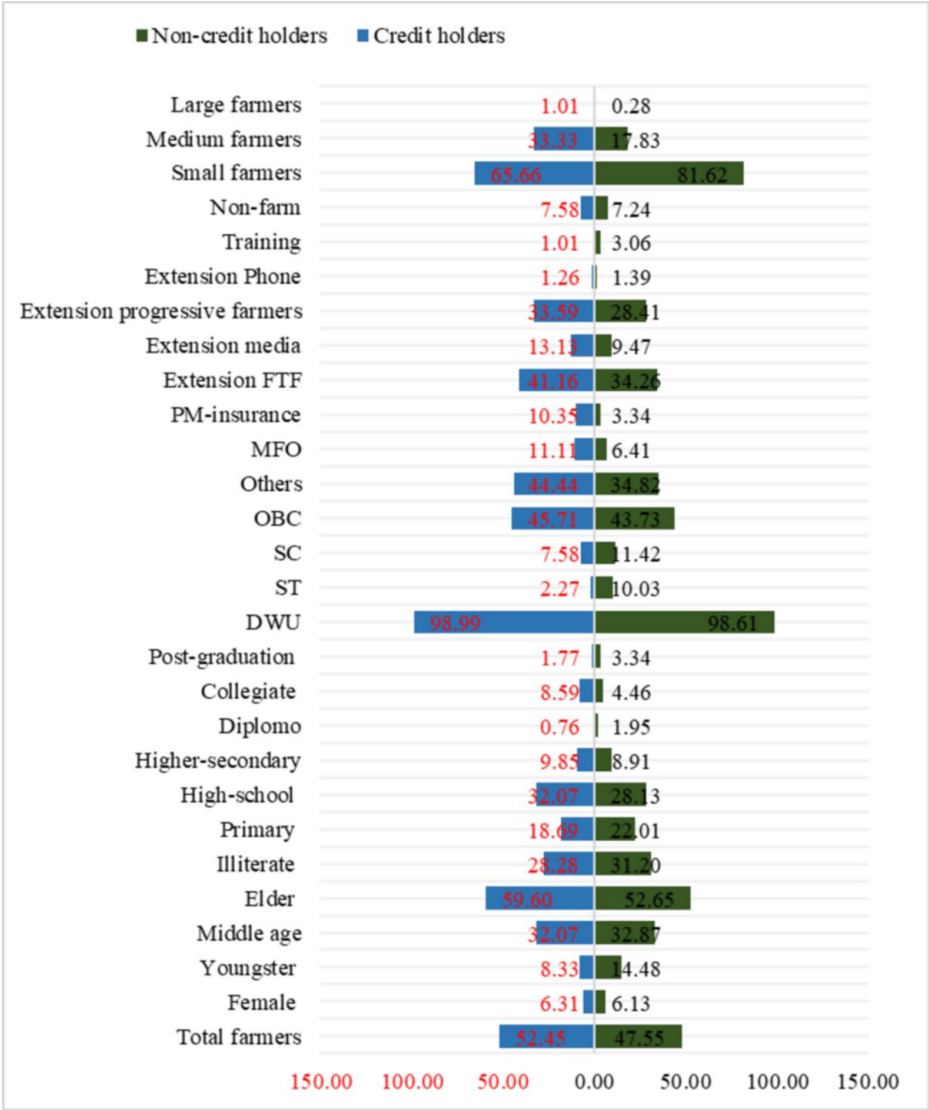


FIGURE 1: Distribution of farmers by household characteristics (in %)

Results

Crop-wise determinants of access to agricultural credit

The estimated results presented in Table 2, reveals that middle-aged farmers have a positive association with accessing credit in the production of sugarcane, indicating that they are more likely to secure credit for this crop, as compared to younger farmers. On the other hand, elderly farmers have a positive and significant association with accessing credit for sugarcane, suggesting a higher probability of obtaining credit for this crop. This further indicates that the age of farmers plays a significant role in accessing credit for sugarcane crop and that it varies across different age groups of farmers.

Accessing credit is also influenced by both the household size and existence of dwelling units. Larger household sizes have a negative impact on accessing credit for sugarcane, implying that financial institutions might perceive that larger households have greater financial responsibilities, that pose a higher credit risk. Social factors also play a crucial role in accessing credit. Farmers belonging to SC, Other Backward Classes and Open Caste have a significantly more probability of access to credit for sugarcane as compared to ST.

Understanding the impact of fair and remunerative price awareness and having crop insurance are crucial in exploring the influence of government policies on credit accessibility. Being aware of fair and remunerative price is observed to have influences positively credit access, indicating that increased awareness regarding the government’s price support policy program may help farmers to obtain agricultural credit. Moreover, having crop insurance is found to have increased the probability of obtaining credit, highlighting the importance of risk mitigating measures in facilitating credit access.

Determinants of productivity of sugarcane in India - results of estimated endogenous switching regression models

Variables	Sugarcane
Middle age	0.311* (0.167)
Elder	0.398** (0.16)
Primary	-0.023 (0.14)
High school	0.071 (0.128)
Higher secondary	-0.072 (0.184)
Diploma	-0.487 (0.44)
Collegiate	0.299 (0.216)
Postgraduate	-0.718** (0.322)
Male	0.025 (0.21)
Extension contacts by face-to-face	0.044 (0.105)
Extension contacts by traditional media	0.057 (0.165)
Extension contacts by progressive farmers	0.027 (0.109)
Extension contacts by phone	-0.542 (0.459)
Training	-0.944** (0.39)
Household size	-0.015* (0.019)
Presence of dwelling units	0.059 (0.445)
Schedule caste	0.717*** (0.28)
Other backward class	0.884*** (0.24)
Other caste	0.952*** (0.236)
Membership with farmers organisation	0.332* (0.187)
Awareness regarding fair and remunerative price	0.204* (0.107)
PM insurance scheme holding	0.585*** (0.22)
Non-farm income generating activities	0.021 (0.192)
Medium farmers	0.407*** (0.119)
Large farmers	0.912 (0.705)
Constant	-1.368** (0.55)

TABLE 2: Estimated logit model for access to agricultural credit (access/no access)

Figures in parentheses are standard errors; ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

Table 3 presents the results of the ESR regression model, which allows us to find the association between credit access and farm outcomes such as productivity and income. As given in the table, the likelihood ratio tests for joint independence of ESR specification concerning sugarcane for both yield and farm income equations are significant. This indicates that selection and outcome equations are dependent, meaning that the decision to participate in the credit market is related to the observed outcomes. In other words, there are factors influencing credit market participation that are not directly observable. Additionally, the correlation coefficients (ρ) between error terms in the selection and outcome for productivity and farm income are found insignificant for sugarcane. This suggests the presence of selectivity bias, meaning that there are unobservable factors influencing credit market participation. The usage of credit might have distinguished effects on both credit holders and non-credit holders. All these findings support the use of ESR model, which accounts for both observable and unobservable factors. It

allows us to better understand the relationship between credit access and agricultural outcomes by controlling for these unobservable factors. Finally, the statistically significant covariance (sigma) for sugarcane indicates that access to credit and outcome equations of agricultural productivity and farm income are truly endogenous. This means that credit access is not exogenous, but rather influenced by other factors that are also related to agricultural outcomes. Thus, the results from the ESR regression model provide valuable insights into the relationship between credit access and agricultural outcomes. The presence of heterogeneity effects, selectivity bias and endogeneity highlight the importance of considering both the observable and unobservable factors while analyzing the impact of credit access on productivity and farm income.

The assessed coefficients of ESR model suggest that irrespective of credit-assessing and non-credit-assessing farmers equations, all the input expenditures have a positive and significant effect on the productivity of sugarcane, with a few exceptions. This suggests that farm households, regardless of their access to credit, are adopting intensive farming practices by investing more in fertilizers, labor, machinery, irrigation and seeds, which ultimately lead to increased productivity. It is further observed that education level of farmers influences crop productivity. In most cases, higher educational levels have a negative effect on productivity, excepting specific instances such as high-school education for credit holders of sugarcane. Surprisingly, farmers with a collegiate degree are found with a mostly negative effect on crop productivity. This points to the existence of a complex relationship between education and agricultural outcomes, i.e., higher education does not always translate into higher productivity.

In addition to productivity, the study also explored the relationship between farm income and its determinants of sugarcane production (Table 4). The findings reveal a similar pattern like productivity estimation of crop, despite some variations in the estimations. Overall, the estimated ESR regression provides valuable insights into the factors influencing crop productivity and farm income. It also highlights the importance of factors such as access to credit, age, education, gender and extension services in determining productivity and farm income.

Variables	Productivity		Income	
	Credit holders	Non-credit holders	Credit holders	Non-credit holders
Price of farm output	-	-	10.954 (22.08)	-1,164.097 (866.466)
Fertilizer expenditure	0.998*** (0.215)	1.205*** (0.256)	3.906*** (0.494)	3.623*** (0.590)
Labor expenditure	0.611*** (0.133)	0.235* (0.123)	1.165*** (0.3)	0.997*** (0.281)
Machine expenditure	-0.043 (0.224)	0.817*** (0.252)	1.317** (0.6)	1.535*** (0.572)
Irrigation expenditure	1.767*** (0.413)	-0.133 (0.312)	4.656*** (1.113)	0.966 (0.681)
Seed expenditure	0.304* (0.156)	0.308* (0.168)	1.228*** (0.342)	0.976** (0.378)
Middle age	122.437 (2,381.674)	-1,158.494 (2,072.718)	-2,471.441 (5,411.947)	-590.389 (4,399.754)
Elder	3,698.45 (2,339.399)	-1,117.187 (2,194.804)	-1,464.825 (5,347.371)	1,034.35 (4,399.754)
Primary	2,487.413 (1,767.459)	-2,221.703 (1,742.887)	3,197.251 (3,903.461)	-1,517.292 (3,852.586)
High school	2,737.059* (1,555.452)	2,022.451 (1,721.198)	8,967.926** (3,481.524)	-1,669.507 (3,737.172)
Higher secondary	2,160.922 (2,202.38)	-1,447.055 (2,373.653)	4,679.372 (4,856.02)	-2,708.041 (5,284.646)
Diploma	1,814.124 (6,024.076)	315.420 (4,998.455)	20,198.13 (15,269.03)	-2,225.715 (10,950.32)
Collegiate	3,344.158 (2,516.839)	2,308.542 (3,430.954)	7,399.852 (5,714.233)	1,432.084 (7,142.727)
Postgraduate	1,061.078 (4,633.137)	-5,308.96 (3,567.792)	9,881.932 (10,070.34)	-10,657.85 (7,850.707)
Male	-1,533.464 (2,488.054)	978.962 (2,660.714)	-7,065.879 (5,557.217)	1,581.197 (5,949.851)
Extension contacts by face-to-face	-1,404.044 (1,308.329)	643.023 (1,366.858)	-4,241.498 (2,929.419)	275.473 (3,018.892)
Extension contacts by traditional media	-349.9709 (1,857.981)	1,370.242 (2,271.456)	-6,712.32 (4,111.219)	-2,044.013 (4,984.833)
Extension contacts by progressive farmers	-1,728.728 (1,313.759)	1,801.678 (1,479.592)	-7,672.744 *** (2,944.591)	3,756.297 (3,203.689)
Extension contacts by phone	1,693.892 (5,457.016)	-4,577.99 (5,472.772)	-14,835 (11,888.77)	-11,364.29 (12,278.6)
Training	15,231.82** (6,272.978)	-412.861 (4,096.054)	24,230.15 * (13,990.82)	-738.177 (8,370.053)
Constant	15,125.87 *** (4,437.679)	15,749.55*** (3,733.911)	32,786.67*** (10,438.49)	29,088.79*** (7,597.289)
Sigma	11,538.62*** (414.844)	11,475.3*** (534.77)	25,081.79 *** (1,317.521)	25,071.6*** (968.392)
Rho	-0.051 (0.293)	-0.13 (0.38)	-0.19 (0.361)	0.067 (0.225)

TABLE 3: Estimated ESRM for productivity and income of sugarcane

Figures in parentheses are standard errors; ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

ESRM, Endogenous Switching Regression Model

Impact of access to agricultural credit on productivity and farm income of sugarcane

Table 4 shows the average treatment effects of accessing agricultural credit on productivity and farm income of farms producing sugarcane. The study reveals that farmers who had access to credit for sugarcane farming achieved a substantial increase in yield and income. The estimated ATT shows that these farmers experienced an impressive increase of 1,411 kg per acre, representing a considerable gain of over 5% as compared to their counterparts with no access to credit. This finding suggests that credit availability plays a crucial role in enhancing the productivity of sugarcane. Moreover, the study also highlights the positive impact of credit access on farm income. The estimated ATT for farm income indicates that farmers who had availed credit realized a significant increase in farm income at Rs. 3,497 per farm, reflecting a significant rise of 7.31%. This finding suggests that credit access not only contributes to higher yields but also has the potential to improve the income of sugarcane farmers. On the other hand, the study also examined the potential benefits of credit access for farmers not availing credit. The estimated average treatment effect on the untreated (ATU) reveals that if these farmers were to access credit, they could potentially experience an increase of 1,172 kg per acre in terms of yield, representing a gain of 4% as compared to their counterparts. This finding suggests that credit access has the potential to further enhance productivity of sugarcane farmers, who are currently not utilizing credit facilities. Similarly, the study finds that if farmers, who did not avail of credit were to access it, their farm income could increase by Rs. 1,0221 per farm, indicating a sharp rise of 20%. Similar results were found by Uthamalingam et al. [7] and Chandio et al. [8], indicating that access to institutional credit helped increase the technical efficiency and yield of sugarcane production.

Crops	Outputs	Type of effect	Treated groups	Control groups	Effect due to credit access	% increase
Sugarcane	Productivity (kg/acre)	ATT	25,701.34	24,290.24	1,411.106*** (260.565)	5.81
		ATU	27,035.28	25,863.11	1,172.17*** (317.912)	4.53
	Income/farm	ATT	51,331.43	47,834.29	3,497.14 (3,794.945)	7.31
		ATU	61,694.7	51,473.68	10,221.01*** (653.784)	19.86

TABLE 4: Impact of access to agricultural credit on productivity and income of sugarcane

Figures in parentheses are standard errors; ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

ATT, Average Treatment Effect on the Treated; ATU, Average Treatment Effect on the Untreated

Discussion

Results from Table 2 highlighted similar findings obtained by many studies [10,34,35]. Conversely, Luan and Bauer [36] found that younger farmers were more likely to access credit for adopting new technology and managing on-farm physical activities [37]. Surprisingly, farmers with higher education - particularly those with postgraduate degrees - tend to have a negative association with credit access. It is imperative to observe that these impacts are not statistically significant in most cases. In this line, Ogubazghi and Muturi [38] and Agbodji and Johnson [39] found that education does not always have a favorable effect on credit access.

Extension services, such as face-to-face contacts and over-phone consultations, have a significant impact on credit access. Face-to-face extension contacts increase the probability of accessing credit for sugarcane, highlighting the importance of personalized interactions and information dissemination in facilitating credit access. Providing extension services likely imparts knowledge about credit sources and production skills [36]. According to Hoang et al. [40], extension services not only support the expansion of social networks but also foster increased participation in credit markets. However, training has a significant and negative effect on accessing credit for sugarcane, indicating the existence of specific challenges or requirements associated with obtaining credit for sugarcane cultivation.

Results from Table 2 indicate that farmers belonging to SC, other backward class and other caste have a significantly higher probability of accessing credit for sugarcane. Similar results were found by Kumar et al. [35] and Karthick and Madheswaran [41] in India, emphasizing the particular challenges ST may encounter in obtaining credit. This calls for targeted interventions to ensure equitable access to credit for all farmers. The size of the farm also plays a pivotal role in accessing credit, with medium and large farmers exhibiting a significantly higher probability of accessing credit for sugarcane compared to small farmers. This indicates that financial institutions may prefer providing credit to farmers with larger landholdings, possibly due to lower credit risks associated with larger-scale farming operations, as noted

by Ramasamy and Malaiarasan [42].

As discussed in the results section, there exists a complex relationship between education and agricultural outcomes, i.e., higher education does not always translate into higher productivity. In line with the results of this study, some literature has found that each additional year of schooling of the head of household is associated with the adoption of unfamiliar technologies and a decrease in farm output and farm income [30,43-45].

The study also examined the impact of extension services and training on crop productivity. It was found that the impact of extension contact services is mostly negative and insignificant. This suggests that the effectiveness of extension contact services may vary depending on the context, mode of communication, and specific needs of farmers for sugarcane crops. Khandker and Faruquee [46] observed that a 10% rise in credit access would significantly improve the livelihood of households by 0.04%. Results from Table 4 suggest that credit access has a positive impact on both yield and income for sugarcane farmers.

Conclusions

The study concludes that access to agricultural credit plays a pivotal role in enhancing both the productivity and income of sugarcane farmers in India. Farmers with access to credit achieved significant gains in yield (an increase of 1,411 kg per acre) and income (Rs. 3,497 per farm), showcasing the importance of credit in supporting capital-intensive crops like sugarcane. This underscores that timely and sufficient credit availability helps farmers invest in essential inputs, adopt modern technologies, and mitigate risks associated with crop failure and market fluctuations. Furthermore, the study highlights that even non-credit holders, if given access to credit, could witness substantial improvements in productivity and income, which reflects the untapped potential among farmers without credit access.

To improve the welfare of farmers, particularly small and marginal sugarcane farmers in India, policymakers should focus on expanding access to institutional credit, particularly through formal channels. Strengthening the outreach of schemes like the KCC and improving financial literacy can ensure that farmers, especially those from disadvantaged groups, can fully benefit from credit facilities. Furthermore, reducing bureaucratic barriers and providing targeted support to farmers with limited collateral can bridge the gap in credit access. Furthermore, promoting crop insurance schemes and extension services that emphasize financial management and sustainable agricultural practices could further boost productivity and resilience. Expanding these initiatives will not only enhance the income and productivity of individual farmer but also contribute to the broader goal of agricultural development and food security in India.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Paramasivam R, Umanath Malaiarasan, Karthick V, Hafsal K

Acquisition, analysis, or interpretation of data: Paramasivam R, Umanath Malaiarasan, K Jafar

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Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue.

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