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DOES CONTRACT FARMING PARTICIPATION PROMOTE HOUSEHOLD'S FOOD SECURITY FOR SMALLHOLDERS? EMPIRICAL EVIDENCE FROM INDONESIA

Abstract

Despite contract farming's widespread implementation to overcome market constraints and enhance farmers' livelihoods, its impact on food security remains inadequately investigated and questionable. This study employs propensity score matching (PSM) to mitigate selection bias in examining the impact of contract farming on the food security of smallholder farm households in Indonesia. It utilizes the 2021 Indonesia Agricultural Integrated Survey (SITASI) data, designed to monitor the indicators of sustainable development goals (SDGs) in the agriculture sector. We use the food insecurity experience scale (FIES) to measure food security. Our research shows that participating in contract farming can improve food security with a small size effect. Furthermore, our investigation revealed that this beneficial effect is particularly prominent among farmers residing in rural areas, female farmers, and farmers who do not own land or livestock. These results indicate that while contract farming can be utilized to improve food security, it should not be relied upon only as a comprehensive plan, as it may not be sufficient in itself.

Keywords: contract farming, food security, farm households

JEL Classification: L14, Q18, Q12

Introduction

Literature has widely endorsed contract farming as a viable approach to help smallholder farmers overcome their market constraints (Mishra et al., 2018). Engaging in contract farming offers smallholders the prospect of increased profits and the expansion of their production scales. This is attributed to the prospect of contract farming to enable market entry (Meemken & Bellemare, 2020; Soullier & Moustier, 2018), enhance inputs and credit accessibility (Debela et al., 2022; Gatto et al., 2017), and facilitate the adoption of technological advancements (Ganewo et al., 2022; Ragasa et al., 2018). For this reason, policymakers in numerous developing countries have utilized contract farming to stimulate agricultural development and alleviate rural poverty (Bellemare & Novak, 2017).

Studies on the impacts of contract farming have predominantly centred on its impact on income (Hoang, 2021; Mwambi et al., 2016; Khan et al., 2019). The prevailing consensus among these studies is that contract farming yields positive outcomes for farmers, particularly in terms of income enhancement. Conversely, the scholarly discourse surrounding its impact on food security has been comparatively limited. It is an important issue since its impact on food security can be ambiguous. According to Soullier & Moustier (2018), contract farming improves the food security of rice farmers in Senegal through the increase of income. Suppose contract farming is capable of increasing farmers' income and considering that those with higher income can acquire a greater amount of food of better quality. In that case, it is reasonable to expect that contract farming will improve food security.

On the contrary, it is possible that contract farming can adversely impact food security. Andriamparany et al. (2021) and Olounlade et al. (2020) discovered that contract farming adversely affects the food security of vanilla farmers in Madagascar and rice farmers in Benin. According to Soullier & Moustier (2018), contract farming may lead to competition between own consumption and sales. Participating households may be forced to allocate a portion of their production, formerly allocated for their own consumption, to meet their agreed-upon quota. In some circumstances, contracted farmers must grow a crop or raise livestock not commonly consumed within the household

(Olounlade et al., 2020). Contract farming may also redirect the farmer's attention towards the contracted commodities, decreasing the time allocated to subsistence farming, off-farm jobs, and domestic duties such as food preparation (Andriamparany et al., 2021). As a result, these households need to procure food from the market for their own consumption. If the market is not easily accessible or the market price is high, it will result in lower food security status.

All prior empirical studies on the impact of contract farming on food security focus on a particular contract scheme (Andriamparany et al., 2021; Soullier & Moustier, 2018), specific commodity (Debela et al., 2022; Ganewo et al., 2022; Olounlade et al., 2020), or for limited regions such as several districts (Bellemare & Novak, 2017). Hence, the conclusion is not generalizable to other cases because it is specific to the common scheme and commodities in that region. As each nation may have its contract farming schemes and commodities vary, conducting country-specific research is necessary.

The Minister of Agriculture's Decision Number 484/KPTS/RC.020/M/8/2021 has included contract farming as a component of the National Economy Recovery Programs or Pemulihan Ekonomi Nasional (PEN) to strengthen food security and improve the welfare of farmers. Our data indicates, however, that the participation rate in Indonesia remains extremely low at 1.64%. In comparison, the participation rates in contract farming in the United States and China were 9% (Whitt, 2022) in 2020 and 24% in 2017 (Lixia et al., 2021).

On the other hand, Indonesia is far from attaining the SDGs' objective of eliminating hunger or food insecurity. According to Statistics Indonesia (Badan Pusat Statistik), in 2022, approximately 4.85% of the Indonesian population, equivalent to over 13.3 million individuals, still experience food insecurity. Food security-wise, Indonesia lags significantly behind the United States and China. According to the Global Food Security Index (GFSI), Indonesia is ranked 63rd, while China and the United States are ranked 26th and 13th, respectively. A higher rate of contract farming participation, while not the only determinant, could contribute to better food security in both countries, given its beneficial impact on food security. This disparity highlights the necessity for Indonesia to reassess and potentially promote the adoption of contract farming to strengthen food security. Unfortunately, there has been no study on the impact of contract farming on food security in Indonesia.

In order to address this research gap, this study attempts to evaluate the impact of contract farming on the food security of smallholder farm households in Indonesia. In contrast to prior research focusing on a limited number of commodities, this study covers all agricultural commodities (including crops and livestock) cultivated or reared in Indonesia. The analysis utilizes the data obtained from SITASI 2021. The sample covers all 34 provinces in Indonesia. We recognize that contract farming participation in our non-experimental/observational data is not random. The relationships between contract farming and food security could be confounded by numerous factors. To minimize the potential bias, we utilized propensity score matching (PSM) particularly to address the selection bias issue.

This study has two distinct contributions. First, as mentioned, all previous studies were conducted for particular contract schemes, certain commodities, or limited regions such as several districts. This study is the first to employ nationwide data with broad coverage of commodities. This strategy would enable generalization beyond specific contracts or commodities.

Second, this study is the first to use the FIES to study the impact of contract farming and food security. Previous studies employed duration of hunger season and food consumption adequacy indicators such as food consumption score (FCS), food security index (FSI), and dietary diversity score (DDS). According to Cafiero et al. (2014), the weakness of the food consumption adequacy indicator lies in

the use of a single threshold. It is inappropriate since the quantity of nutrition for everyone depends on their gender, age, body mass composition, or physical activity. Meanwhile, the duration of the hunger season only accounts for severe food insecurity when household members eat less than three times a day. It did not consider moderate food insecurity, such as reducing meal portions, consuming less at each meal, or worrying about running out of food. In contrast to these measurements, FIES is based on individuals' perceptions of their encounters and experiences with varying degrees of food inaccessibility (FAO, 2016).

Our findings reveal that participating in contract farming has the potential to improve food security. The treatment effect in reducing the probability of food insecurity is in the range between 0.92% and 1.17%. However, this impact can be considered minor. Our results also show that the positive impact is more pronounced among rural farmers, female farmers, and farmers who do not own land or livestock. Regarding factors influencing contract farming participation, the study highlights that location (urban/rural), market and credit access, gender, education, membership in farmer associations, household size, and exposure to agricultural training play significant roles.

Research Method

Data

This study utilizes data from the Indonesia Agricultural Integrated Survey or Survei Pertanian Terintergrasi (SITASI) that was carried out in 2021. The data collection covered the period of one year, from September 2020 to September 2021. Although SITASI 2021 also collected data for the forestry and fishery sectors, this study only uses data for the agriculture sector. The agriculture sector consists of crops and livestock production. The analysis only accounts for farms that conducted crop or livestock production activities during the survey period. The data from 34 provinces is utilized to obtain the national-level analysis.

There are some missing items in the food security data. In order to fill in the missing items on the FIES questions, an imputation procedure was implemented using the IMPUTERASCH command in STATA. However, due to the large number of covariates and the considerable effort required to perform imputation for each of them (while also raising doubts about the validity of the imputation results), observations missing items on their covariates are excluded from this study. A total of 3.76% of the observations are excluded from the analysis because of missing data. The final dataset comprised 230,189 farm households.

Contract Farming Definition

Contract farming is an agreement between farmers and purchasers, typically processing or marketing firms. This agreement outlines the terms and conditions for producing, purchasing, and selling agricultural goods. The agreement is made in advance and typically includes predetermined prices (Bellemare & Lim, 2018; Eaton & Shepherd, 2001). The foundation of such a contract is the farmer's commitment to produce agreed-upon quantities and quality and the buyer's commitment to purchase the products. Frequently, the contract specifies the delivery date, the amount and standard of the product that purchasers demand, and the amount of money to be paid to the farmer. Occasionally, additional information, such as the production method or whether the buyer would provide inputs like seeds, fertilizer, and technical assistance, may be included in the contract.

Two distinct types of contract farming exist: marketing and production contracts (Bellemare & Lim, 2018). In a production contract, buyers are the ones who make decisions on production and supply essential inputs like seeds and fertilizer, as well as technology, technical assistance, and loans. On the other hand, marketing contracts give farmers control over production, while buyers have authority over pricing and quantity requirements. Marketing contracts do not provide provisions for input and other forms of support.

We operationalize the definition of contract farming participation in the SITASI data as follows. The SITASI questionnaire asked whether the farm or agricultural holdings had a production or marketing contract. A household might own multiple farms. We code a household participating in contract farming if it possesses a minimum of one farm or holding with a production, marketing, or both contract arrangement.

Food Security Measurement

Food security is attained when individuals have consistent access to an adequate, nourishing, and safe food supply that fulfils their needs and enables them to maintain good health (World Food Summit, 1996). This study uses Food Insecurity Experience Scale (FIES) to measure food security. It is a metric that assesses food security using experiential data. The FIES consider not only the dietary quality and quantity of food but also the psychological elements associated with worry or uncertainty regarding the ability to access enough food. It is a feature that is absent in other measures. There are three levels of food insecurity resulting from the FIES: food security, moderate food insecurity, and severe food insecurity. In this study, "food insecure" refers to moderate and severe food insecurity, whereas "food secure" has the exact definition as FIES. All of the information about FIES in the remainder of this section is from the Voice of Hungry (VoH) 2016 Technical Report (FAO, 2016).

The methodology of FIES depends upon the individual's perceptions of their encounters with limited food accessibility, as expressed through their responses to the eight questions of FIES. Each question relates to a different experience and corresponds to the different severity of food insecurity. The questions inquire whether, in the last 12 months, the respondent experienced worries about not having enough food, inability to access healthy and nutritious food, limited food options, skipping meals, eating less than desired, depletion of food supplies in households, experiencing hunger without eating, and even going without food for an entire day.

The Rasch model is used to construct FIES based on the responses to the questions. This model uses a logistic function to estimate the likelihood of a responder reporting a specific episode of food insecurity based on the distance between the responder's condition (θ_h) and an item's position (β_i) on the severity scale:

$$\text{Prob}\left(x_{h,i} = 1 \middle| \theta_{h,\beta_i}\right) = \frac{e^{\theta_h - \beta_i}}{1 + e^{\theta_h - \beta_i}} \quad (1)$$

where $x_{h,i}$ is the respondent h response to the item i, with the value of 1 if "yes" and 0 if "no". The model estimation is conducted by employing conditional maximum likelihood (CML) using FIES estimation software built by VoH. The software can be accessed through the VoH website (https://www.fao.org/in-action/voices-of-the-hungry).

The Causal Inference Framework

Contract farming participation is influenced by an array of factors. As a result, contract farming is not random but rather happens upon selection. The problem is that the factors determining a farm household's choice to participate in contract farming may also be related to its security status. If this claim is valid, the model will suffer from selection bias because the error term is associated with the treatment assignment. Utilizing a simple binary regression would result in biased estimations.

Adding the source of selection to the regression as control variables might solve the issue of observed selection bias. However, this method is susceptible to model specification. Therefore, this study will use PSM, which is widely used to address the issue of selection on observable. Unlike the former method, PSM is robust to model specification. PSM eliminates the selection bias by matching the treatment and control group units based on their similarity in observed characteristics (Khandker et al., 2009). The matched data should establish a balance in which observed characteristics of the treatment group units are similar to those of the control group. These characteristics will be reflected in the probability of receiving treatment. Units with similar characteristics should have equal probabilities of receiving treatment. The estimated value of this probability is called the propensity score.

The analysis begins with estimating the propensity score, which represents the probability that a farm household participates in contract farming using the probit model. The probit model is given by:

$$\Pr(T_i = 1|X_i) = \Phi(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_J X_{Ji}) \quad (2)$$

where T_i is the treatment variable, which in this study represents the household's status of contract farming participation. X_{ji} are factors that influence households' choice to participate in contract farming, while Φ is the cumulative density function (CDF) of standard normal distribution. The propensity score is the fitted value obtained from equation (2) estimation. After obtaining the propensity score, participants will be matched with non-participants with similar propensity scores. The treatment effect will then be estimated by comparing matched and non-participant outcomes. As a measure of treatment effect, this study focuses on the average treatment effect on the treated (ATT), which is defined as:

$$ATT = E(Y_i(1)|T_i = 1) - E(Y_i(0)|T_i = 1) \quad (3)$$

Before using the matching result, one needs to check the validity of the PSM. Common support is the primary assumption that needs to be satisfied to ensure the validity of PSM results. The common support condition requires that treatment group units are similar to the control group units in terms of observed covariates. This assumption is considered satisfied when a significant overlap exists between the propensity scores distribution of the treatment and control groups. One can also conduct balancing tests to assess whether the mean of propensity scores within each distribution quantile is the same. For PSM to be effective, it is necessary to ensure that the treatment and control groups exhibit balance.

As PSM only considers selection based on observable factors, it is necessary to examine the possibility of unobserved selection that might bias the estimated treatment effect. Within the framework of PSM, this is the conditional *unconfoundedness* assumption. In order to evaluate this assumption, this study conducts sensitivity analysis using Rosenbaum bounds (Rosenbaum, 2002) for binary outcome variables. The bounds are calculated using the MHBOUNDS function in STATA. The test identifies "hidden bias" caused by unobserved confounders that might affect the estimation of treatment effects.

This study conducted PSM using the STATA PSMATCH2 command by Leuven & Sianesi (2003). The common support assumption and balancing property are assessed using the STATA PSTEST command. The common support result is considered satisfied if the standardized difference of the mean propensity score between the treatment and control group is less than 25% and the variance ratio is between 0.5 and 2.0 (Rubin, 2001). Covariates are considered to be balanced if the mean difference of the variable between the treatment and control group is not significant according to the t-test result and the variance ratio is between 0.94 and 1.07.

This study used a double-adjustment strategy to eliminate residual selection bias from imbalanced covariates (Nguyen et al., 2017). Double-adjustment refers to applying regression of the outcome variable on the treatment variable using matched data obtained from PSM. This step added covariates that have not yet achieved balance after the matching procedure as control variables. The probit regression will be employed since the outcome variable is a binary variable. In order to enhance its robustness, the matching weight acquired via PSMATCH2 is also utilized as a probability weight to correct for bias arising from dropping unmatched observations. The estimated ATT is equivalent to the marginal effect obtained from the probit regression analysis using the weight resulting from PSM.

Result and Discussion

Summary Statistics

Appendix 1 shows summary statistics of our samples, and **Appendix 2** shows the mean of each variable based on contract participation. The last column of **Appendix 2** shows the test results of the equality of proportion or mean between contract participants and non-participants. Only 1.64% of farm households in our sample participate in contract farming. This participation rate is likely underestimated, as those who engaged in verbal or informal contracts (without written legal contracts) may not be aware they are participating in such arrangements. Marketing contracts are more common than production contracts. Approximately 1.37% and 0.92% of farm households participate in marketing and production contracts, respectively.

The majority of farm households are food secure, with only 4.29% experiencing food insecurity. Based on the test of the equality of two proportions, A significant difference exists in the percentage of households experiencing food insecurity between those who practice contract farming and those not involved, with the former exhibiting a comparatively lower rate. It is possible that this finding suggests a positive correlation between contract farming participation and food security.

As anticipated, more than half of agricultural households in our sample reside in rural areas. Regarding market and credit accessibility, most of these households reside in villages that lack direct access to conventional markets but possess favourable access to credit. Most farmers in our sample are male, indicating the continued male dominance in the agricultural sector. Most of them also have not completed compulsory education. Their mean age is 52 years, providing evidence of the phenomenon of ageing farmers. Contrary to popular belief, most of them have their own land or livestock. Regarding institutional connection, most farm households are not members of farmer associations or cooperatives. The level of agricultural training exposure is minimal, with less than one member per household on average having received training. The typical household size is approximately three individuals, indicating that most farm households are relatively small.

Based on the test of equality of proportions or means, it can be concluded that contract participants and non-participants differ in various characteristics, including the type of domicile area (urban or rural), access to markets and credit, gender, age, education level of the farmers, membership in

associations and cooperatives, ownership of assets, household size, and exposure to agricultural training. There appears to be a potential self-selection issue with participation in contract farming, as both groups possess distinctive characteristics.

Selection Into Contract Farming Participation

Before looking into the impact of contract farming on food security, we analyzed the factors that influence the choice of farm households to participate in contract farming. We used probit regression to estimate equation (1). The findings are presented in **Table 1**.

Table 1. Probit Estimation for Determinant of Contract Farming Participation

Determinants	Coef.	SE	t-stat	p > |t|
Living in urban areas (dummy)	0.1041	0.0136	7.64	0.000***
Has access to traditional market (dummy)	-0.0887	0.0145	-6.12	0.000***
Has access to credit (dummy)	0.0490	0.0170	2.89	0.004***
Female farmer (dummy)	-0.0982	0.0218	-4.51	0.000***
Farmer's age (years)	-0.0007	0.0006	-1.15	0.252
Farmer completed compulsory School (dummy)	0.0272	0.0143	1.90	0.057*
Member of farmer association (dummy)	0.2395	0.0159	15.08	0.000***
Member of farmer cooperative (dummy)	0.5444	0.0302	18.04	0.000***
Own land or livestock (dummy)	0.0133	0.0141	0.94	0.347
Number of members in the household (people)	0.0158	0.0044	3.60	0.000***
Number of trained members (people)	0.0838	0.0161	5.20	0.000***
Constant	-2.2978	0.0408	-56.37	0.000***
Number of obs.: 230,189			Prob > chi2: 0.000***	
Pseudo R^2: 0.0241				

$***\alpha = 1\%$ $**\alpha = 5\%$ $*\alpha = 10\%$

Contract farming is more prevalent among farm households residing in urban areas than rural ones. This occurrence may be attributed to the classification of peri-urban areas as urban areas in the data. Due to the region's proximity to agricultural land and urban markets, contract farming may be more prevalent in this area. In addition, infrastructure in urban areas, including communication and transportation, is better than in rural areas. It has the potential to facilitate better connections between agribusiness and farmers (Barrett et al., 2012).

Farmers' direct access to traditional markets reduces their willingness to engage in contract farming. This result indicates that rather than entering a contract with an agribusiness, producers would rather sell their products directly on the spot market. Given that producers are contractually bound to conform to the specified quality standards and they lack the ability to seek alternative buyers, they may be discouraged from participating if the contract does not offer more favourable pricing compared to the market price, risk sharing, or input provision (Widadie et al., 2021).

Contractor farming is more prevalent among farmers who have access to credit. Contract farming may necessitate investment in novel technologies or particular inputs. Farmers with access to credit have an edge as they can secure a loan to finance this investment. They will, therefore, be more likely to accept a contract opportunity (Ganewo et al., 2022).

Contract farming is less prevalent among female farmers. Since contract farming typically favours farmers who own land ownership and female farmers lack land ownership (Quisumbing et al., 2015),

they are more often marginalized in terms of contract farming opportunities. Contract farming also often involves the production of traditional cash crops or products intended for export, typically cultivated by male farmers (Quisumbing et al., 2015).

Compared to farmers who do not complete compulsory education, those who accomplish it are more likely to participate in contract farming. According to Kutawa (2016), farmers with a better education level would comprehend the benefits of contract farming. Higher education also helps farmers understand the contract terms better and makes them better at negotiating (Ganewo et al., 2022). Consequently, they will feel more confident and enthusiastic about contract farming.

Membership in farmer associations and cooperatives positively affects contract farming participation. Both are a viable source of various information related to agricultural activities, including contract farming opportunities. Cooperatives also frequently provide contractual arrangements to their members. The members will produce products that will be sold to cooperatives, which will in turn sell them to end consumers. Farmers may also collectively participate in contract schemes via associations or cooperatives to strengthen their ability to negotiate favourable terms or secure a better price (Ganewo et al., 2022).

A positive correlation has been observed between the size of a household and the probability of participating in contract farming. This favourable outcome can be attributed to the ability of households to employ their family members as a source of labour (Ganewo et al., 2022). Contract farming frequently comes with an opportunity to expand production scale. Scaling up requires additional labour. If more members are employed as family workers, farm owners do not need to take on additional paid labour. Hence, they may find it easier to accept contract farming offers.

Exposure to agricultural training positively impacts contract farming participation. The favourable outcome can be attributed to the knowledge and expertise individuals gain through training (Ba et al., 2019). By acquiring these competencies, farmers can meet the buyers' requirements and effectively utilize the new technologies they provide. They would appeal to more potential buyers, boosting their chances of being offered a contract.

The Impact of Contract Farming on Food Security

The analysis begins with estimating the baseline estimation using probit regression without (Baseline 1) and with control variables (Baseline 2). All factors that influence participation in contract farming are included as control variables and covariates in all following analyses. The results are displayed in the first and second rows of **Table 2**. Both estimates produce the same results regarding the direction, with slight differences in the magnitude of the impact. Both estimates show that those participating in contract farming may have a significantly lower probability of experiencing food insecurity.

Table 2. Estimation of ATT of Contract Farming on Food Security

Estimation Methods	Number of Observations	ATT	SE	z-stat	p > |z|
Baseline 1	230,189	-0.0151	0.0027	-5.56	0.000***
Baseline 2	230,189	-0.0114	0.0026	-4.33	0.000***
NNM(1)	6,925	-0.0123	0.0045	-2.72	0.007***
NNM(5)	19,117	-0.0092	0.0031	-2.96	0.003***
NNM(10)	33,369	-0.0099	0.0029	-3.45	0.001***
Radius(0.001)	230,172	-0.0117	0.0027	-4.30	0.000***

Radius(0.005)	230,184	-0.0117	0.0026	-4.44	0.000***
Radius(0.01)	230,186	-0.0116	0.0027	-4.37	0.000***
EPAN(0.01)	230,186	-0.0118	0.0027	-4.46	0.000***

Baseline 1 may suffer from selection bias, while baseline 2 may be susceptible to model specification. Therefore, we employed PSM to address both issues. We used several matching algorithms: one nearest neighbour matching or NNM(1), NNM(5), NNM(10), radius matching with 0.001 caliper or Radius(0.001), Radius(0.005), Radius(0.01), and epanechnikov kernel matching with 0.01 caliper or EPAN(0.01). The double-adjustment approach is employed after obtaining the matching data to rectify any remaining imbalance that cannot be resolved through matching. The estimated ATT, shown in **Table 2**, is the marginal effect from the double adjustment regression for each matching method.

The estimated ATT from all PSM estimates demonstrates similar outcomes, indicating that the estimation is robust. All estimates consistently suggest that those who practice contract farming experience a significantly lower probability of experiencing food insecurity, thereby highlighting its beneficial impact on food security. In addition, the outcomes do not deviate significantly from the baseline estimates. It raises a question regarding the effectiveness of the PSM in mitigating potential biases. The effectiveness of PSM is greatly dependent on the choice of covariates. The similarity between PSM and baseline estimates might suggest that there may be limitations in the selected covariates to account for selection bias. We reserve a possibility that the PSM omits variables that play a role in contributing to the remaining source of selection bias.

Among the estimates, Radius(0.001) yielded the best-matched data with the lowest mean difference of propensity score between the treatment and control groups while retaining most observations. This method also portrays good balancing properties, as shown by the result of the balancing test in **Appendix 3** and the propensity distribution graph in **Picture 1**. Based on this estimate, participating in contract farming lowers the probability of a household experiencing food insecurity by 1.17%. The size is about 27% relative to the mean of the control group (see column 4 of the first row in Appendix 2). It appears that this impact is relatively small.

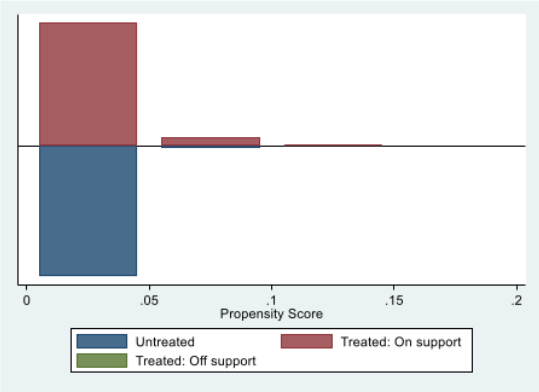

Figure 1. Distribution of Propensity score between the treatment and the control group

Robustness Test

For the robustness test, we conducted several alternative estimations: 1) direct NNM(1); 2) inverse probability weight regression adjustment (IPWRA); 3) probit regression using propensity score as control; and 4) placebo test using randomly generated treatment variable. The result is presented in

Table 3. The first four estimations exhibit consistent and similar results with previous estimates regarding direction. Therefore, the findings in **Table 2** are robust. If the placebo treatment significantly affects food security, the treatment effect estimated in prior estimates cannot be considered causal. The insignificant placebo effect implies that contract farming and food security are causally related.

We conducted a sensitivity analysis in STATA using the MHBOUNDS command to address potential unobserved selection bias, employing Rosenbaum bounds for binary outcomes. The result is displayed in **Appendix 4**. It indicates that any unobserved bias in contract farming participation would have to modify the odds ratios of contract farming participation for the treated and control groups by a factor of 1.4 to 1.75 in order to undermine the interpretation of the impact of contract farming on food security. Such a level of bias is likely to manifest. Should such bias exist, it could result in the conclusion that contract farming does not significantly affect food security. Given that prior estimates indicate a minor impact of contract farming, it would not be so unexpected if the existence of any unobserved bias would lead to the conclusion that contract farming does not affect food security. Thus, instead of confidently stating that contract farming definitively improves food security, we tentatively propose that contract farming can potentially improve food security.

Table 3. Robustness Test

Estimation Methods	Number of Observations	ATT	SE	z-stat	p > |z|
Radius(0.001) with sample weight	230,172	-0.0082	0.0032	-2.58	0.010**
Direct NNM(1)	230,189	-0.0152	0.0036	-4.18	0.000***
IPWRA	230,189	-0.0102	0.0033	-3.11	0.002***
Probit-PSCORE	230,189	-0.0128	0.0029	-4.46	0.000***
Placebo test	181,127	0.0015	0.0012	1.29	0.197

Mechanism Analysis

One mechanism in which contract farming positively affects food security is through the positive income effect. Competition between production for contract and own consumption or competition in time allocation might happen sometimes, but the positive income effect dominates the negative substitution effect. Literature suggests that contract farming increases productivity and farm income (Hoang, 2021; Khan et al., 2019; (Selorm et al., 2023)). With a higher income, farmers can purchase more and higher-quality food, thereby improving their food security. They can also save additional income from contract farming to buy food during the off-season (Bellemare & Novak, 2017). Thus, they can guarantee a continuous food supply and achieve food security throughout the year.

Due to the unavailability of data, testing the mechanism through efficiency improvements is not feasible. This study is also unable to assess whether contracted farms have a higher yield or income due to the poor quality of yield data and the absence of income data. However, the data contains a variable about whether the household income has increased since last year. The information provided is based exclusively on the respondent's recall, not the original time series data.

We estimated the ATT of contract farming on the income comparison variable, and the resulting ATT is statistically significant. Our research reveals that participating in contract farming is associated with a 6.54% rise in the probability of earning a higher income. Upon further examination, we reassessed the ATT of contract farming on food security, considering the income comparison variable as a control. We found that the ATT only changed minimally to 0.0114 in absolute value, differing by only 0.0003 from the first estimate. It indicates that approximately 2% of the aggregate impact of contract farming

on food security may be attributable to the positive effect on income. This contribution is relatively minor. This minor result could be attributed to the inadequacy of the income comparison variable in accurately assessing changes in income. Due to its reliance on the respondent's recall, the variable is highly subjective and susceptible to bias. Moreover, there may be a more substantial mechanism beyond the income effect, which provides a more precise justification for the favourable impact of contract farming on food security.

Heterogeneity Analysis

This study also estimates the impact heterogeneity based on domicile area type, farmer's gender, and asset ownership.

Tabel 4. Impact Heterogeneity based on Village Type

Village Type	Number of Observations	ATT	SE	z-stat	p > |z|
Urban	84,753	-0.0074	0.0036	-2.05	0.041**
Rural	145,226	-0.0136	0.0039	-3.48	0.000***

Our findings indicate that contract farming enhances food security of farm households, irrespective of their location (urban or rural). However, the impact will be more significant for farm households residing in rural areas. Rural farm households experience nearly double the impact compared to urban areas. It might be attributed to the fact that rural farmers mostly rely on on-farm income as their main source of income. Hence, income earned through contract farming might serve as the primary source of income for most rural farmers. In addition, rural farmers, especially those living in isolated areas, may face difficulties locating markets for their agricultural products. Less than a third of rural farmers lack direct access to traditional markets. Hence, contract farming may be the only way to market their agricultural products and earn income. Therefore, it would be unsurprising if contract farming were to yield more advantages for them.

Table 8. Impact Heterogeneity Based on Farmer's Gender

Farmer's Gender	Number of Observations	ATT	SE	z-stat	p > |z|
Female	31,728	-0.0186	0.0099	-1.88	0.059*
Male	198,273	-0.0107	0.0028	-3.81	0.000***

We also found that, while the differences may not be substantial, contract farming has a greater impact on food security for households with female farmers. Women often play a crucial role in managing household income and expenditures. Women also are often responsible for food production and distribution within households. If the beneficiary is a female, the income generated is more likely to be used for the benefit of the entire household, including food and nutrition. According to Debela et al. (2022), if women lose authority over income through contract farming, it might have a detrimental impact on food security, as women are known to allocate more of their money towards purchasing nutritious food. There is a potential for contract farming income to be used for personal expenses, such as alcohol or meat, rather than being allocated towards healthy food, mainly if men assume the responsibility of managing the income.

Table 8. Impact Heterogeneity Based on Asset Ownership

Asset Ownership	Number of Observations	ATT	SE	z-stat	p > |z|
Own asset	152,923	-0.0071	0.0031	-2.27	0.023**
Do not own asset	77,108	-0.0219	0.0053	-4.12	0.000***

Finally, our research demonstrates that farmers who do not own land or livestock will experience greater improvements in food security as a result of contract farming. Farmers without assets experience roughly twice the impact. It can be attributed to the production risk encountered by farmers lacking land or livestock ownership. Farmers lacking land or livestock ownership must lease land or livestock for agricultural production. Consequently, the cost of production for these farmers will be higher than those who possess their own land or livestock, as they have to pay for rental expenses. They will suffer substantial financial losses if they cannot market their products and generate income successfully. Contract farming is potentially the optimal choice for guaranteeing their income. Therefore, contract farming will assume greater significance and yield more advantages.

Conclusion

Utilizing a causal inference approach with PSM and SITASI 2021 data covering all commodities and 34 provinces of Indonesia, this study empirically examines the impact of contract farming on food security of smallholder farm households in Indonesia. Food security is measured using FIES. Our findings show that contract farming has the potential to improve food security. Participating in contract farming may slightly decrease the probability of experiencing food insecurity. However, the impact is relatively minor. We demonstrated the robustness of our estimations of the impact of contract farming through the use of various alternative methods and placebo tests. However, it appears that our results are at some point influenced by unobserved selection bias. Contract farming may not have significant impacts on food security when this bias is present.

Concerning the mechanism, we conclude that the suggested positive income effect, as indicated by multiple prior studies, only explains two percent of the total impact on food security. The remaining should be explained by mechanisms unrelated to the income effect. Furthermore, our findings demonstrate that a rise in income does not guarantee an improvement in food security. Regarding impact heterogeneity, our findings show that the positive impacts are more evident among farmers who live in rural areas, are female, and do not possess land or livestock. These findings demonstrate the effectiveness of contract farming in promoting rural development, empowering women, and alleviating poverty.

Regarding the factors that influence contract farming participation, this study shows that location (urban/rural), market access, credit access, farmers' gender and education, membership in farmers' associations and cooperatives, household size, and exposure to agricultural training affect contract farming participation. The fact that participation is more prevalent among male farmers, those who have completed compulsory education, and those who reside in urban areas provides further evidence that discrimination continues to exist with regard to contract farming opportunities. The likelihood of engaging in contract farming was positively correlated with credit accessibility, membership in agricultural associations or cooperatives, and agricultural training.

It is important to note that this study has several limitations. First, this study may not adequately capture the prevalence and dynamics of informal contract farming, especially regarding informal

contract farming, such as verbal contracts. A dedicated and detailed study designed to examine informal contract farming is recommended, as it cannot be effectively captured through national-level surveys. Second, this study cannot properly confirm and measure the presence and extent of the income effect of contract farming due to the absence of income data. In order to assess the degree to which contract farming affects food security via the income effect, it is essential to employ actual income data. Therefore, it is essential to incorporate such data to understand better the relationship between contract farming, income, and food security.

From these results, several recommendations can be made. Given the findings indicating that contract farming has only a minor impact on food security, we recognize that while contract farming can function as a tool to improve food security, it should not be relied upon as the sole strategy, as it may not be adequate on its own. We advocate for a holistic approach to improve food security. It may entail assisting with a combination of farming methods, adoption of technology, and other income-generating efforts to strengthen the total capacity of households to withstand food insecurity. Given our findings, it is evident that contract farming has a greater impact on individuals who have been marginalized, such as those residing in rural areas, women, and those without assets. Therefore, it is recommended to prioritize targeted interventions that specifically address the implementation of contract farming for this marginalized group. In order to increase contract farming participation, the first thing that should be addressed is gender, education, and urban-rural discrimination in contract farming. Efforts should be made to create equal opportunities for all farmers. It can include providing support, access to land, inputs, and credit facilities specifically designed for female, uneducated, or rural farmers. Investing in training programs for farmers can help improve their understanding of contract farming and its benefits. Efforts also should be made to strengthen farmer associations and cooperatives.

Appendix

Appendix 1: Summary Statistics of The Variables

Variables	Obs	Mean	SD	Min	Max
Outcome variables					
Household is food insecure	230,189	0.0429	0.2027	0	1
Treatment variables					
Participate in contract farming	230,189	0.0164	0.1271	0	1
Participate in production contract	230,189	0.0092	0.0954	0	1
Participate in marketing contract	230,189	0.0137	0.1164	0	1
Covariates					
Living in urban areas	230,189	0.3687	0.4825	0	1
Has access to traditional market	230,189	0.3310	0.4706	0	1
Has access to credit	230,189	0.7770	0.4163	0	1
Female farmer	230,189	0.1385	0.3455	0	1
Farmer's age	230,189	52.2620	12.2750	11	98
Farmer completed compulsory School	230,189	0.3842	0.4864	0	1
Member of farmer association	230,189	0.1714	0.3768	0	1
Member of farmer cooperative	230,189	0.0207	0.1423	0	1
Own land or livestock	230,189	0.6648	0.4721	0	1
Number of members in the household	230,189	3.4501	1.5776	1	10
Number of trained members	230,189	0.0760	0.3189	0	9

Appendix 2: Mean of Variables Based on Contract Farming Participation

Variables	Participant		Non-participant		t-stat/chi-square[1]
	Mean	SD	Mean	SD	
(1)	(2)	(3)	(4)	(5)	(8)
Household is food insecure	0.0280	0.1651	0.0432	0.2032	0.000***
Living in urban areas	0.4328	0.4955	0.3676	0.4822	0.000***
Has access to traditional market	0.3008	0.4587	0.3315	0.4708	0.000***
Has access to credit	0.8127	0.3902	0.7764	0.4167	0.000***
Female farmer	0.1003	0.3004	0.1392	0.3461	0.000***
Farmer's age	51.886	11.895	52.268	12.281	0.050*
Farmer completed compulsory School	0.4220	0.4939	0.3835	0.4863	0.000***
Member of farmer association	0.3098	0.4625	0.1690	0.3748	0.000***
Member of farmer cooperative	0.0860	0.2804	0.0196	0.1386	0.000***
Own land or livestock	0.6828	0.4654	0.6645	0.4722	0.018**
Number of members in the household	3.5952	1.5624	3.4477	1.5778	0.000***
Number of trained members	0.1336	0.3950	0.0751	0.3174	0.000***

[1] The chi-square test for the contingency table and t-test were employed to assess the proportional and mean equality between contract participants and non-participants, respectively. T-test was applied to continuous variables. For the remaining categorical variables, the chi-square test was utilized.

Appendix 3. Balancing Test

Covariates	Mean		%Bias	t-test		Var.
	Treated	Control		t	p > |t|	Ratio
Living in urban areas	0.4327	0.4218	2.2	0.95	0.340	.
Has access to traditional market	0.3009	0.3002	0.1	0.07	0.948	.
Has access to credit	0.8127	0.8096	0.8	0.34	0.731	.
Female farmer	0.1003	0.0980	0.7	0.34	0.735	.
Farmer's age	51.8870	51.8040	0.7	0.30	0.761	0.99
Farmer completed compulsory School	0.4218	0.4215	0.1	0.02	0.981	.
Member of farmer association	0.3096	0.3120	-0.6	-0.22	0.826	.
Member of farmer cooperative	0.0857	0.0854	0.1	0.05	0.963	.
Own land or livestock	0.6827	0.6796	0.7	0.29	0.770	.
Number of members in the household	3.5951	3.5942	0.1	0.03	0.978	0.99
Number of trained members	0.1328	0.1360	-0.9	-0.34	0.736	0.82

Appendix 4: MHBOUNDS Result for Sensitivity Analysis

Gamma	Q_mh+	Q_mh+	p_mh+	p_mh+
1	4.50619	4.50619	3.30E-06	3.30E-06
1.05	5.01324	4.00183	2.70E-07	0.000031
1.1	5.49943	3.52313	1.90E-08	0.000213
1.15	5.96676	3.06748	1.20E-09	0.001079
1.2	6.41693	2.63265	7.00E-11	0.004236
1.25	6.85142	2.21668	3.70E-12	0.013323
1.3	7.27151	1.81790	1.80E-13	0.034540
1.35	7.67836	1.43482	8.10E-15	0.075669
1.4	8.07296	1.06617	3.30E-16	0.143174
1.45	8.45620	0.71078	0	0.238610
1.5	8.82888	0.36766	0	0.356565
1.55	9.19172	0.03588	0	0.485689
1.6	9.54535	0.18522	0	0.426530
1.65	9.89035	0.49519	0	0.310233
1.7	10.22720	0.79602	0	0.213010
1.75	10.55650	1.08830	0	0.138232
1.8	10.87860	1.37256	0	0.084944
1.85	11.19380	1.64929	0	0.049544
1.9	11.50270	1.91894	0	0.027496
1.95	11.80540	2.18191	0	0.014558
2	12.10230	2.43858	0	0.007373

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