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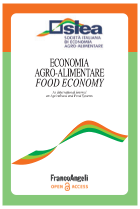

Impact of Contract Farming on the Technical Efficiency of Broiler Farmers in Indonesia

Rokhani[a], **Mohammad Rondhi**[*,a], **Ebban Bagus Kuntadi**[a], **Anik Suwandari**[a], **Rizky Yanuarti**[a], **Ahmad Fatikhul Khasan**[a], **Yasuhiro Mori**[b], **Takumi Kondo**[c]

[a] University of Jember, Indonesia
[b] Rakuno Gakuen University, Japan
[c] Hokkaido University, Japan

Abstract

The objective of this paper is to estimate the effect of Contract Farming (CF) on the efficiency of broiler farmers in Indonesia. We used comprehensive socio-economic data of 438 broiler farmers in Indonesia. To achieve the objective we used *causal-comparative research* (CCR) design. Stochastic frontier production (SFP) employed to estimate farm efficiency. Then, the effect of CF on farm efficiency was estimated using propensity score matching (PSM). The results showed that the average technical efficiency of broiler farmers is 74.22%. Participation in CF increases TE by 7.4% and chick productivity by 12.5%. A policy that promotes farmer participation in CF is likely to improve the efficiency of broiler farmers since it is associated with improved input use intensity.

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* *Corresponding author*: Mohammad Rondhi - University of Jember, Indonesia. E-mail: rondhi.faperta@unej.ac.id.

1. Introduction

The Indonesian broiler sector experiences significant growth due to increasing population and per capita incomes. The consumption of broiler meat is higher than that of other meat such as beef and lamb. Although per capita consumption of broilers in Indonesia is 5.6 kg per year, which is lower than in other broiler producing countries, the growth increased by 8.9% annually for the last ten years (Ministry of Agriculture, 2018). An increase in productivity is needed to meet the demand for broiler meat. Technological and institutional development promises means to increase broiler sector productivity since the broiler sector is primarily dominated by smallholder farmers that are characterized with limited capital, low technology, and fluctuating market (Rondhi *et al.*, 2020).

Contract farming (CF) can be regarded as a solution for market imperfections. Specifically, contracts are a result of three factors: quality, timing and risk (Patrick, 2004). Risk management is the application of risk reduction (Harwood *et al.*, 1999). Despite the uncertainty in production and price, risk in all decision-making processes of farming arrangements is very common (Adnan *et al.*, 2020; Kimura *et al.*, 2010). Agricultural processing industries often require a sustainable supply of specific quality or type of product. To avoid the uncertainty associated with the spot market they strike contracts with farmers to ensure prompt delivery of a highly specified product (MacDonald *et al.*, 2004; Prager *et al.*, 2020).

Formally CF is an institutional arrangement to coordinate smallholder farmers and overcome the limitations of small-scale farming. CF facilitates farm technology adoption (Mao *et al.*, 2019), improves the use of quality inputs (Abebe *et al.*, 2013), and enhances the dissemination of technical knowledge through the provision of extension services (Khan *et al.*, 2019). These features of CF lead to increase productivity and farm technical efficiency. Several studies have assessed the effect of CF on the efficiency of broiler farmers. Harianto *et al.* (2019) estimated the efficiency of 87 broiler farmers in West Sumatra (Indonesia) under formal and informal CF and found that farmers under formal CF have higher efficiency. Similarly, Begum *et al.* (2012) studied 75 broiler farmers in Gazipur (Bangladesh) and found that CF increases technical, allocative, and economic efficiency. However, a similar study conducted in Bangladesh (Kishoreganj district) using a sample of 90 farmers found no statistically different effect of CF on technical and allocative efficiency (Akhter & Rashid, 2008).

The results of previous studies indicate that the use of small-sample case studies may lead to biased finding. Small-sample data is often found in primary survey research. Simmons (2018) stated that smaller sample sizes get decreasingly representative of the entire population and could affect the reliability of a survey's results because it leads to a higher variability, which may lead to bias as the result of non-response. Non-response occurs when some subjects do not have the opportunity to participate in the survey (Prince, 2012). Moreover, Suwandari *et al.* (2020) stated that the use of small-sample case study is not suitable as a basis for policymaking at a national level. Hence, this study aimed to analyze the effect of participation in CF on broiler farmers technical efficiency using comprehensive and nationally representative data. This study has two significant contributions. First, it will provide necessary information for policymakers in the Indonesian broiler sector, especially on the effort to improve the productivity sector. Second, the study on the effect of CF on-farm performance in developing countries is well established, but those who utilize nationally representative data is scarce. Thus, this study will contribute to the literature of CF by providing insight into how CF affects nation-wide smallholder farmer performance in developing countries.

2. Materials and methods

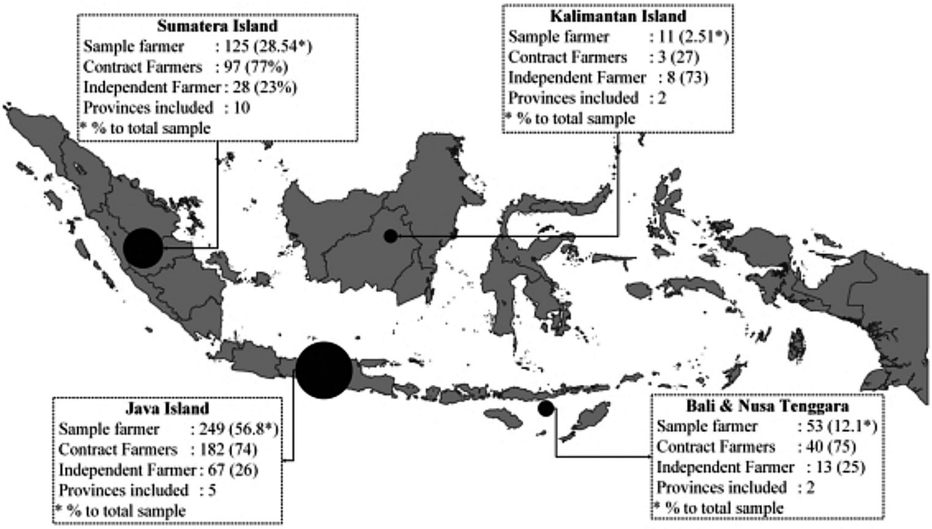
Research Design

This study used *causal-comparative research* (CCR) design. CCR is a quantitative nonexperimental research that investigates or compares two or more groups in terms of a cause (or independent variable) that has already happened (Creswell, 2014). In this study, the aim is to investigate how participation in contract farming (the cause/independent variable) affects the technical efficiency of broiler farmers in Indonesia. The study consisted of two steps. First, the technical efficiency of broiler farmers was estimated using stochastic frontier analysis (SFA). Second, the impact of CF participation on the technical efficiency of broiler farmers was estimated using propensity score matching (PSM) analysis. Furthermore, the impact of CF on inputs use intensity (feeding intensity, labor workload, vaccine, vitamin, and medication intensity) and farm performance (feed conversion ratio and chick productivity) were estimated. The next section describes the data used in the study.

Data

The research employs nationally representative data of Indonesian broiler farmers. The data was the result of *Survei Rumah Tangga Usaha Peternakan 2014* (STU2014) created by the BPS (Indonesian Statistical Agency). STU2014 used a two-stage stratified sampling design (BPS, 2016). The first stage was aimed to select a sample block from the *block sampling frame* (block population) using *systematic probability proportional to size* method based on the number of the farmer in each block. The eligible sample block is those with the size of at least ten farmers. Then, the second stage was aimed to select sample farmer from the *farmer sampling frame* (farmer population) using a *systematic sampling* method. The eligible sample farmer is those who have at least 100 birds. Figure 1 shows the sample distribution.

Figure 1 - Distribution of sample farmers



The original STU2014 data consists of 1142 farmers where 513 (44.9%) are contract farmers and 629 (56.11%) are independent farmers both with varied bird population number. However, this study used farmers with the bird population of 3000/production cycle or more. The purpose of this selection is to create a comparable group between the contract and independent group. So, the final data consist of 438 farmers where 322 (74%) are contract farmers and 116 (26%) are independent farmers. The data has an unbalanced panel structure with each farmer has production cycle ranging between one to twelve cycles. Then, the average value for each farmer was used to create the final data consisting of 438 farmers. The variables used in this study were grouped into two categories. First, the variables used to estimate the technical efficiency (SFA) and second, the variables used to estimate the impact of CF participation on TE (PSM).

Analytical Procedure

This study used the stochastic frontier production function (SFPF) to estimate the technical efficiency of broiler farmers (**first step**). The SFPF estimate the actual farm production relative to its highest potential production. Thus, the estimated TE values inform the potential of attainable production in the sector. The estimation of SFPF was divided into individual and pooled estimation. The former analyzed the contract and independent group separately, while the latter estimated the whole sample. The *Cobb-Douglass* production model was used to estimate the SFPF. Equation 1 specifies the estimation formula of SFPF (Mahaboob *et al.*, 2019).

$$Y = \beta_0 X_1^{\beta 1} X_2^{\beta 2} \ldots X_n^{\beta n} e^{\varepsilon i} \quad (1)$$

Where Y is the annual broiler production for farmer i, β_0 is the constant, β_i is the input coefficient to be estimated, X_i is the farm input (variables coded SFA), and e_i is the regression error term. Then, the technical efficiency was estimated using the formula in Equation 2 (Porcelli, 2009).

$$TE = Q_i \Big/ \left[\exp\,(x_i, \beta)\right] = \exp\,(-u_i) \quad (2)$$

Where TE is technical efficiency of farmer i, Q_i is output for farmer i, and $exp\ (x_i, \beta)$ is the estimated output for farmer i, and u_i is the technical inefficiency of farmer i.

In the **second step**, we used PSM analysis to estimate the average treatment effect (ATT) of CF participation on the technical efficiency of broiler farmers. The PSM analysis was consisted of several stages (Pan dan Haiyan, 2015): creating model to estimate propensity score, choosing matching algorithm, a test on common support area both for treatment and control group, and assessing matching quality. Logistic regression model (LRM) was used to estimate the propensity score of farmers. The propensity score estimation was used to create a comparable group between the contract and independent farmers. There are seven variables used to generate the propensity score (variables coded PSM). Equation 2 specifies the LRM.

$$Y_i = 1\text{n}\left(\frac{p_i}{1 - p_i}\right) = \frac{e^{\sum_{i=0}^{?} b_i x_i}}{1 + e^{\sum_{i=0}^{?} b_i x_i}},\ i = 1,\ldots,7 \quad (3)$$

Where Y_i is farmer participation in contract farming (1 = contract farmers, 0 = independent farmers) and x_i are the independent variables. The used matching algorithms are Nearest Neighborhood Matching (NNM), Kernel Matching (KM), and Radius Matching (RM). The used of different matching method will be helpful for the interpretation of different effect estimates found within the analysis (Fullerton *et al.*, 2016; Yanuarti *et al.*, 2019).

The next stage is to test on common support area. The component is essential for the reason that it rules out the phenomenon of perfect predictability of D given X (Caliendo & Kopeinig, 2008):

$$0 < P\,(D = 1|X) < 1 \tag{4}$$

It ensures that persons with the same X values have a positive probability of being both participants and non-participants (J. Heckman *et al.*, 1999).

For the record, PSM doesn't solve the bias derived from unobservable variables, which could characterise the treated and the control groups differently. PSM eliminates a substantial portion of the sample and may limit the ability to make valid generalizations outside common support (Cram *et al.*, 2009; J.J. Heckman *et al.*, 1998). Moreover, PSM does not address most concerns relating to self-selection or endogeneity that present the largest obstacles to proper identification (i.e., the inability to accurately identify and measure all constructs relating to treatment and outcome) (Shipman *et al.*, 2016).

The following stage in the PSM analysis is the estimation of average treatment effect on the treated (ATT). In this case, the treatment is participation in CF. Thus contract farmers belong to the treated group, and independent farmers belong to the control group. ATT is the difference in the value of outcome variables between the treated and control group. We made two assumptions in the PSM analysis, the overlapping and conditional-independence assumptions. The former assumes that each farmer has a positive probability of participating in CF, and the latter assumes that the common factors that affect the outcome variable are observable. Equation 3 specifies the formula to estimate the ATT.

$$ATT = E\left(TE_{1j} \,\middle|\, D_j = 1, p(x_{ij})\right) = E\left(TE_{0j} \,\middle|\, D_j = 0, p(x_{ij})\right) \tag{5}$$

Where TE_{1j} is the technical efficiency of contract farmer j, and x_{ij} are farmer's observable characteristics. The nearest-neighbourhood matching (NNM) algorithm was used in estimating Equation 3 using STATA software. We performed a balance test to evaluate the robustness of the estimation results.

3. Results

Technical efficiency of broiler farmers in Indonesia

Table 1 provides descriptive statistics of overall farmers profile which include all variables used in the estimation of TE. Contract farmer (CTF), on average, has higher production (11056.05 kg/cycle) than that of independent farmer (10976.60 kg/cycle) (IF). Consequently, CTF recorded a relatively similar input uses such as chick, feed, VMV (vaccine, medication, and vitamin), and house size. The contract farmer has a slightly lower stocking density (13.27 birds/sqm) than that of the independent farmer (22.04 birds/sqm). However, both CTF and IF, on average, use the same number of laborers.

Table 1 - Descriptive statistics of overall farmers profile include all variables used in the estimation of technical efficiency

Group	Variable	Independent farmers			Contract farmers		
		Mean	**S.D.**	**Freq.**	**Mean**	**S.D.**	**Freq.**
SFA	Production (kg)	10976.60	12194.16		11056.05	12129.40	
SFA	Chick (bird)	7066.42	6763.13		7074.73	6703.50	
SFA	Feed (kg)	12403.03	13316.59		12459.68	13194.23	
SFA	VMV (kg)	737.67	2716.45		721.40	2677.89	
SFA	VMV (liter)	167.58	957.55		174.71	946.78	
SFA	VMV (cc)	1870.43	6792.57		1959.73	6836.75	
SFA	VMV (doses)	671.13	2855.81		651.23	2815.32	
SFA	Labor (number of labor)	2.81	2.06		2.79	2.04	
SFA	House size (sqm)	927.76	1397.29		927.50	1381.07	
SFA/PSM	Stocking density (bird/sqm)	22.04	24.05		13.27	16.01	

Table 2 summarizes the estimation results of the production function in Equation 1. The results show that four out of nine factors significantly affect technical efficiency. Chicks and feed have positive and significant effect while broiler house size and stocking density have a negative and significant effect on technical efficiency. In contrast, labor and all types of VMV have no statistically significant effect. The gamma values, sigma-squared and log-likelihood show that the estimation results are robust.

The average technical efficiency of broiler farmers is 74.22% (Table 3). However, comparing the technical efficiency of contract and independent farmers indicates that the former group has higher efficiency. Technical Efficiency (TE) indicated the relationship between actual production and potential production, if the resources are well used, where 1 = technically efficient (100% score) and 0=technically inefficient (< 100%) (Akazili *et al.*, 2008).

Table 2 - The estimation result of cobb-douglas production function

Variables	β	S.E	t value
Ln Chicks	9.83***	2.63	3.74
Ln Feed	0.02***	0.01	2.23
Ln Labor	-0.03 ns	0.02	-1.42
Ln Household size	-8.82***	2.63	-3.35
Ln Stocking density	-8.88***	2.63	-3.38
Ln VMV (kg)	-0.0024ns	0.00	-0.96
Ln VMV (liter)	-0.0005ns	0.00	-0.14
Ln VMV (cc)	-0.0018ns	0.00	-0.75
Ln VMV (doses)	0.0003ns	0.00	0.10
Constant	0.59***	0.20	2.95
Robustness Check			
sigma-squared	0.20	0.02	10.40
gamma	0.89	0.03	31.80
Log-likelihood	-68.73		

Note: *** significant at 1%, ** significant at 5%, * significant at 10%, ns not significant.

Table 3 - Technical efficiency estimates of broiler farmers

Estimates Of Technical Efficiency	Contract	Independent	Pooled
< 50%	18 (5,59%)	21 (18,10%)	39 (8,90%)
50-70%	57 (17,70%)	39 (33,62%)	96 (21,92%)
70.01-80%	88 (27,33%)	23 (19,83%)	111 (25,34%)
80.01-90%	132 (40,99%)	28 (24,14%)	160 (36,53%)
>90%	27 (8,39%)	5 (4,31%)	32 (7,31%)
Mean	76,62	67,564	74,22
Maximum	95,50	95,00	22,59
Minimum	25,40	22,59	95,50
N	322	116	438

The average technical efficiency of contract farmers is 76.62% and 67.56% for the independent farmers. The majority of independent farmers operate at a lower-level efficiency. The percentage of independent farmers who operate below 70% efficiency is 51.72%, much higher than that of contract farmers which only 23.29%. In contrast, the percentage of contract farmers who operate at higher-level efficiency is higher than those of independent farmers. 40.99% of contract farmers operate at a 70-80% efficiency level and 8.39% of them operate at efficiency level higher than 90%. Meanwhile, only 24.14% of independent farmers operate at 70-80% efficiency level and 4.31% operates at higher than 90% efficiency level. The results indicates that contract farmers, on average, have a higher technical efficiency than that of independent farmers. However, a propensity score analysis is required to make a robust comparison.

The estimation results of production function demonstrate that chicks and feed have a positive and statistically significant effect on broiler production. In contrast, broiler house size and stocking density have a negative and statistically significant effect on broiler production. Chicks has a coefficient value of 9.83 which means that a 1% increase in chick quantity will increase production by 9.83%. Similarly, interpretation applies to feed with coefficient of 0.02 which means that a 1% increase in the amount of feed will increase production by 0.02%. However, broiler house size and stocking density have coefficient values of -8.82 and -8.88 respectively. That values mean that a 1% increase in broiler house size and stocking density will decrease production by 8.82 and 8.88% respectively. The results suggest that chick, broiler house size and stocking density have the high production elasticity.

Chick and feed are crucial inputs in broiler farming. Ullah *et al.* (2019) who studied broiler farming at Charsadda district, on Khyber Pakhtunkhwa, in Pakistan found that DOC and feed have partial production elasticities of 0.45 and 0.21% respectively. Similar results were also found in the studies of broiler farming in Punjab, Pakistan (Ali *et al.*, 2014), in Mampong Municipality, Ghana (Ahiale *et al.*, 2019), and in Limapuluh Kota, West Sumatera (Pramita *et al.*, 2018). Labor is not significant to the production of both contract and independent farmers. The sample in this study used farmers with similar farm size (population larger than 3000 birds/cycle) and implies that both group have similar technological adoption and inputs quality which reduces labor intensity in the production stages (Ruml & Qaim, 2019). In contrast, broiler house size and is significant to the production of broiler farmers. The arrangement of broiler CF requires farmers to provide a house with specific minimum capacity and specification (Shumba, 2013).

Stocking density significantly decreases farm technical efficiency. The estimation result reveals that an increase of stocking density by 1% decreases farm technical inefficiency by 8.8%. Several studies have shown that stocking density significantly affects production, health, and welfare of broiler farm. (Weimer *et al.*, 2020) found that broilers raised in high stocking density have a higher prevalence of hock burn. Similarly, Li *et al.* (2019) found that high stocking density reduces muscle and bone growth of broiler which resulted in reduced production. Vaccine, medication, and vitamin (VMV) has no significant effect on technical efficiency. The use of VMV is crucial in improving broiler health and productivity, such as demonstrated by Almeida Paz *et al.* (2019) and Aye Cho *et al.* (2020). However, the non-significant effect of VMV might be caused by the characteristics of farmers in this study.

The impact of CF on the technical efficiency of broiler farmers in Indonesia

Table 4 provides descriptive statistic for variables used in logistic regression in order to asses impact of CF on TE. CTF attained higher education than IF, although both groups, on average, have similar age and household size. The contract farmer has longer broiler farming experience than those independent farmers. Also, the contract group has a higher percentage of farmers who receive the agricultural extension and cooperative services and participate in the farmer group. Factors that affect farmer decision to participate in CF obtained from Rondhi *et al.* (2020) who utilize similar data. There are six variables in this category: education, house size, chick, cooperative services, agricultural extension, and farmer group membership.

Table 4 - Descriptive statistics of overall farmers profile include all variables used in the estimation of logistic regression

Group	Variable	Independent farmers			Contract farmers		
		Mean	S.D.	Freq.	Mean	S.D.	Freq.
PSM	Education (yr)	10.26	5.33		10.30	5.34	
PSM	Age (yr)	44.82	10.69		44.76	10.70	
PSM	Household Size (person)	4.39	1.55		4.39	1.54	
PSM	CF Participation						
	Independent farmers			116(26.48)			0(0)
	Contract farmers			0(0)			322(73.52)
PSM	Farming experience						
	<1 year			8(6.8)			16(4.9)
	1-5 years			33(28.4)			154(47.5)
	5-10 years			39(33.6)			86(26.7)
	>10 years			36(31)			66(20.4)
PSM	Agricultural extension						
	not received			99(85.3)			192(59.6)
	received			17(14.7)			130(40.4)
PSM	Cooperative service						
	not received			106(91)			303(94)
	received			10(9)			19(6)
PSM	Farmer group membership						
	not member			107(92.2)			277(86)
	member			9(7.8)			45(14)
	Sample size (N)			116			322

The estimation of LRM (Table 5) in the first trial demonstrates that farmer's education, farming experience, access to agricultural extension and cooperative, and stocking density have a significant effect on participation in contract farming. Furthermore, the propensity score generated from this model passed the balance test and is suitable for further analysis. However, we removed the institutional variables (agricultural extension and cooperative services) since both variables are correlated with the participation in contract farming. Thus, we selected variables that have direct effect on technical efficiency: farmer's education, farming experience, and stocking density. The second model satisfied the balancing property and made a relevant group for comparison. The log-likelihood of the LRM also demonstrates that the estimation results are robust.

Table 5 - Estimation results of logistic regression model

Variable	**1st trial**			**2nd trial**		
	β	**S.E.**	**z**	**β**	**S.E.**	**z**
Education	0.05	0.02	2.32**	0.05	0.02	2.43**
Age	0.01	0.01	1.13ns		*Removed*	
Household size	-0.05	0.07	-0.75ns		*Removed*	
Farming experience	-0.40	0.13	-3.07***	-0.33	0.12	-2.67
Agricultural extension	1.34	0.30	4.45***		*Removed*	
Cooperative service	-0.79	0.44	-1.78*		*Removed*	
Farmer group membership	0.37	0.42	0.37ns		*Removed*	
Stocking density	-0.02	0.00	-3.75***	-0.02	0.00	3.98***
Constant	0.97	0.69	1.42ns	1.80	0.45	3.98***
Robustness Check						
Balance test		*Satisfied*			*Satisfied*	
Pseudo R^2		0.12			0.06	
Log-likelihood		-222.38***			-237.85***	

Note: *** significant at 1%, ** significant at 5%, * significant at 10%, ns not significant.

The analysis proceeded to the estimation of ATT (Table 5), which shows that participation in CF increases technical efficiency by 7.4%. The results also demonstrate that contract farmers have higher feeding and VMV intensity than those of independent farmers. Contract farmers allocate 1.31 kg feed/chick, significantly higher than that of independent farmers (1.30 kg feed/chick). Similarly, the contract farmers used higher VMV of 96.3 kg/1000 chicks, significantly higher than that of independent farmers (62.4 kg/1000 chicks). However, both contract and independent farmers do not differs significantly in the use of labor, VMV (l), and VMV (cc). The analysis also estimate the productivity difference between contract and independent farmers. There are two variables used to estimate the productivity of broiler farmers, feed conversion ratio and chick productivity. Contract and independent farmers do not differs significantly in term of feed conversion ratio. The contract farmers recorded higher chick productivity than that of independent farmers. On average, contract farmers produce 1.61 kg per chick, significantly higher than that of independent farmers 1.41 kg per chick.

Figure 2 represent the common support area related to propensity score estimation both for broiler farmer who participate in CF and not. Both top and bottom of the diagram show the distribution of propensity scores for participants and CF participants. The Y axis represents the propensity values of the two groups. According to the figure, it is known that the distribution of propensity scores for the two groups is in the common support area, which is between 0 to 1 or between the minimum and maximum values obtained, as stated by Caliendo & Kopeinig (2008). This means that each respondent has a positive and good probability of being a participant and non CF participant.

Figure 2 - Distribution of propensity scores in the common support area

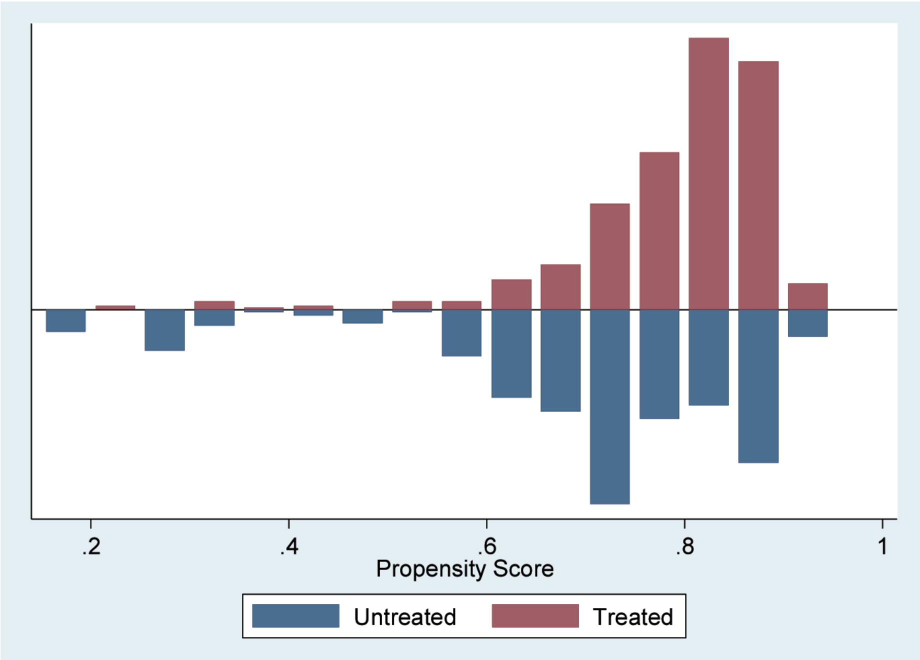


Table 6 display the assessment of matching quality using NNM, KM, and RM. Table 6 showed a decrease in the mean bias and median bias before matching compared to after matching using NNM, RM, and KM. The

Table 6 - Balance Test Results for Propensity Scores using NNM, RM, KM

Matching Algorithm	Pseudo-R²		P > Chi²		Mean Bias		Median Bias	
	before	after	before	after	before	after	before	after
Technical Efficiency								
NNM	0.073	0.024	0.000	0.000	36.2	16.1	28.7	12.6
KM	0.073	0.005	0.000	0.001	36.2	8.6	28.7	6.8
RM	0.073	0.022	0.000	0.000	36.2	17.2	28.7	16.0
Feed conversion ratio								
NNM	0.073	0.025	0.000	0.000	36.2	16.1	28.7	12.6
KM	0.073	0.005	0.000	0.001	36.2	8.6	28.7	6.8
RM	0.073	0.022	0.000	0.000	36.2	17.2	28.7	16.0
Productivity								
NNM	0.073	0.025	0.000	0.000	36.2	16.1	28.7	12.6
KM	0.073	0.005	0.000	0.001	36.2	8.6	28.7	6.8
RM	0.073	0.022	0.000	0.000	36.2	17.2	28.7	16.0
Feeding intensity								
NNM	0.073	0.025	0.000	0.000	36.2	16.1	28.7	12.6
KM	0.073	0.005	0.000	0.001	36.2	8.6	28.7	6.8
RM	0.073	0.022	0.000	0.000	36.2	17.2	28.7	16.0
Labor workload								
NNM	0.073	0.025	0.000	0.000	36.2	16.1	28.7	12.6
KM	0.073	0.005	0.000	0.001	36.2	8.6	28.7	6.8
RM	0.073	0.022	0.000	0.000	36.2	17.2	28.7	16.0
VMV intensity (kg/1000 birds)								
NNM	0.026	0.009	0.027	0.089	12.8	12.1	22.7	12.8
KM	0.026	0.001	0.027	0.807	22.8	3.5	22.7	2.5
RM	0.026	0.014	0.027	0.015	22.8	13.9	22.7	9.7
VMV intensity (l/1000 birds)								
NNM	0.026	0.009	0.027	0.089	22.8	12.1	22.7	12.8
KM	0.026	0.001	0.027	0.807	22.8	3.5	22.7	2.5
RM	0.026	0.014	0.027	0.015	22.8	13.9	22.7	9.7
VMV intensity (cc/1000 birds)								
NNM	0.026	0.009	0.027	0.089	22.8	12.1	22.7	12.8
KM	0.026	0.001	0.027	0.807	22.8	3.5	22.7	2.5
RM	0.026	0.014	0.027	0.015	22.8	13.9	22.7	9.7

distribution of the covariates is balanced if the mean and median values of the bias between the treatment and control groups decrease after matching (Rosenbaum & Rubin, 1985). The analysis value of mean and median have decreased after matching, so it can be said that the distribution of the covariates is balanced.

The pseudo-R^2 value describes the ability of the covariates to explain the possibility of farmers participating in CF. Theoretically, after the matching process, pseudo-R^2 value must be lower (Sianesi, 2004). In Table 5, the pseudo-R^2 value decreased for each pairing process. This means that there was no difference in the distribution of the covariates between the treatment and control groups. So from the results of the covariate balance analysis that has been carried out, it can be concluded that the matching process has succeeded in balancing the covariate distribution between the two groups. This can be interpreted that the difference that may occur in farmers' income is caused by the treatment, namely the participation of farmers in CF.

The ATT estimate for technical efficiency demonstrates that participation in CF, on average, increases broiler farmers technical efficiency on each matching process by 5,316%; 6.056%; 6.518% respectively from NNM, KM, RM. Furthermore, contract farmer has higher chick productivity than that of independent farmer. The positive value of ATT for chick productivity demonstrates that contract farmer has higher production than that of independent farmer. The improvement in technical efficiency of contract farmers is associated with higher use of feeding and VMV intensity. The positive ATT value for feeding intensity indicates that contract farmers used more feed for each chick placed in each production cycle. Similarly, the positive value of ATT for VMV (kg and l) intensity demonstrates that contract farmers used more VMV that of independent farmers. However, CF participation does not affect feed conversion ratio in all matching method and labor workload in RM matching). The results of this study confirm the findings of previous studies, such as Harianto *et al.* (2019) and Begum *et al.* (2012). Both of these studies associated the improved technical efficiency of contract farmers to improved access to quality inputs which is confirmed by the finding of this study.

Contract farming arrangements address the problem of liquidity and enhance access and better use of agricultural inputs in production. Farmers who are contracted attain higher technical efficiency because as part of their contract farming arrangements, the contractor provides extension support and specialized farm training to improve farm productivity. Le Ngoc (2018) found that participation in CF increases farm TE compared to conventional farming practices. (Mishra & Dey, 2018) state that farmer participation in CF significantly increases TE.

Furthermore, Benalywa *et al.* (2019) stated that government intervention on broiler production is needed in order to make the broiler industry efficient and enhance its competitiveness. Putri & Rondhi (2020) suggest to provide facilities such as technical counseling and coaching for farmer who applied

Table 7 - The estimation results of PSM analysis

Variable	**ATT**		
	NNM	**KM**	**RM**
Technical efficiency (%)	5.316	6.056	6.518
Feed conversion ratio (kg feed/kg bird)	-0.106	-0.042	-0.0027
Productivity (kg/chicks)	0.170	0.196	0.213
Feeding intensity (kg feed/chicks)	0.094	0.232	0.314
Labor workload (bird/person)	753.68	282.091	-61.836
VMV intensity (kg/1000 birds)	68.360	78.726	89.456
VMV intensity (l/1000 birds)	115.737	117.193	115.524
VMV intensity (cc/1000 birds)	-5540.21	-2502.405	-1114.86

Note: NNM (Nearest neighborhood matching), KM (Kernel matching), RM (Radius matching).

CF. Suwarta & Hanafie (2021) added that in order to reduce the cost of cultivating broiler chickens, farmers need to be assisted by setting competitive prices for DOC and feed. Broiler chicken contract farming should be disseminated to other farm communities in rural areas in view of the fact that CF has improved the welfare of the rural community through increased income (Setiadi *et al*., 2022).

4. Conclusions

This study aimed to estimate the impact of participation in contract farming on the technical efficiency of Indonesian broiler farmers. This study found that participation in contract farming increases the technical efficiency of broiler farmers by 7.4% and chick productivity by 12.5%. The improvement in technical efficiency of contract farmers is the result of increased access to farm inputs. Contract farmers used more feed, VMV, and lower stocking density than independent farmers. An improvement in feeding and VMV intensity as well as stocking density is crucial for maximizing the attainable production potential of Indonesian broiler sector. Furthermore, increasing farmer participation in contract farming is imperative since it associated with input use (feed and VMV) intensity and stocking density.

There is a limitation in this study. This study discusses impact of farmers' participation in CF with national dataset but is not be able to linked and capture the possibility of different region characteristic that might influence farmers' decision and TE. To have to do that, it would be necessary to conduct a primary data collection in order to strengthen the secondary national dataset. Further studies need to be carried out in this field, in particular with reference to the possibility of significant efficiency differences by farmers from different regions.

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References

Abebe, G.K., Bijman, J., Kemp, R., Omta, O., & Tsegaye, A. (2013). Contract farming configuration: Smallholders' preferences for contract design attributes. *Food Policy*, *40*, 14-24. doi: 10.1016/j.foodpol.2013.01.002.

Adnan, K.M.M., Ying, L., Ayoub, Z., Sarker, S.A., Menhas, R., Chen, F., & Yu, M.M. (2020). Risk management strategies to cope catastrophic risks in agriculture: The case of contract farming, diversification and precautionary savings. *Agriculture (Switzerland)*, *10*(8), 1-16. doi: 10.3390/agriculture10080351.

Ahiale, E.D., Abunyuwah, I., & Yenibehit, N. (2019). Technical Efficiency Analysis of Broiler Production in the Mampong Municipality of Ghana. *Journal of Economics and Sustainable Development*, *10*(14), 152-158. doi: 10.7176/JESD.

Akazili, J., Adjuik, M., Chatio, S., Kanyomse, E., Hodgson, A., Aikins, M., & Gyapong, J. (2008). What are the Technical and Allocative Efficiencies of Public Health Centres in Ghana? *Ghana Medical Journal*, *42*(4), 149-155.

Akhter, S., & Rashid, M. (2008). Comparative Efficiency Analysis of Broiler Farming Under Aftab Bahumukhi Farm Limited Supervision and Farmers’ *Own Management. Progressive Agriculture*, *19*(2), 195-204. doi: 10.3329/pa.v19i2.16962.

Ali, S., Ali, S., & Riaz, B. (2014). Estimation of Technical Efficiency of Open Shed Broiler Farmers in Punjab, Pakistan: A Stochastic Frontier Analysis. *Journal of Economics and Sustainable Development*, *5*(7), 79-88.

Almeida Paz, I.C. de L., de Lima Almeida, I.C., de La Vega, L.T., Milbradt, E.L., Borges, M.R., Chaves, G.H.C., dos Ouros, C.C., Lourenço da Silva, M.I., Caldara, F.R., & Andreatti Filho, R.L. (2019). Productivity and Well-Being of Broiler Chickens Supplemented With Probiotic. *Journal of Applied Poultry Research*, *28*(4), 930-942. doi: 10.3382/japr/pfz054.

Aye Cho, T.-Z., Sadiq, M.B., Srichana, P., & Anal, A.K. (2020). Vitamin D3 enhanced intestinal phosphate cotransporter genes in young and growing broilers. *Poultry Science*, *99*(4), 2041-2047. doi: 10.1016/j.psj.2019.11.038.

Begum, I.A., Alam, M.J., Buysse, J., Frija, A., & van Huylenbroeck, G. (2012). Contract farmer and poultry farm efficiency in Bangladesh: A data envelopment analysis. *Applied Economics*, *44*(28), 3737-3747. doi: 10.1080/00036846.2011.581216.

Benalywa, Z.A., Ismail, M.M., Shamsudin, M.N., & Yusop, Z. (2019). Assessing the comparative advantage of broiler production in Peninsular Malaysia using policy analysis matrix. *Tropical Animal Health and Production*, *51*(2), 321-327. doi: 10.1007/s11250-018-1690-8.

BPS (2016). *Survei Rumah Tangga Usaha Peternakan 2014*.

Caliendo, M., & Kopeinig, S. (2008). Some Practical Guidance For The Implementation Of Propensity Score Matching. *Journal of Economic Surveys*, *22*(1), 31-72. doi: 10.1111/j.1467-6419.2007.

Cram, D.P., Karan, V., & Stuart, I. (2009). Three threats to validity of choice-based and matched-sample studies in accounting research. *Contemporary Accounting Research*, *26*(2), 477-516.

Creswell, J.W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). SAGE Publications, Inc.

Fullerton, B., Pöhlmann, B., Krohn, R., Adams, J.L., Gerlach, F.M., & Erler, A. (2016). The Comparison of Matching Methods Using Different Measures of Balance: Benefits and Risks Exemplified within a Study to Evaluate the Effects of German Disease Management Programs on Long-Term Outcomes of Patients with Type 2 Diabetes. *Health Services Research*, *51*(5), 1960-1980. doi: 10.1111/1475-6773.12452.

Harianto, H., Kusnadi, N., & Paramita, D.A. (2019). The Impact of Vertical Integration Intensity on Broiler Farms Technical Efficiency: The Case of Contract Farming in West Sumatera. *Tropical Animal Science Journal*, *42*(2), 167-174. doi: 10.5398/tasj.2019.42.2.167.

Harwood, J.L., Heifner, R., Coble, K., Perry, J., & Somwaru, A. (1999). Managing risk in farming: concepts, research, and analysis. *Economic Research Service, USDA, Report No. 774*, *774*, report n. 774.

Heckman, J.J., Ichimura, H., & Todd, P. (1998). Matching As An Econometric Evaluation Estimator. *The Review of Economic Studies*, *65*(2), 261-294. doi: 10.1111/1467-937X.00044.

Heckman, J., LaLonde, R., & Smith, J. (1999). The economics and econometrics of active labor market programs. In: O. Ashenfelter & D. Card (Eds.), *Handbook of Labor Economics* (1st ed., Vols. 3, Part A, pp. 1865-2097). Elsevier. -- https://econpapers.repec.org/RePEc:eee:labchp:3-31.

Khan, M.F., Nakano, Y., & Kurosaki, T. (2019). Impact of contract farming on land productivity and income of maize and potato growers in Pakistan. *Food Policy*, *April*, 1-12. doi: 10.1016/j.foodpol.2019.04.004.

Kimura, S., Antón, J., & Lethi, C. (2010). Farm Level Analysis of Risk and Risk Management Strategies and Policies Farm Level Analysis of Risk. *Risk Management*, *26*, 1-20. doi: 10.1787/5kmd6b5rl5kd-en.

Le Ngoc, H. (2018). Contract farming effects on technical efficiency of the export-oriented rice production sector in Vietnam. *International Association of Agricultural Economists*. doi: 10.22004/ag.econ.277409.

Li, X.M., Zhang, M.H., Liu, S.M., Feng, J.H., Ma, D.D., Liu, Q.X., Zhou, Y., Wang, X.J., & Xing, S. (2019). Effects of stocking density on growth performance, growth regulatory factors, and endocrine hormones in broilers under appropriate environments. *Poultry Science*, *98*(12), 6611-6617. doi: 10.3382/ps/pez505.

MacDonald, J.M., Perry, J., Ahearn, M.C., Banker, D., Chambers, W., Dimitri, C., Key, N., Nelson, K.E., & Southard, L.W. (2004). Contracts, Markets, and Prices: Organizing the Production and Use of Agricultural Commodities. In: *United States Department of Agriculture*. doi: 10.2139/ssrn.754986.

Mahaboob, B., Ajmath, K.A., Venkateswarlu, B., Narayana, C., & Praveen, J.P. (2019). On Cobb-Douglas production function model. *AIP Conference Proceedings*, *2177*(December), 1-5. doi: 10.1063/1.5135215.

Mao, H., Zhou, L., Ifft, J., & Ying, R.Y. (2019). Risk preferences, production contracts and technology adoption by broiler farmers in China. *China Economic Review*, *54*, 147-159. doi: 10.1016/j.chieco.2018.10.014.

Ministry of Agriculture. (2018). *Agricultural Statistics* (A.A. Susanti & B. Waryanto (Eds.)). Center for Agricultural Data and Information System (Ministry of Agriculture).

Mishra, P.K., & Dey, K. (2018). Governance of agricultural value chains: Coordination, control and safeguarding. *Journal of Rural Studies*, *64*(January), 135-147. doi: 10.1016/j.jrurstud.2018.09.020.

Patrick, I. (2004). Contract farming in Indonesia: Smallholders and agribusiness working together. *ACIAR Technical Reports*, *54*(54).

Porcelli, F. (2009). Measurement of Technical Efficiency. A brief survey on parametric and non-parametric techniques. *Retrieved February*, *January*, 1-27.

Prager, D., Burns, C., Tulman, S., & Macdonald, J. (2020). Farm Use of Futures, Options, and Marketing Contracts. *Economic Information Bulletin*, *EIB 219*, 1-27.

Pramita, D.A., Kusnadi, N., & Harianto, H. (2018). Efisiensi Teknis Usaha Ternak Ayam Broiler Pola Kemitraan Di Kabupaten Limapuluh Kota. *Jurnal Agribisnis Indonesia*, *5*(1), 1. doi: 10.29244/jai.2017.5.1.1-10.

Prince, M. (2012). Epidemiology. *Core Psychiatry: Third Edition*, 115-129. doi: 10.1016/B978-0-7020-3397-1.00009-4.

Putri, A.T.R., & Rondhi, M. (2020). Contract farming and the effect on price risk in broiler farming. In: M. Rondhi, & H.S. Addy (Eds.), *International Conference on Agricultural and Life Science* (Vol. 05002, pp. 1-5). E3S Web of Conferences. doi: 10.1051/e3sconf/202014205002.

Rondhi, M., Aji, J., Khasan, A., Putri, A., & Yanuarti, R. (2020). Risk Aversion, Risk Preference and Farmers' Decision to Participate in Broiler Contract Farming: A Case Study in Jember, Indonesia. *Caraka Tani: Journal of Sustainable Agriculture*, *35*(1), 98. doi: 10.20961/carakatani.v35i1.37964.

Rosenbaum, P.R., & Rubin, D.B. (1985). Constructing a Control Group Using Multivariate Matched Sampling Methods That Incorporate the Propensity Score. *The American Statistician*, *39*(1), 33-38. -- www.jstor.org/stable/2683903.

Ruml, A., & Qaim, M. (2019). *New evidence regarding the effects of contract farming on agricultural labor use* (No. 135; GlobalFood Discussion Papers, Issue December). doi: 10.13140/RG.2.1.4345.1767.

Setiadi, A., Santoso, S.I., Mukson, M., & Roessali, W. (2022). Contract broiler farming as an effective pathway to improve rural prosperity in Indonesia. *International Social Science Journal*, *72*(244). doi: 10.1111/issj.12330.

Shipman, J.E., Swanquist, Q.T., & Whited, R.L. (2016). Propensity Score Matching in Accounting Research. *The Accounting Review*, *92*(1), 213-244. doi: 10.2308/accr-51449.

Shumba, T. (2013). *Strategies to link broiler farmers to lead firm processors for guaranteed market and improved income*. Van Hall Larenstein University of Applied Science.

Sianesi, B. (2004). An Evaluation of the Swedish System of Active Labor Market Programs in the 1990s. *The Review of Economics and Statistics*, *86*(1), 133-155. -- https://econpapers.repec.org/RePEc:tpr:restat:v:86:y:2004:i:1:p:133-155.

Simmons, A.E. (2018). *The Disadvantages of a Small Sample Size*. Sciencing.Com.

Suwandari, A., Hariyati, Y., Agustina, T., Kusmiati, A., Hapsari, T.D., Khasan, A.F., & Rondhi, M. (2020). The Impacts of Certified Seed Plant Adoption on the Productivity and Efficiency of Smallholder Sugarcane Farmers in Indonesia. *Sugar Tech*, *22*(3). doi: 10.1007/s12355-020-00821-2.

Suwarta, S., & Hanafie, R. (2021). The production risk of broiler farm management at plasma breeders: Evidence from Indonesia. *Journal of Socioeconomics and Development*, *4*(1), 134. doi: 10.31328/jsed.v4i1.1501.

Ullah, I., Ali, S., Ullah Khan, S., & Sajjad, M. (2019). Assessment of technical efficiency of open shed broiler farms: The case study of Khyber Pakhtunkhwa province Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, *18*(4), 361-366. doi: 10.1016/j.jssas.2017.12.002.

Weimer, S.L., Mauromoustakos, A., Karcher, D.M., & Erasmus, M.A. (2020). Differences in performance, body conformation, and welfare of conventional and slow-growing broiler chickens raised at 2 stocking densities. *Poultry Science*, 1-10. doi: 10.1016/j.psj.2020.06.009.

Yanuarti, R., Aji, J.M.M., & Rondhi, M. (2019). Risk aversion level influence on farmer's decision to participate in crop insurance: A review. *Agricultural Economics (Czech Republic)*, *65*(10), 481-489. doi: 10.17221/93/2019-AGRICECON.

Rokhani
Department of Agricultural Extension, Faculty of Agriculture, University of Jember
Jl. Kalimantan No. 37 Jember, 68121
E-mail: rokhanisaid.faperta@unej.ac.id
She is lecture at Agricultural Extension, University of Jember. She got Ph.D from Bogor Agricultural University (Indonesia, 2018). Her research interest are in agricultural extension, and agricultural sociological issues in Indonesia.

Mohammad Rondhi
Department of Agribusiness, Faculty of Agriculture, University of Jember
Jl. Kalimantan No. 37 Jember, 68121
E-mail: rondhi.faperta@unej.ac.id
He is associate professor at agribusiness department, University of Jember. He got Ph.D from Hokkaido University (Japan, 2015). His research interest are in agricultural economics, environment and natural resources economics, irrigation management, agricultural institutions.

Ebban Bagus Kuntadi
Department of Agribusiness, Faculty of Agriculture, University of Jember
Jl. Kalimantan No. 37 Jember, 68121
E-mail: ebban.unej.faperta@unej.ac.id
He is lecturer on agribusiness department. He got Master Degree from Gadjah Mada University. His research interest is in agricultural economics, and agricultural institutions.

Anik Suwandari
Department of Agribusiness, Faculty of Agriculture, University of Jember
Jl. Kalimantan No. 37 Jember, 68121
Email: anik.faperta@unej.ac.id
She is associate professor at agribusiness department at University of Jember. She got Master Degree from Padjadjaran University (Indonesia, 1997). Her research interest are in agricultural economics development, entrpreneurship.

Rizky Yanuarti
Department of Agribusiness, Faculty of Agriculture, University of Jember
Jl. Kalimantan No. 37 Jember, 68121
E-mail: rizkyyanuarti@unej.ac.id
She is young lecturer on agribusiness study program, University Jember. She got Master Degree from University of Jember (Indonesia, 2019). Her research interest are agricultural economics development and commodity certification.

Ahmad Fatikhul Khasan
Department of Agribusiness, Faculty of Agriculture, University of Jember
Jl. Kalimantan No. 37 Jember, 68121
E-mail: ahmad.fatih@unej.ac.id
He is Ph.D student on agricultural science. He got Master Degree from University of Jember. His research interest are in agricultural economics, development economics mostly in Indonesia.

Yasuhiro Mori
Department of Sustainable Agriculture, College of Agriculture, Food and Environment Sciences, Rakuno Gakuen University
Midorimachi 582, Bunkyodai, Ebetsu, Hokkaido, Japan, 069-0836
E-mail: y-mori@rakuno.ac.jp
Hie is lecturer at agricultural economics at Rakuno Gakuen University. He got Ph.D from Hokkaido University(Japan, 2018). His research interest are in agricultural economics, development economics in Japan and Indonesia.

Takumi Kondo
Research Faculty of Agriculture, Hokkaido University, Sapporo, Hokkaido, Japan
E-mail: kondot@agecon.agr.hokudai.ac.jp
He is professor at agricultural and rural economics in Hokkaido University. His research interest are in agricultural economics, development economics in Japan and Indonesia.