Vol 7 No 2 June 2026 Pages 1-12 e-ISSN 2708-5694

Journal of Agriculture, Food and Environment (JAFE)

Journal Homepage: https://journal.safebd.org/index.php/jafe

https://doi.org/10.47440/jafe.2026.

*Research Article*

OPEN ACCESS

# Determinants and impacts of contract farming on bean production, income, and prices in Bangladesh: Evidence from propensity score matching

**Hasan MR[1] and Islam MA[2]**

[1]Professor, Department of Agribusiness and Marketing, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, Email address: rashidul_prince@yahoo.com

[2]Principal Scientific Officer, Agricultural Economics Division, Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh, Email address: arifagecon@gmail.com

**Article History**

**Received: 20 March 2026**

**Accepted: 14 May 2026**

**Published: 30 June 2026**

***Corresponding Author**

Hasan MR, E-mail: rashidul_prince@yahoo.com

**Keywords**

Bean, contract farming, production, propensity score matching, price, profitability

**How to cite:** Hasan MR and Islam MA 2026: Determinants and impacts of contract farming on bean production, income, and prices in Bangladesh: Evidence from propensity score matching. J. Agric. Food Environ. 7(2): 1-12.

**A B S T R A C T**

This study evaluates the impact of contract farming on bean production, farm income, and output prices in Bangladesh. Using primary data collected from 300 bean growers in Narsingdi district, the study employs Propensity Score Matching (PSM) to compute the average treatment effect on the treated (ATT), supplemented with Inverse Probability Weighting (IPW) and Inverse Probability Weighted Regression Adjustment (IPWRA) to ensure robustness. The determinants of farmers' participation in contract farming are first identified using a probit model. The results indicate that number of trainings, bean cultivation area, access to off farm income significantly increase the likelihood of participation, whereas bicycle ownership, organizational membership reduce participation probability. Impact estimates consistently show that contract farming significantly improves farm performance. Contract farmers achieve 3.4 - 5.2% higher bean yields, 33.2 - 36.1% higher gross margins, 47.4 - 49.4% higher net revenues, and receive 26.6 - 27.4% higher output prices than comparable non-contract farmers. Robustness checks using IPW and IPWRA confirm these findings. The results suggest that contract farming can enhance smallholder market integration and income in Bangladesh, although supportive institutional mechanisms and farmer awareness remain critical for sustained benefits.



## INTRODUCTION

Contract farming has become a key institutional mechanism connecting smallholder farmers to modern agribusinesses and retail supply chains. Under contractual agreements, farmers typically receive a predetermined price for their produce-often higher than prevailing rural market prices-and are assured that the contracting firm will purchase their harvest. Such arrangements reduce market uncertainty and mitigate price volatility, which are particularly acute challenges for smallholder vegetable producers in developing countries.

The rapid expansion of supermarkets across developing economies has further accelerated the adoption of contract farming. Supermarkets increasingly integrate rural farmers into structured value chains, supplying improved seeds, fertilizers, technical support, and modern production technologies (Ikeda and Natawidjaja, 2022). These vertical coordination mechanisms enhance farmers' competitiveness and often enable them to secure higher and more stable prices (Hoang, 2021). In contexts characterized by imperfect markets, weak infrastructure, and limited institutional support, contract farming can serve as a mechanism to overcome market failures and transaction costs (Barrett *et al.*, 2012).

A substantial body of empirical literature documents the income-enhancing effects of contract farming across diverse countries. Saigenji and Zeller (2009) reported that Vietnamese tea growers engaged in contract farming exhibited significantly greater technical efficiency compared to their non-contract-farming counterparts. Miyata *et al.* (2009) found that contract farming led to higher incomes for apple and green onion farmers in China relative to non-contract growers. Sokchea and Culas (2015) observed that organic rice farmers in Cambodia who participated in contract farming with farmer organizations earned significantly higher incomes than those who did not. Wainaina *et al.* (2014) showed that contracted poultry farmers in Kenya achieved higher net income per bird compared to non-contracted farmers. Beyond income and efficiency gains, contract farming has been associated with broader socioeconomic benefits, including youth development (Ntabakirabose *et al.*, 2021), increased social trust, and the adoption of environmentally friendly production practices (Mao *et al.*, 2021).

Cahyadi and Waibel (2015) discovered that contract participation significantly reduces the likelihood of price shocks for oil palm smallholders in Indonesia, as existing contract schemes provide effective price protection. According to Swain and Teufel (2025), contract farming in India positively influenced farm productivity, farmers' income, and market access, while negatively impacting soil health and water use.

Abdulai *et al.* (2024) reported that the factors positively associated with soybean farmers' participation in contract farming in Ghana include gender, education, off-farm business, FBO membership, farm size, access to extension services, and distance to market centres. Azumah *et al.* (2016) found that participation in contract farming in Ghana was positively affected by access to extension services and credit, but negatively affected by farm size and off-farm income. In the Nigerian context, Adah *et al.* (2024) identified the key factors influencing cassava farmers' participation in contract farming as education, sex, access to extension services, awareness of contract farming, and farming experience.

Nevertheless, the impacts of contract farming remain contested. Critics argue that contracts may shift production and market risks onto farmers and reinforce power imbalances between smallholders and large agribusiness firms (Hoang, 2021). Moreover, participation is not universally accessible; various institutional, socioeconomic, and geographic factors shape farmers' choices to participate in contract farming. For example, age and distance to markets negatively affected participation among export-oriented organic rice farmers in Pakistan (Mazhar *et al.*, 2022), while access to extension services, credit, and social networks significantly increased the likelihood of participation in Bangladesh (Islam *et al.*, 2019). These heterogeneous findings underscore the need for commodity- and location-specific analyses.

Studies on contract farming in Bangladesh have examined a range of crops and revealed diverse dimensions of the practice across different agricultural contexts. Early research by Sarkar and Rashid (2011) found that contract growers of brinjal (eggplant) seeds achieved slightly higher benefit-cost ratios compared to non-contract growers, suggesting initial economic benefits. Expanding on this, Adnan *et al.* (2018) identified a correlation between contract farming participation and farmers' reliance on precautionary savings as a risk mitigation strategy. Taslim *et al.* (2021) further highlighted several key factors influencing farmers' participation, including education level, spouse's occupation, family size, labor and fertilizer usage, access to training, savings, and overall income. Complementing these findings, Islam *et al.* (2019) reported that contract farmers in Bangladesh are more likely to benefit from improved access to agricultural extension services, attend more community meetings, have household members involved in various organizations, and enjoy greater access to credit. In the vegetable sector, Azad (2021) found that contract farming enables small-scale farmers to produce high-quality vegetables and recommended establishing a regulatory authority to ensure contract clarity and proper implementation. Finally, Haq *et al.* (2021) examined poultry contract farming and found that it plays a crucial and widely adopted role in the country's poultry industry, demonstrating the model's relevance beyond crop production.

Vegetable cultivation serves a crucial function in raising farm income, reducing poverty, and improving nutritional security in developing countries (Shrestha *et al.*, 2022). With over 50.0% of global fresh vegetable production, China is the leading producer (FAO, 2016). Asia accounts for the largest share of global vegetable production (FAO, 2016), with South Asia being a major contributor. India ranks as the second-largest agricultural landholder globally and accounts for 13.0% of the world's vegetable production (NHB, 2018). Bangladesh is the world's third-largest producer of vegetables (FAO, 2017). Vegetables offer higher returns per hectare compared to many staple crops, shorter production cycles, and greater market value (Kundu and Mandal, 2020; Nayak *et al.*, 2020). Additionally, vegetables are rich sources of vitamins, minerals, and dietary fiber, contributing significantly to food and nutritional security (Ramya and Priya, 2019; Kuntariningsih, 2018).

In Bangladesh, beans constitute an important winter vegetable crop widely cultivated by smallholder farmers. Existing studies have primarily focused on production economics, indicating that bean cultivation is profitable (Taslim *et al.*, 2021; Hasan *et al.*, 2014), while also identifying constraints such as pests, diseases, soil fertility management, and inadequate crop management practices (Khan *et al.*, 2020). Study has also underscored the advantages of integrated pest management (IPM) in lowering pesticide application and production expenses (Rahman *et al.*, 2018). However, prior studies have largely overlooked marketing challenges and institutional arrangements that could enhance farmers' post-harvest outcomes.

A major constraint faced by Bangladeshi vegetable farmers is price instability and the inability to secure remunerative prices during peak harvest periods. Although contract farming is gradually expanding in Bangladesh, empirical evidence on its effectiveness in addressing marketing inefficiencies in the bean sector remains scarce. To date, no research has systematically investigated how contract farming affects bean farmers' production performance and market outcomes.

This study contributes to filling this gap by assessing the effects of contract farming on bean production and marketing in Narsingdi district, Bangladesh. Specifically, the study (i) compares the socioeconomic characteristics of contract and

non-contract bean growers, (ii) identifies the determinants influencing farmers' engagement with contract farming, and (iii) evaluates the impact of contract farming on bean output, output price, and farm income. By providing commodity-specific and context-driven evidence, this research contributes to the growing literature on contract farming and offers policy insights for strengthening inclusive agricultural value chains in Bangladesh.

## METHODOLOGY

### Study areas and data sources

The present study was conducted in Shibpur and Belabo upazilas of Narsingdi district, Bangladesh. Narsingdi is recognized as one of the country's key vegetable-producing district, with an established network of contract-based country bean growers.

A multi-stage sampling method was used. First, two upazilas Shibpur and Belabo were purposively selected from Narsingdi district due to the prevalence of contract bean farming in these areas. Subsequently, six villages from each upazila (twelve villages in total) were selected for data collection.

A comprehensive list of farmers residing in the selected villages was obtained from the respective Upazila Agriculture Offices. Based on this information, a sampling frame comprising 1,200 bean growers was constructed, including 400 contract farmers and 800 non-contract farmers. The required sample size was calculated using the standard formula for sample size determination, following Kanyenji *et al*. (2020) and Rahman *et al*. (2021).

$$S_s = \frac{z^2 pq}{e^2} = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.06)^2} = 267 \cong 300 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

In the sample size determination formula, $S_s$ represents the required sample size while $z^2$ is the critical value at the 95% confidence level, $p$ represents the estimated proportion of the attribute of interest in the population; $q = 1 - p$; and $e$ indicates the acceptable margin of error.

Based on the sampling frame, twenty-five farmers choose from each village, comprising 10 contract farmers and 15 non-contract farmers. Using simple random sampling, a total of 120 contract farmers and 180 non-contract farmers were selected from the farmer lists. Consequently, 300 country bean producers were selected and interviewed through face-to-face interviews to fulfill the study objectives.

In Narsingdi district, farmers operate solely under verbal contracts, which lack formal provisions for inputs or credit. Under these agreements, only a future price for their beans is set at the outset, and this price remains unchanged regardless of the final selling price of the output. Furthermore, farmers are required to sell their entire harvest to the contracting company. The contracting company assists farmers with postharvest handling and packaging.

### Data collection

Primary data were collected from the selected bean growers using two separate pre-tested structured interview schedules-one designed for contract farmers and the other for non-contract farmers. The survey instruments were pre-tested with 16 bean growers from Shibpur and Belabo upazilas of Narsingdi district to assess clarity, relevance, and logical consistency. The responses obtained during the pre-test were excluded from the final analysis. Following feedback and observations from the pilot survey, the questionnaires were revised and finalized.

Data collection was carried out between February and April 2022. The final questionnaire consisted of two major sections. The first section captured socio-demographic and institutional characteristics of the respondents, including age, family size, educational attainment, farming experience, extension contact, access to market information, and credit availability. The second section collected detailed information on bean production costs, output levels, and output prices.

After data collection, the responses were meticulously checked, coded, and entered into Microsoft Excel to reduce entry errors. The cleaned dataset was subsequently analyzed using STATA version 15. Both descriptive statistics and econometric modeling techniques were employed to achieve the study objectives.

### Diagnostic Tests and Model Specifications

Prior to model estimation, diagnostic tests were conducted to assess potential violations of classical regression assumptions, particularly multicollinearity and heteroscedasticity.

Multicollinearity among the explanatory variables can lead to unstable coefficient estimates and inflated standard errors, thereby compromising statistical inference (Gujarati, 2003). To evaluate the presence of multicollinearity, the Variance Inflation Factor (VIF) was computed for each explanatory variable. The VIF values computed ranged from 1.05 to 2.66, which is far below the usual threshold of 10 (Maddala, 1983). These results indicate that multicollinearity problem is not a serious concern in the estimated model.

The Breusch–Pagan (BP) test was employed to check for heteroscedasticity. The null hypothesis of homoscedasticity was rejected ($\chi^2 = 10.18$; $p = 0.0014$), indicating the presence of heteroscedasticity in the error terms. To address this issue and obtain consistent statistical inference, bootstrapped standard errors were employed in the final estimation.

### Analytical technique for assessing farm level impact of contract farming

A random utility model was employed to model the choice of adopting a new approach (Becerril and Abdulai, 2010; Crost *et al*., 2007). Let $C^*$ denoted the distinction between the benefit received under a contract ($U_{iA}$) and the utility not derived from a contract ($U_{iN}$), such that farmer was chosen the contract if $P^* = U_{iA} - U_{iN} > 0$. In the latent variable model, the two unobservable utilities can be expressed as functions of observable components, as described below:

$$C_i^* = Z_i\alpha + \varepsilon_i \text{ with } C_i = \begin{cases} 1 \; if \; C_i^* > 0 \\ 0 \; Otherwise \end{cases} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Here, C is a binary dummy variable (1 or 0) indicating the use of contract farming; C = 1 if the farmers was in a contract and C =0 if the farmers was not in a contract. α represents an estimated parameter vector, Z was a vector that represented attributes at household and farm levels, and the random error term was ε.

Contract farming has the potential to boost bean production, income, and market prices. The following equations are derived by assuming that bean production, gross revenue, net

revenue, and market price are linear functions of a contract farming dummy variable and a vector of other explanatory variables (X):

$$Y_f = \gamma X_f + \delta C_f + \mu_f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, $Y_f$ represented the outcome variables, $C_f$ used as an indicator variable for the previously described contract farming, the vectors of parameters to be calculated were γ and δ, and μ was an error term. The effect of contract farming on the outcome variable was evaluated by estimating the parameter δ. Nevertheless, for δ to yield an unbiased estimate of contract farming's effect on the outcome variable, farmers must be randomly allocated to either the contract or non-contract group (Rosenbaum and Rubin, 1983).

The study examined the average treatment effect on the treated (ATT), defined as follows:

$$ATT = E\,(Y_i\,(1) - Y_i\,(0)\,|D_i = 1, X_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Here, Di is a dummy variable indicating whether farmer i was under contract, $Y_i$ was the outcome variable of the farmer i, or the bean production, gross revenue, net revenue, market price, as a function of $D_i$ and $X_i$ denoted farmers characteristics. ATT was the average difference between the contract farmer's production and revenue and their counterfactual production and revenue if they had not in a contract.

Strong ignorability, such as unconfoundedness and overlap, was required in order to determine the ATT:

$$Y\,(1), Y\,(0)\ \text{Ц}\ D|X, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\text{and } 0 < Pr\,(D=1|X) \equiv C\,(X) < 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Equation (4) formalizes the unconfoundedness assumption, under which potential outcomes are independent of treatment assignment once observable characteristics X are controlled for. The overlap assumption, specified in Equation (5), guarantees a positive likelihood of being classified as either a contract or non-contract farmer.

This study utilized the Propensity Score Matching (PSM) technique to estimate the ATT. Under the assumption of strong ignorability, potential outcomes are independent of treatment assignment once conditioned on the propensity score C(X)—that is, the probability that a farmer participates in contract farming. Then the ATT in equation (3) is then expressed as:

$$ATT = E\,(Y_i\,(1) \mid D_i = 1, C(X_i)) - E\,(Y_i\,(0)\,|D_i = 1, C(X_i)) \quad .(7)$$

The average of the observed outcomes for contract farmers can be used to estimate the first term on the right-hand side of equation (6). The second term provides an estimate of the outcome that contract farmers would have experienced in the absence of treatment, was the typical result of non-contract parties that were paired with contracts based on propensity scores.

### Propensity-score Matching Procedures

The Propensity Score Matching (PSM) approach was employed to estimate the impact of contract farming on bean production, gross revenue, net revenue, and output price. The estimation of propensity scores relied on a Probit model, in which the treatment variable was defined as involvement in contract farming.

Matching was implemented under the Conditional Independence Assumption (CIA), which requires that, conditional on observable covariates X, treatment assignment is independent of potential outcomes. To ensure the validity of this assumption, covariate balance between contract and non-contract farmers was assessed after matching. Balance diagnostics included tests of mean differences and changes in the pseudo-$R^2$. A reduction in pseudo-$R^2$ and statistically insignificant differences in covariates after matching indicate that the balancing property is satisfied.

The common support condition was imposed to ensure comparability between treatment and control groups. This was examined by comparing the minimum and maximum propensity scores across groups. Observations with propensity scores lying outside the overlapping region were excluded from the analysis, following the approach of Smith and Todd (2005). However, limited overlap in propensity score distributions may result in the loss of observations. Therefore, trimming was applied to define the region of common support where the propensity score exhibits positive density for both treated (T=1) and control (T=0) groups (Imbens, 2004).

Although Abadie and Imbens (2006) highlight certain limitations of bootstrapping in matching estimators, bootstrapped standard errors remain widely applied in empirical practice. In particular, combining bootstrapping with kernel-based matching has been shown to produce reliable inference (Robalino and Pfaff, 2013; Wooldridge, 2007). Therefore, this study used bootstrapped standard errors to compute the average treatment effect on the treated (ATT).

To evaluate the robustness of the PSM estimates, two additional estimators, Inverse Probability Weighting (IPW) and Inverse Probability Weighted Regression Adjustment (IPWRA), were applied.

The IPW estimator assigns weights based on the inverse of the estimated propensity scores to construct a weighted sample in which treatment assignment is independent of observed covariates (Abadie and Imbens, 2006; Robalino and Pfaff, 2013). In this framework, individuals with a lower predicted probability of treatment receive larger weights, thereby improving comparability across groups.

The IPWRA estimator integrates inverse probability weighting with regression adjustment and is considered "doubly robust," as it yields consistent estimates if the estimator remains valid if either the treatment model or the outcome model is correctly specified (Wooldridge, 2010). A two-stage procedure was used to estimate the ATT under IPWRA (Imbens and Wooldridge, 2009). In the first stage, a Probit model was employed to calculate the propensity scores. In the second stage, a linear outcome model was estimated using the inverse probability weights generated in the first stage.

### Outcome variables

The following outcome indicators were used to assess the farm-level effects of contract farming:

Production (kg/ha): Total quantity of country bean produced per hectare during the production season.

Gross margin (Tk): Total revenue (Tk) earned from the sale of country bean minus the total variable cost (Tk) incurred in production.

Net revenue (Tk): Total revenue (Tk) from bean sales minus total production costs, including both total variable costs (Tk) and total fixed costs (Tk).

Market price (Tk/kg): The prevailing market price per kilogram of country bean in a specific market at a given point in time.

The factors influencing participation in contract farming were estimated using a probit model. The dependent variable, adoption of contract farming, was defined as a binary indicator, equal to 1 if the farmer participated in contract farming and 0 otherwise.

**Table 1:** Overview of the variables included in the model

| Variable | Notation | Description |
|---|---|---|
| **Farmer's farming experience** | $X_1$ | Vegetable cultivation experience of the respondent farmer in year. |
| **Number of trainings** | $X_2$ | Total number of trainings of the respondent farmers |
| **Number of active family member** | $X_3$ | Total numbers of active family members in the family |
| **Time required to go to pesticide shop** | $X_4$ | Minutes needed to travel to the pesticide store from farmers house |
| **Number of extensions contact** | $X_5$ | Total number of contact of farmers with the extension worker in a year |
| **Market information (yes/no)** | $X_6$ | One if the farmer answering got market information from different source; if not, zero |
| **Bicycle (yes/no)** | $X_7$ | If the farmer answering had a bicycle, then 1; if not, 0. |
| **Membership of any organization (yes/no)** | $X_8$ | If the responding farmer belongs to any organization, give them 1; if not, 0. |
| **Access to modern seed (yes/no)** | $X_9$ | If respondent farmer has access to modern seed = 1, 0 for otherwise. |
| **Credit source bank (yes/no)** | $X_{10}$ | 1 if the responding farmer received credit from any bank, 0 for otherwise. |
| **Credit source company (yes/no)** | $X_{11}$ | 1 if the responding farmer received credit from any contracting company, 0 for otherwise. |
| **Rented in land** | $X_{12}$ | The responding farmer's entire land rental, expressed in decimals. |
| **Own land** | $X_{13}$ | The respondent farmers own land expressed in decimals. |
| **Bean cultivation area** | $X_{14}$ | The respondent farmers bean cultivation area expressed in decimals. |
| **Distance to nearest market** | $X_{15}$ | Distance to travel to the nearest market from farmers house, expressed in km |
| **Access to off farm income** | $X_{16}$ | 1 if responding farmers had access to off farm income, 0 for otherwise |
| **Number of cyclone shock** | $X_{17}$ | Total numbers of cyclone shocks last year. |
| **Number of unusual rain shock** | $X_{18}$ | Total numbers of unusual of rain shock last year. |

## RESULTS

### Descriptive statistic between contract and non-contract farmers

Table 2 compare the socioeconomic, institutional, and production characteristics between contract and non-contract farmers. The comparative analysis reveals that contract and non-contract farmers were largely homogeneous across most demographic and asset-related indicators, yet exhibit statistically significant divergences in several institutional and production-specific variables. Regarding human capital and physical assets, the two groups did not differ significantly in farming experience, number of active family members, or land ownership (both owned and rented-in), suggesting that contract participation is not systematically biased by household demographic structure or farm size. Similarly, infrastructural access, proxied by time to pesticide shops and distance to the nearest market, and exposure to climate shocks (cyclone and unusual rain events) were not differ across groups, indicating that geographic location and risk exposure were not primary determinants of contract enrollment. Notably, while access to market information, off-farm income, and organizational membership were nearly equivalent, bicycle ownership was significantly lower among contract farmers (mean difference = -2.92, $p < 0.01$).

Conversely, the most pronounced and statistically meaningful differences emerged in domains directly linked to institutional support and production intensity. Contract farmers reported substantially more training opportunities (mean = 3.28 vs. 1.69, $p < 0.001$) and significantly greater access to modern seed varieties (mean difference = 2.17, $p < 0.05$), underscoring the role of contracting firms in delivering technical assistance and improved inputs to their affiliated growers. Furthermore, contract farmers allocated significantly larger areas to bean cultivation (40.15 vs. 27.94, $p < 0.001$), reflecting a strategic commitment to the contracted crop, likely driven by guaranteed market access and price stability. In contrast, no significant differences were observed in extension contact frequency or credit access from banks or companies, suggesting that while contract farming facilitates certain forms of capital and knowledge transfer, it does not necessarily improve formal financial inclusion. Overall, the findings indicate that contract farming primarily enhances access to agronomic resources and training, rather than altering the fundamental socioeconomic or risk profile of participating households.

**Table 2:** Descriptive statistic of contract and non-contract farmers

| Items | Contract farmer | | Non-contract farmer | | Mean difference |
|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | |
| **Farmer's farming experience** | 20.47 | 11.71 | 21.73 | 12.42 | -0.88$^{ns}$ |
| **Number of trainings** | 3.28 | 3.93 | 1.69 | 1.88 | 4.67*** |
| **Number of active family member** | 3.70 | 1.44 | 3.72 | 1.42 | -0.08$^{ns}$ |
| **Time required to go to pesticide shop** | 12.21 | 6.78 | 12.58 | 5.52 | -0.51$^{ns}$ |
| **Number of extensions contact** | 4.95 | 3.27 | 4.6 | 3.20 | 0.94$^{ns}$ |

| | | | | | |
|---|---|---|---|---|---|
| **Market information (yes/no)** | 0.97 | 0.15 | 0.97 | 0.14 | -0.16$^{ns}$ |
| **Bicycle (yes/no)** | 0.44 | 0.49 | 0.61 | 0.48 | -2.92*** |
| **Membership of any organization (yes/no)** | 0.30 | 0.46 | 0.38 | 0.48 | -1.48$^{ns}$ |
| **Access to modern seed (yes/no)** | 0.716 | 0.45 | 0.594 | 0.49 | 2.17** |
| **Credit source bank (yes/no)** | 0.13 | 0.34 | 0.11 | 0.31 | 0.58$^{ns}$ |
| **Credit source company (yes/no)** | 0.016 | 0.12 | - | - | 0.95$^{ns}$ |
| **Rented in land** | 3.08 | 15.16 | 2.79 | 12.76 | 0.18$^{ns}$ |
| **Own land** | 102.23 | 71.84 | 93.87 | 78.54 | 0.93$^{ns}$ |
| **Bean cultivation area** | 40.15 | 34.57 | 27.94 | 15.13 | 4.18*** |
| **Distance to nearest market** | 1.58 | 0.71 | 1.58 | 0.75 | -0.03$^{ns}$ |
| **Access to off farm income** | 0.88 | 0.32 | 0.83 | 0.37 | 1.20$^{ns}$ |
| **Number of cyclone shock** | 1.02 | 0.95 | 0.84 | 0.92 | 1.64$^{ns}$ |
| **Number of unusual rain shock** | 2.84 | 1.31 | 2.73 | 1.15 | 0.75$^{ns}$ |

Source: Farmer's household survey, 2022

Notes: The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. NS means not significant.

## Determinants of adoption of contract farming

The Probit model was employed to estimate the likelihood of farmers participating in contract farming in the study areas (Table 3). The econometric analysis identifies a distinct set of determinants that significantly influence a farmer's decision to participate in contract farming, while also revealing that many traditional socioeconomic characteristics were poor predictors of adoption. Among the statistically significant predictors, the number of trainings received emerges as the strongest institutional driver (dy/dx = 0.036, $p < 0.001$), indicating that each additional training session increases the probability of contract farming adoption by approximately 3.6 percentage points. Similarly, bean cultivation area exhibits a positive and highly significant marginal effect (dy/dx = 0.004, $p < 0.001$), suggesting that farmers with larger allocations to the bean cultivation were more inclined to formalize production through contracts, a finding consistent with economies of scale in marketing and quality control. Most notably, access to off-farm income exerts the largest marginal impact (dy/dx = 0.278, $p < 0.001$), implying that farmers with supplementary income sources were nearly 28 percentage points more likely to adopt contract farming.

Conversely, several variables exert significant negative effects on contract adoption, revealing barriers or disincentives to participation. Ownership of a bicycle (dy/dx = -0.149, $p < 0.01$) and membership in any organization (dy/dx = -0.172, $p < 0.01$) were both negatively associated with contract farming adoption. The existing mobility options may have less need for the market linkages that contract farming provides or that such assets enable them to pursue alternative, more flexible marketing channels. Organizational membership shows a significant negative effect on contract farming adoption because farmers likely prioritize different organization over individual commercial contracts. While both contract companies and external organizations offer similar services (such as input access and credit). As a result, farmers who are actively engaged with multiple organizations tend to avoid the additional constraints of contract farming. Consequently, organizational membership significantly reduces the likelihood of contract farming participation.

Variables conventionally expected to drive adoption, such as farming experience, access to modern seeds, credit sources, land ownership, and exposure to climate shocks, all yield statistically insignificant coefficients, indicating that contract farming participation in this context was shaped more by institutional engagement (training), production scale, and income diversification than by demographic profiles or resource endowments. The model demonstrates acceptable overall fit (Pseudo $R^2 = 0.15$, Wald $\chi^2 = 54.82$, $p < 0.001$), confirming that while the explanatory variables collectively hold predictive power, substantial unobserved heterogeneity remains in farmers' adoption decisions.

**Table 3:** Estimation of the factors driving contract farming adoption using a Probit model

| Items | Coefficients | Marginal effect (dy/dx) |
|---|---|---|
| **Outcome variable (Adoption of contract farming)** | - | - |
| **Independent variables** | | |
| **Farmer's farming experience** | -0.0103$^{ns}$ | -0.003$^{ns}$ |
| **Number of trainings** | 0.112*** | 0.036*** |
| **Number of active family member** | 0.037$^{ns}$ | 0.0120$^{ns}$ |
| **Time required to go to pesticide shop** | -0.004$^{ns}$ | -0.0014$^{ns}$ |
| **Number of extensions contact** | 0.016$^{ns}$ | 0.005$^{ns}$ |
| **Market information (yes/no)** | -0.106$^{ns}$ | -0.034$^{ns}$ |
| **Bicycle (yes/no)** | -0.461** | -0.149** |
| **Membership of any organization (yes/no)** | -0.531** | -0.172** |
| **Access to modern seed (yes/no)** | 0.224$^{ns}$ | 0.072$^{ns}$ |
| **Credit source bank (yes/no)** | -0.156$^{ns}$ | -0.050$^{ns}$ |
| **Credit source company (yes/no)** | 0.284$^{ns}$ | 0.092$^{ns}$ |
| **Rented in land** | -0.0009$^{ns}$ | -0.0003$^{ns}$ |
| **Own land** | 0.001$^{ns}$ | 0.0003$^{ns}$ |
| **Bean cultivation area** | 0.012*** | 0.004*** |
| **Distance to nearest market** | 0.105$^{ns}$ | 0.034$^{ns}$ |
| **Access to off farm income** | 0.859*** | 0.278*** |
| **Number of cyclone shock** | 0.137$^{ns}$ | 0.044$^{ns}$ |
| **Number of unusual rain shock** | 0.046$^{ns}$ | 0.015$^{ns}$ |
| **Constant** | -1.74** | - |
| **Model summary** | | |
| **Log- pseudolikelihood** | -171.51 | |

| | |
|---|---|
| **Wald chi$^2$** | 54.82 |
| **Probability of chi$^2$** | 0.00 |
| **Pseudo R$^2$** | 0.15 |
| **Sample size** | 300 |

Source: Farmer's household survey, 2022
Notes: The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. NS means not significant

## PSM (ATT) results of contract farming in Narsingdi district of Bangladesh

The study assessed the impact of contract farming on net revenue, gross margin, market price of beans, and bean production, with particular emphasis on the direct causal effects of participation in contract farming. Propensity scores were estimated using the Probit model, and the Propensity Score Matching (PSM) approach was applied with multiple matching techniques (Table 4). An alternative matching method was also employed to evaluate the consistency and robustness of the results.

Contract farming was found to have a positive and statistically significant causal effect on bean production, with estimates ranging from 0.034 to 0.052. This reflects the output difference between matched pairs of contract and non-contract households. On average, contract farmers produced 3.4% to 5.2% more beans than their non-contract counterparts. Similarly, contract farming exhibited a positive and statistically significant impact on gross margin across different matching algorithms. Compared with comparable non-contract farmers, contract farmers achieved gross margins that were, on average, 33.2% to 36.1% higher.

The results further indicated a positive and significant influence on net revenue, with estimated impacts ranging from 0.474 to 0.494. On average, contract farmers earned 47.4% to 49.4% higher net revenue than non-contract farmers, indicating that contract farming substantially increased farmers' income in the study area. Additionally, the results indicate a positive and statistically significant impact on bean market prices, with an estimated impact ranging from 0.266 to 0.274. On average, contract farmers received bean prices that were 26.6% to 27.4% higher than those obtained by non-contract farmers, suggesting that contract farming significantly improves price outcomes for bean producers.

**Table 4:** PSM (ATT) results of contract farming in Narsingdi district of Bangladesh

| Items | Nearest Neighbor (with repl.) | Radius matching (cal. = 0.05) | Radius matching (cal. = 0.1) | Radius matching (cal. = 0.5) | Kernel matching (BW = 0.03) | Kernel matching (BW = 0.06) | Kernel matching (BW = 0.25) | Stratification matching |
|---|---|---|---|---|---|---|---|---|
| **Production** | 0.052*** | 0.039*** | 0.038*** | 0.034*** | 0.049*** | 0.047*** | 0.036*** | 0.051*** |
| | (0.017) | (0.011) | (0.010) | (0.009) | (0.013) | (0.012) | (0.009) | (0.012) |
| | t = 3.152 | t = 3.671 | t = 3.865 | t = 3.613 | t = 3.944 | t = 4.056 | t = 4.021 | t = 4.257 |
| **Gross Margin (Tk.)** | 0.356*** | 0.339*** | 0.338*** | 0.332*** | 0.356*** | 0.354*** | 0.337*** | 0.361*** |
| | (0.023) | (0.018) | (0.017) | (0.016) | (0.019) | (0.018) | (0.016) | (0.018) |
| | t = 15.749 | t = 18.61 | t = 19.55 | t = 20.37 | t = 18.60 | t = 19.68 | t = 20.55 | t = 20.23 |
| **Net revenue (Tk.)** | 0.477*** | 0.483*** | 0.479*** | 0.474*** | 0.483*** | 0.482*** | 0.474*** | 0.494*** |
| | (0.035) | (0.027) | (0.026) | (0.024) | (0.025) | (0.025) | (0.023) | (0.025) |
| | t = 13.67 | t = 17.86 | t = 18.34 | t = 19.48 | t = 18.93 | t = 19.12 | t = 20.47 | t = 19.44 |
| **Market price (Tk.)** | 0.271*** | 0.266*** | 0.267*** | 0.267*** | 0.272*** | 0.272*** | 0.268*** | 0.274*** |
| | (0.018) | (0.014) | (0.013) | (0.013) | (0.016) | (0.015) | (0.014) | (0.014) |
| | t = 14.85 | t = 18.94 | t = 19.93 | t = 19.77 | t = 16.55 | t = 18.51 | t = 19.78 | t = 19.88 |
| **Balancing property satisfied** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Common support imposed** | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Treated** | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| **Controls** | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 |
| **Sample size (N)** | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |

Source: Farmer's household survey, 2022
Note: 1. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.
1. Parentheses indicate bootstrapped of standard errors with 1000 iterations.

### Robustness check of the results

To verify the robustness of the findings, inverse probability weighting (IPW) and inverse probability weighted regression adjustment (IPWRA) were employed. The results from both methods were highly consistent, indicating that IPW and IPWRA produced nearly identical estimates (Table 5).

**Table 5:** Estimated results (ATT) of contract farming in the study area

| Items | Inverse probability weight method | Inverse probability weight regression adjustment method |
|---|---|---|
| **Log of production** | 0.045*** (0.011)<br>z = 3.89 | 0.0471*** (0.011)<br>z = 4.28 |
| **Log of gross margin** | 0.352*** (0.018)<br>z = 18.77 | 0.349*** (0.017)<br>z = 19.70 |
| **Log of net revenue** | 0.475*** (0.024)<br>z = 19.13 | 0.462*** (0.026)<br>z = 17.43 |
| **Log of output market price** | 0.273*** (0.013)<br>z = 19.53 | 0.269*** (0.014)<br>z = 18.41 |

Source: Farmer's household survey, 2022
Note: 1. The symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.
2. Parentheses indicate cluster standard errors.

### Quality of Matching

To verify the reliability of the estimated findings and the effectiveness of the matching procedure, the study conducted a series of diagnostic checks. The balancing assessment, performed using the "pstest, both" routine (Leuven and Sianesi, 2003) alongside the "pscore, detail" command (Becker and Ichino, 2002), reveals that, following matching, contract farming participants and non-participants exhibit statistically comparable characteristics—unlike what is observed in the unmatched sample. More precisely, the mean-equality test between the two groups shows no statistically meaningful difference after matching. These results confirm that the balancing condition is adequately met and that common support is upheld in the study's models (Table 6). Nonetheless, Figure 1 highlights variations in matching quality across covariates prior to and following the matching process.

**Table 6:** Matching quality

| Sample | Ps $R^2$ | LR $chi^2$ | $p>chi^2$ | Mean Bias | Med Bias | B | R | % concern | % bad | Balancing property satisfied | Common support imposed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Unmatched | 0.0146 | 59.01 | 0.000 | 15.7 | 10.8 | 90.4* | 1.62 | 19 | 19 | - | - |
| Matched | 0.0087 | 03.25 | 0.580 | 4.80 | 3.60 | 41.5* | 0.50 | 28 | 0 | Yes | Yes [.07651084, .99993378] |

* if B>25%, R outside [0.5; 2]

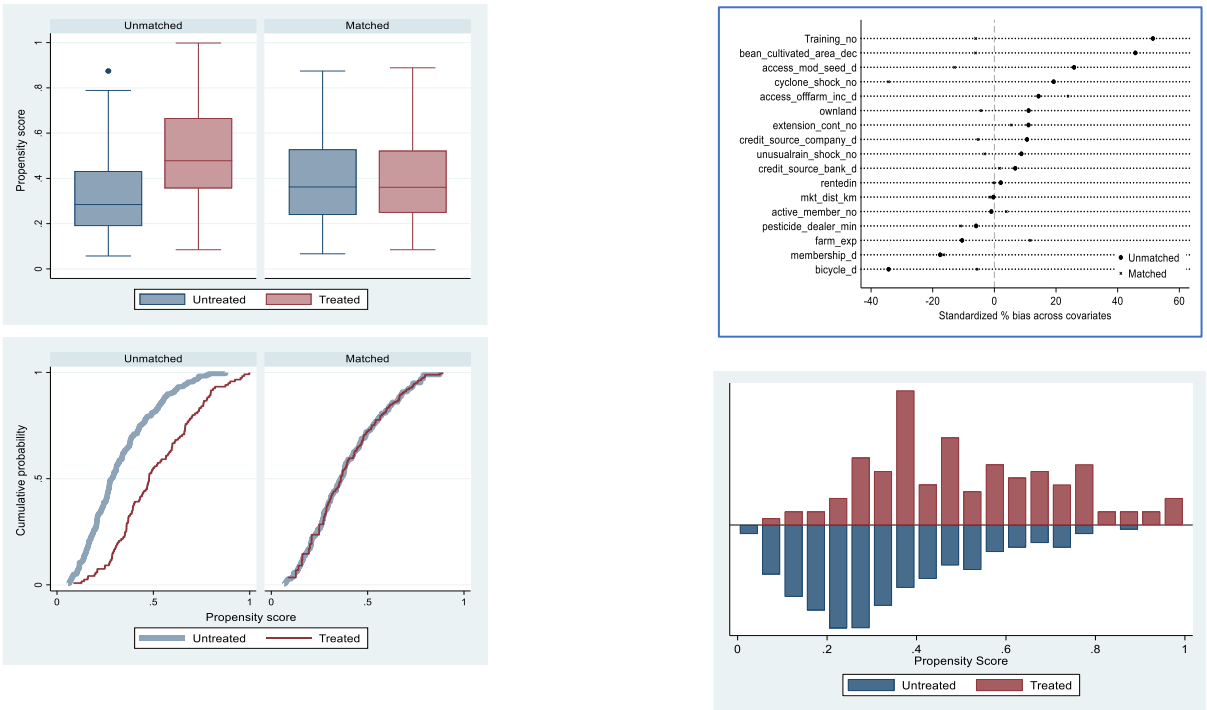


**Figure 1:** Matching quality (treated and untreated)
Note: Treated means the contract growers and untreated means the non-contract growers.

## DISCUSSION

This study examines the factors influencing farmers' participation in contract farming using a probit model, while employing propensity score matching to assess the causal effects of contract arrangements on bean production, output prices, and farm income in Narsingdi district, Bangladesh. Results reveals that, contract farmers had an average of 20.47 years of farming experience in this study, which is slightly higher than the 18.93 years reported for contract farmers in Vietnam (Hoang, 2021). Socioeconomic comparisons reveal that contract farming attracts relatively less experienced farmers, who may view contractual arrangements as a strategy to transfer production and marketing risks to contracting firms. In contrast, more experienced growers, confident in their market knowledge and production skills, appear to prefer the flexibility of spot market transactions. Moreover, this study found that contract farmers received considerably more training than non-contract farmers, reflecting the technical support provided by contracting firms. Importantly, this training differential appears to be a determinant of contract participation, as

farmers with greater exposure to capacity-building programs were more inclined to join contractual arrangements. The empirical evidence thus establishes training as both a correlate and a catalyst of contract farming adoption in the study area.

The results also show that contract farmers maintained more frequent contact with extension workers than non-contract farmers. In Sri Lanka, about 85.0% of contract farmers reported satisfaction with the extension services and seed support provided by contracting companies (Wijesooriya and Champika, 2015).

The findings of this study provide robust empirical evidence that contract farming significantly enhances the production and marketing outcomes of country bean farmers in Narsingdi district, Bangladesh. The Propensity Score Matching results demonstrated that contract participation increases bean production by 3.4% to 5.2%, gross margins by 33.2% to 36.1%, net revenue by 47.4% to 49.4%, and market prices by 26.6% to 27.4% compared to non-contract farmers. These substantial income gains align with previous research documenting the positive effects of contract farming on smallholder welfare in diverse contexts, including Vietnam (Saigenji and Zeller, 2009), China (Miyata *et al*., 2009), Cambodia (Sokchea and Culas, 2015), and Kenya (Wainaina *et al*., 2014). The consistency of these estimates across multiple matching algorithms, nearest neighbor, radius, kernel, and stratification matching, along with robustness checks using IPW and IPWRA estimators, strengthens confidence in the causal interpretation of the results and confirms that the observed advantages were attributable to contract participation rather than unobserved heterogeneity.

The analysis of participation determinants reveals that contract farming adoption was shaped primarily by institutional engagement and production scale rather than by traditional socioeconomic characteristics. The strongest positive predictors, training participation, bean cultivation area, and off-farm income, highlight the importance of technical capacity building, economies of scale, and income diversification in facilitating contract enrolment. Each additional training session increased the probability of adoption by 3.6 percentage points, underscoring the critical role of contracting firms as conduits of agricultural knowledge and technology transfer in contexts where public extension services were limited. Notably, the findings showed that off-farm income exerts the largest marginal impact (28 percentage points) suggests that diversified households may be better positioned to manage the risks associated with contractual arrangements, challenging assumptions that contract farming primarily benefits full-time, specialized farmers. Conversely, the negative associations between bicycle ownership and organizational membership with contract participation indicate that farmers with greater mobility or alternative institutional affiliations may prefer traditional marketing channels.

The policy implications of these findings are particularly relevant for strengthening inclusive agricultural value chains in Bangladesh and similar developing country contexts. The substantial price premiums and income gains observed under even simple verbal contracts, without formal input or credit provisions, suggest that guaranteed purchase and price stability alone can deliver meaningful benefits to smallholder vegetable farmers facing volatile markets. However, the significant role of training in facilitating adoption and the positive correlation between bean cultivation area and participation raise important considerations regarding equity and access. Policymakers and development practitioners should consider mechanisms to enhance smallholder participation, such as facilitating group contracts, reducing transaction costs through farmer aggregation, and strengthening the technical capacity of contracting firms to provide training and support to smaller-scale producers. Additionally, the negative relationship between organizational membership and contract participation warrants further investigation to understand how different institutional arrangements can be better integrated or coordinated to maximize smallholder benefits. While this study provides valuable commodity-specific evidence from Bangladesh's bean sector, future research employing longitudinal designs and broader geographic coverage would help assess the long-term sustainability of contract farming benefits and identify strategies to ensure more inclusive participation across diverse farming populations.

## CONCLUSION AND POLICY IMPLICATIONS

This study evaluated the determinants of smallholder participation in contract farming and its causal impacts on country bean production, output market prices, gross margins, and net revenues in the Narsingdi district of Bangladesh. By integrating Propensity Score Matching (PSM) with Inverse Probability Weighting (IPW) and Inverse Probability Weighted Regression Adjustment (IPWRA), the empirical framework controlled for observable selection bias and demonstrated robust treatment effects.

The empirical results show that contract farming is not driven primarily by traditional demographic endowments or household assets, but rather by institutional engagement, specialized scale of production, and income flexibility. Specifically, technical training, bean cultivation area, and access to off-farm income significantly increase the likelihood of contract participation. Conversely, bicycle ownership and membership in external local organizations reduce the probability of contract adoption, indicating that asset-mobile or institutionally committed farmers frequently prefer spot-market flexibility over contractual ties.

Despite relying solely on informal verbal agreements that lack formal credit or input provisions, contract farming delivers substantial socioeconomic benefits to smallholder vegetable growers. Contract farmers achieve higher yields, receive higher output prices, and realize greater net revenues compared to non-contract growers. Guaranteed purchasing and price stabilization effectively shield smallholders from seasonal spot-market price collapse during peak harvest periods.

Based on these findings, the following targeted interventions are recommended:

1. **Institutionalization of Capacity Building:** Since technical training is a major catalyst for contract adoption, public extension agencies such as the Department of Agricultural Extension (DAE), in partnership with private agribusinesses, should formalize training programs focusing on post-harvest handling, quality standard compliance, and contractual literacy.

2. **Promoting Farmer Aggregation Mechanisms:** To prevent the exclusion of resource-poor, small-scale producers who lack large bean cultivation areas, developmental policies should encourage the formation of Farmer Producer Organizations (FPOs) or block-farming clusters. Aggregating smallholders reduces transaction costs for contracting firms and ensures equitable access to contract value chains.
3. **Establishing Dispute-Resolution Frameworks:** Because verbal contracts are prone to opportunistic side-selling by farmers during price spikes or contract default by buyers during gluts, local agricultural offices should establish basic dispute-monitoring units to improve enforcement, foster trust, and minimize contract breaches.
4. **Facilitating Credit and Modern Inputs Integration:** Contracting companies and formal financial institutions should expand current agreements to incorporate affordable credit and high-quality certified seeds, further unlocking productivity potential.

This study is limited by its cross-sectional dataset and regional focus on Narsingdi district. Future research should employ longitudinal panel data across diverse agro-ecological zones and multiple high-value vegetable crops to examine the long-term sustainability, spillover effects, and dynamic stability of contract arrangements in Bangladesh.

**Acknowledgment**

This work was financially supported by the Sher-e-Bangla Agricultural University Research System (2021-2022), Sher-e-Bangla Agricultural University, Bangladesh.

**Conflict of Interests**

The authors declare that there is no conflict of interests regarding the publication of this paper.

**Ethical approval**

For this type of research formal consent is not required

**Authorship**

Hasan MR: Fund acquisition, conceptualization, methodology, investigation, data collection, writing the original draft and review and editing.

Islam MA: Conceptualization, methodology, formal analysis, review and editing.

All authors are agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

## REFERENCES

Abadie A, Imbens DW 2006: On the failure of the bootstrap for matching estimators. NBER Technical Working Paper 325, Cambridge, MA: National Bureau of Economic Research. https://www.nber.org/papers/t0325

Abdulai Y, Abdulai AM, Abdul-Manan K 2024: Factors affecting farmers' participation in contract farming: The case of soybean producers in the eastern corridor of the northern region of Ghana. *Journal of Development and Agricultural Economics* **16**(2): 15-25. DOI: 10.5897/JDAE2024.1405

Adah CO, Raji SA, Shaibu UM, Oluyomi MS 2024: Analyzing the adoption of improved production technologies among cassava contract and non-contract farmers in Kogi State, Nigeria. *Tikrit Journal for Agricultural Sciences* **24** (3): 161-181. DOI: https://doi.org/10.25130/tjas.24.3.14

Adnan KMM, Ying L, Sarker SA, Hafeez M, Razzaq A, Raza MH 2019: Adoption of contract farming and precautionary savings to manage the catastrophic risk of maize farming: Evidence from Bangladesh. Sustainability **11**(1), 29: 1-19. https://doi.org/10.3390/su11010029

Azad F 2021: Supply chain analysis of organic vegetable export from Bangladesh: Is contract farming a feasible solution? Khulna University Business Review **16**(1): 101-124.

Azumah S, Donkoh S, Ehiakpor D 2016: Examining the determinants and effects of contract farming on farm income in the northern region of Ghana. *Ghana Journal of Science, Technology and Development* **4** (1): 1-10.

Becker SO, Ichino A 2002. "Estimation of average treatment effects based on propensity scores. *The Stata Journal* **2**(4): 358-377.

Barrett CB, Bachke ME, Bellemare MF, Michelson HC, Narayanan S, Walker TF 2012: Smallholder participation in contract farming: Comparative evidence from five countries. World Development **40**: 715–730.

Becerril J, Abdulai A 2010: The impact of improved maize varieties on poverty in Mexico: A propensity score-matching approach. World Development **38**(7): 1024-1035. https://doi.org/10.1016/j.worlddev.2009.11.017

Bidzakin JK, Fialor SC, Awunyo-Vitor D, Yahaya I 2020: Contract farming and rice production efficiency in Ghana. *Journal of Agribusiness in Developing and Emerging Economies* **10** (3): 269-284. https://www.emerald.com/insight/content/doi/10.1108/JADEE-11-2018-0160/full/html

Cahyadi ER, Waibel H 2015: Contract farming and vulnerability to poverty among oil palm smallholders in Indonesia. *Journal of Development Studies* **52**: 1-15.

Crost B, Shankar B, Bennett R, Morse S 2007: Bias from farmer self-selection in genetically modified crop productivity estimates: Evidence from Indian data. *Journal of Agricultural Economics* **58**(1): 24–36.

Food and Agriculture Organization of the United Nations (FAO) 2016: FAO Statistics. Rome, Italy.

Food and Agricultural Organization of the United Nations (FAO) 2017: FAO Statistics. Rome, Italy.

Gujarati DN 2003: Basic econometrics. Fourth ed., McGraw-Hill, New York.

Haq MK, Arman SM, Nazera F 2021: How contract farming in poultry industry contribute to the sustainable community economic development of Bangladesh: A literature review. *Journal of University of Shanghai for Science and Technology* **23**(1): 433-488. http://doi.org/10.51201/Jusst12585

Hasan MR, Mutatisse AA, Nakamoto E, Bai H 2014: Profitability of cauliflower and bean production in Bangladesh - A case study in three districts. *Bangladesh Journal of Extension Education* **26**(1 & 2): 63-75.

Hoang V 2021: Impact of contract farming on farmers' income in the food value chain: A theoretical analysis and empirical study in Vietnam. Agriculture. **11**:1-16, https://doi.org/10.3390/agriculture11080797

Ikeda S, Natawidjaja RS 2022: The sustainability of contract farming with specialized suppliers to modern retailers:

Insights from vegetable marketing in Indonesia. Agriculture **12**(3): 1-11, https://doi.org/10.3390/agriculture12030380

Islam AHMS, Roy D, Kumar A, Tripathi G, Joshi PK 2019: Dairy contract faming in Bangladesh, Implications for welfare and food safety. IFPRI discussion paper 01833, The International Food Policy Research Institute (IFPRI), Washington DC, USA, 1-39.

Imbens G 2004: Nonparametric estimation of average treatment effects under exogeneity: A review. The Review of Economics and Statistics **86**: 4–29.

Imbens G, Woolridge J 2009. Recent developments in the econometrics of program evaluation. *Journal of Economic Literature* **47** (1): 5–86. https://doi.org/10.1257/jel.47.1.5

Khanal AR, Mishra AK, Mayorga J, Hirsch S 2020: Choice of contract farming strategies, productivity, and profits: Evidence from high-value crop production. *Journal of Agricultural and Resource Economics* **45**(3): 589–604. https://doi.org/ 10.22004/ag.econ.303604

Khan AU, Choudhury MAR, Talucder MSA, Hossain MS, Ali S, Akter T, Ehsanullah M 2020: Constraints and solutions of country bean (Lablab purpureus L.) Production: A review. Acta Entomol. Zool. **1**(2): 37-45, https://doi.org/10.33545/27080013.2020.v1.i2a.17

Khan MF, Nakano Y, Kurosaki T 2019: Impact of contract farming on land productivity and income of maize and potato growers in Pakistan. Food policy **85**: 28-39. https://doi.org/10.1016/j.foodpol.2019.04.004

Kundu P, Mandal T 2020: A survey on vegetable production and productivity on some selected vegetable growing belts of South 24 Parganas district of West Bengal. International *Journal of Recent Scientific Research* **11**(10): 39760-39773, https://doi.org/ 10.24327/IJRSR

Kanyenji GM, Oluoch-Kosura W, Onyango CM, Ng'ang'a SK 2020: Prospects and constraints in smallholder farmers' adoption of multiple soil carbon enhancing practices in Western Kenya. Heliyon **6**: 1-10. e03226. https://doi.org/10.1016/j.heliyon.2020.e03226

Kumar A, Tripathi G, Roy D, Joshi PK, Karandikar B 2018: Impact of contract farming on profits of smallholders. IFPRI discussion paper 01787, South Asia Regional Office, International Food Policy Research Institute, New Delhi, India.

Kuntariningsih A 2018: Impact analysis of school garden program to overcome malnutrition of children. KesKom **4**(1): 26–32.

Kutawa II 2016: Empirical evidence on contract farming in northern Nigeria: Case study of tomato production. Asian *Journal of Agriculture and Rural Development* **6**(12): 240-253. https://doi.org/10.18488/journal.1005/2016.6.12/1005.12.240.253

Leuven E, Sianesi B 2003: PSMATCH2: Stata module to perform full mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing, http://ideas.repec.org/c/boc/bocode/s432001.html.

Loquias MP, Digal LN, Placencia SG, Astronomo IJT, Orbeta MLG, Balgos CQ 2021: Factors affecting participation in contract farming of smallholder cavendish banana farmers in the Philippines. Agric Res **11**(1):146–154. https://doi.org/10.1007/s40003-021-00544-0

Maddala GS 1983: Limited-dependent and qualitative variables in econometrics. Cambridge University Press, Cambridge, UK.

Mao H, Fu Y, Cao G, Chen S 2021: Contract farming, social trust, and cleaner production behavior: field evidence from broiler farmers in China. Environmental Science and Pollution Research **29**: 4690–4709, https://doi.org/10.1007/s11356-021-15934-8

Manjunatha AV, Ramappa KB, Lavanya BT, Mamatha NC 2016: Present status and prospects of contract farming in India. *International Journal of Agriculture Sciences* **8**(7): 1072-1075.

Mazhar R, Xuehao B, Dogot T, Skominas R, Tanaskovik V, Azadi H, Wei Z 2022. Contract farming and technical efficiency: A case of export-oriented organic rice farmers in Pakistan. Land **11**: 1-16. https://doi.org/10.3390/land11111953

Mishra AK, Kumar A, Joshi PK, D'Souza A 2018: Impact of contract farming on yield, costs and profitability in low-value crop: evidence from a low-income country. *The Australian Journal of Agricultural and Resource Economics* **62**: 589–607. https://doi.org/10.1111/1467-8489.12268

Miyata S, Minot N, Hu D 2009: Impact of contract farming on income: Linking small farmers, packers, and supermarkets in China. World Development **37**(11): 1781- 1790.

Mulatu G, Haji J, Legesse B, Ketema M 2017: Impact of participation in vegetables' contract farming on household's income in the central rift valley of Ethiopia. *American Journal of Rural Development* **5**(4): 90-96. https://pubs.sciepub.com/ajrd/5/4/1/index.html.

National Horticulture Board (NHB) 2018: Handbook of Indian Horticulture Database. National Horticulture Board. New Delhi, India.

Nayak US, Das SR, Shial G 2020: Perception and adoption level of improved off-season tomato cultivation practice among farm women of Odisha. *International Journal of Bio-resource and stress management* **11**(6): 297-303, https://ojs.pphouse.org/index.php/IJBSM/article/view/4017

Nazifi B, Hussaini YI 2021: Determinants of participation in contract farming among smallholder maize farmers in North-Western Nigeria. Acta Sci. Pol. Agricultura **20**(4) :147–160. https://doi.org/ 10.37660/aspagr.2021.20.4.2

Ntabakirabose G, Tumukunde R, Tuyisenge JC, Musabyimana JC, Mburu DM, Murindangabo Y T, Ndaruhutse F, Vianney SJMV 2021: An economic analysis of the impact of contract farming of broccoli production on youth development: A case of Musanze district. Innovation **2**(4) :56-66, https://doi.org/10.11648/j.innov.20210204.12

Rahman MS, Majumder MK, Sujan MHK, Manjira S 2021: Livelihood status of coastal shrimp farmers in Bangladesh: Comparison before and during COVID-19. Aquaculture Reports **21**: 1-9. 100895. https://doi.org/10.1016/j.aqrep.2021.100895

Rahman MS, Norton GW, Rashid MH 2018: Economic impacts of integrated pest management on vegetables production in Bangladesh. Crop Protection **113**: 6-14. https://doi.org/10.1016/j.cropro.2018.07.004

Ramya V, Priya P 2019: Health benefits of vegetables. *Int. J. Chem. Stud.* **7**(2): 82-87.

Rosenbaum PR, Rubin DB 1983: The central role of the propensity score in observational studies for causal effects. Biometrika **70**: 41–55.

Robalino J, Pfaff A 2013: Eco-payments and deforestation in Costa Rica: A nationwide analysis of PSA's initial years. Land Economics **89**(3): 432-448.

Saigenji Y, Zeller M 2009: Effect of contract farming on productivity and income of small holders: The case of tea production in north-western Vietnam. Contributed Paper presented for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009.

Sambuo D 2012: Tobacco contract farming participation and income in Urambo: Heckma's selection model. *Journal of Economics and Sustainable Development* **5**: 230-237.

Sarkar MAR, Rashid MHA 2011: An economic analysis on contract farming in vegetables seed production in selected areas of Rangpur district. *Bangladesh Journal of Political Economy* 27 (1&2): 297-314.

Shrestha RB, Bhandari H, Pandey S 2022: Profit efficiency of smallholder vegetable farms in Nepal: Implications for improving household income. Frontiers in Sustainable Food Systems **5** :1-12, https://doi.org/10.3389/fsufs.2021.691350

Smith J, Todd P 2005: Does matching overcome LaLonde's critique of non-experimental estimators? *Journal of Econometrics* **125**: 205–253.

Sokchea A, Culas RJ 2015: Impact of contract farming with farmer organizations on farmers' income: A case study of reasmey stung sen agricultural development cooperative in Cambodia. Australasian Agribusiness Review **23**: 1-11.

Susilowati KDS, Riwajanti NI, Rachmi A 2019: Critical analysis of contract farming practice in East Java – Indonesia. 1st Annual Management, Business and Economic Conference, Advances in Economics, Business and Management Research, volume 136, Atlantis Press SARL.

Swain BB and Teufel N 2025: Emergence of contract farming and its impact on Indian agriculture: A study from two Indian states, Agricultural Economics Research Review **38**(1): 71- 80. DOI: 10.1177/09713441251389412

Taslim A, Karim MR, Rahman MS 2021: Factors influencing participation of farmer in contract farming in Narsingdi district of Bangladesh. *Asian Journal of Agricultural Extension, Economics & Sociology* **39**(11): 569-576.

Taslim A, Rahman MS, Karim MR, Sumon MMH 2021: Financial Analysis of Country Bean in Narsingdi District of Bangladesh. *Asian J. Adv. Agric. Res.* **17**(2): 42-50.

Velde KV, Maertens M 2014: Contract farming in staple food chains: The case of rice in Benin. Working paper 2014/9, Department of earth and environmental sciences, KU Leuven, Belgium.

Wainaina PW, Okello JJ, Nzuma JM 2014: Blessing or evil? Contract farming, smallholder poultry production and household welfare in Kenya. *Quarterly Journal of International Agriculture* **53**: 319-340.

Wijesooriya N, Champika J 2015: Agricultural forwards contracts as pre-harvest commodity marketing: Problems and prospect. Research report no. 180, Hector Kobbekaduwa Agrarian Research and Training Institute, 114, Wijerama Mawata, Colombo 7, Sri Lanka.

Wooldridge JM 2007: Inverse probability weighted estimation for general missing data problems. *Journal of Econometrics* **141**(2):1281–1301. https://doi.org/10.1016/j.jeconom.2007.02.002

Wooldridge JM 2010: Econometric Analysis of Cross Section and Panel Data. Second ed., The MIT Press, USA.