Research article

Impact of Technology Adoption on the Economic Well-being of Rice Farmers in Cambodia

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Received 7 December 2023 Accepted 22 April 2024 (*Corresponding Author)

Abstract Variety is a key factor in the quality and productivity of paddy rice. In 2010, the Royal Government of Cambodia promulgated a paddy/rice policy that introduced 10 high-yielding rice varieties to farmers. This study investigated the socio-economic factors influencing farmers' decisions to adopt these high-yielding rice varieties while examining the impact of their adoption on yields and profits. Probit regression and propensity score matching methods were applied for analysis. The empirical results of the probit regression indicated that factors such as gender (male), paddy field size, and distance to a paved road had a significantly positive influence on farmers' adoption of the improved rice varieties. Meanwhile, household size, the number of paddy field plots owned, car ownership, off-farm job engagement, and the number of cows owned had a significantly negative effect. The results from propensity score matching methods revealed that farmers who had adopted high-yielding rice varieties experienced a significantly positive impact on yields and profits.

Keywords technology adoption, economic well-being, high-yielding rice varieties, Cambodia

INTRODUCTION

Agriculture is a vital sector for economic growth and development in Cambodia. Paddy rice in Cambodia is grown mainly under rainfed conditions, and the adoption of high-yielding rice varieties is generally limited. Constraints in policy promotion and technology dissemination have led to the low uptake of new technologies and the corresponding limitation in rice yield (FAO, 2010). The average rice yield in Cambodia in 2013 was 3.3 t/ha, the lowest among selected ASEAN countries. Vietnam led with an average paddy rice yield of 6.2 t/ha, followed by Indonesia (5.7 t/ha), Lao PDR (4.1 t/ha), and Thailand (3.5 t/ha), respectively (ADB, 2014). In an effort to boost rice production and enhance the net farm income of farmers, the Royal Government of Cambodia introduced a total of 10 high-yielding rice varieties. According to research conducted by CARDI (2011), all 10 rice varieties yielded higher than traditional varieties, with the total average being 18 percent higher. Generally, farmers tend to abstain from adopting new farming technology due to the risks and uncertainties it may pose. However, once they observe improvements in outcomes resulting from its use, they become more willing to adopt it, leading to faster diffusion (Feder and Umali, 1993).

To assess the effects of adopting new technology, a simple comparison between adopters and non-adopters without controlling for differences in characteristics can lead to biased estimations (Faltermeier and Abdulai, 2009). Therefore, this study utilizes the propensity score matching method to control variations in farmers' characteristics.

OBJECTIVE

This case study aims to identify the socio-economic factors influencing farmers' decisions to adopt high-yielding rice varieties and to examine the effects of adoption on their economic well-being in Bati district, Takeo province, Cambodia.

METHODOLOGY

A two-stage sampling technique was employed in this study. The first stage involved purposive sampling, wherein two communes in the Bati district of Takeo province were selected. In the second stage, random sampling was conducted using a random integer generator website (Randomness and Integrity Services Ltd., 2010). Farmers cultivating any of the 10 high-yielding rice varieties were categorized as adopters, while those still cultivating traditional varieties were classified as non-adopters. This selection, initially proposed as a 'dichotomous choice' by Feder et al. (1985), was followed (Awotide et al., 2011). Consequently, 151 adopter farmers and 151 non-adopter farmers, totaling 302 farmers, were selected as the respondent household sample. The field survey took place from late August to early October 2014, and semi-structured face-to-face interviews were conducted.

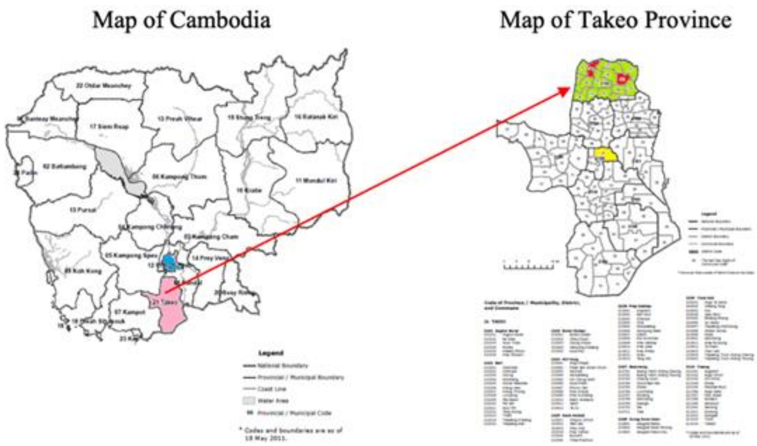

Fig. 1 Map of the study area

Farmers' adoption of technology may be influenced more by their individual characteristics than by their farming practices. A straightforward comparison without accounting for these varying characteristics can lead to biased estimations. Therefore, the study utilized a propensity score matching method to control for differences in farmers' characteristics. Following Beker and Ichino (2002), a two-step procedure was employed for propensity score matching. In the first step, a probability model was estimated to determine the propensity scores of each farmer. In this study, the probit model was defined as Eq. (1):

$$D_i = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_n X_n + \varepsilon_i \quad (1)$$

where D_i is a dummy dependent variable indicating the adoption of the improved rice varieties, X is the independent variable to be estimated, β represents the coefficients to be estimated, α_0 is the intercept term, and ε_i is the error term. Moving on to the second step, each farmer in the adopter group was paired with a traditional rice farmer having similar propensity score values to estimate the average treatment effect. The propensity score matching equation is written as Eq. (2):

$$P_{score} = 1 / (1 + e^{-Di}) \quad (2)$$

In this matching method, both single nearest neighbor matching (NNM) and kernel-based matching (KBM) were employed. The covariate balance test is typically necessary to ensure the quality of the matching. Asfaw and Shiferaw (2010) introduced overall covariate balance test criteria both before and after matching. Sianesi (2004) proposed that the pseudo R^2 should decrease after matching to validate the success of the matching process, and joint significance should be rejected post-matching. Additionally, the mean bias should decrease after matching to affirm the quality of the matching. Rosenbaum and Robin (1985) recommended the use of mean absolute standardized bias (MASB), where a standardized difference should be less than 20% to confirm the success of the matching process.

RESULTS AND DISCUSSION

Descriptive Results

Table 1 presents the summary statistics of the basic profile of the respondent farmers and the results of t-tests indicating statistical differences between the two farmer groups. Several variables indicate that the adopter group has significantly lower values than the non-adopter group. These variables include household size, the number of paddy field plots owned, ownership of cars, ownership of cows, off-farm job engagement, livestock sales, income from off-farm activities, farming labor, and the receipt of extension service. The non-adopter farmers leverage larger family sizes to engage in more off-farm jobs and raise more livestock, leading to increased income. The non-adopters, with significantly higher off-farm income and livestock sales, and a greater percentage of households owning a car, appear to be economically wealthier than the adopters in terms of their non-farm economic status. Additionally, the non-adopters own more paddy field plots than the adopters. This higher number of plots for rice cultivation may require more farming labor, making it challenging for the non-adopters to embrace labor-intensive new technology as their family members are significantly committed to off-farm activities. Furthermore, limited contact with extension service is observed among the adopters due to the scarcity of extension officers in the communities.

Table 1 Socio-economic and demographic profile of the respondent farmers

Variables	Unit	Adopters (n=151)		Non-adopters (n=151)		Difference	t-Test
		Mean	SD	Mean	SD		
Household size	No. person	4.54	1.43	5.03	1.68	-0.49***	2.73
Age	Years	47.95	12.84	47.09	12.61	0.86	0.59
Education	Years	5.17	3.08	5.00	3.43	0.17	0.46
Gender (1=men)	Dummy	0.83	0.38	0.70	0.46	0.13***	2.73
Paddy field size	Ha	0.99	0.64	0.81	0.52	0.19***	2.79
Number of paddy field plots	Number	1.66	0.83	2.35	1.42	-0.70***	5.19
Distance to paved roads	Km	4.85	2.29	3.64	1.99	1.22***	4.93
Distance to the market	Km	6.84	1.67	6.23	1.66	0.61***	3.18
Own cars (1=yes)	Dummy	0.02	0.14	0.09	0.29	-0.07***	2.77
Own motorbikes (1=yes)	Dummy	0.76	0.43	0.68	0.47	0.08	1.54
Own cows	Number	1.27	1.34	1.68	1.41	-0.41***	2.30
Engage in off farm job (1=yes)	Dummy	0.14	0.35	0.70	0.46	-0.56***	11.83
Livestock sales	USD/year	55.76	290.14	169.17	713.84	-113.41*	1.81
Farmgate price per kg (rice)	USD/kg	0.31	0.02	0.25	0.03	0.06***	20.53
Off farm income	USD/year	101.17	391.82	747.92	1,223.29	-646.75***	6.19
Sell rice (1=yes)	Dummy	0.92	0.71	0.42	0.49	0.50***	10.96
Has source of water (1=yes)	Dummy	0.17	0.37	0.09	0.28	0.08**	2.09
Farming labor	No. person	2.91	1.05	3.95	1.33	-1.04***	7.54
Receive extension service (1=yes)	Dummy	0.08	0.27	0.25	0.44	-0.17***	4.12
Yield	t/ha	3.25	0.79	2.02	0.61	1.23***	15.10
Gross revenue	USD/ha	980.48	634.72	385.60	253.10	594.88***	10.70
Fixed cost	USD/ha	51.84	75.50	14.95	20.99	37.38***	5.79
Total variable cost	USD/ha	554.18	285.64	301.95	161.97	252.23***	9.44
Profit	USD/ha	426.30	392.24	83.65	137.33	342.65***	10.13

Source: Own survey, 2014

*Note: p < 0.01***, p < 0.05**, p < 0.1*; family labor cost has been included in the calculation; 1 USD was equivalent to 4,065 Riel (National Bank of Cambodia as of 1 September 2014)*

Meanwhile, the variables for which the adopter group in Table 1 exhibited a significantly higher value than the non-adopter group are gender, paddy field size, distance to paved roads, distance to the market, farmgate rice price, whether selling rice or not, and accessibility to water source. The adopter farmers have significantly more males than the non-adopters, probably because this pertains to the more labor-intensive features of improved rice farming, such as land preparation and application of synthetic pesticides, than traditional rice farming. Additionally, the adopter farmers own a significantly larger paddy field than the non-adopter farmers. This is likely because high-yielding rice varieties are more commercially oriented than traditional varieties in terms of market demand, and their benefits are better cultivated by growing them in a larger paddy field. The commercial orientation of the high-yielding varieties is also evident in the higher farmgate price received by the adopters compared to the non-adopters. The adopter farmers have a longer distance to paved roads and markets than the non-adopter farmers, probably because buyers tend to visit their rice farms to make purchases, while the non-adopter farmers must sell their rice themselves at the nearest market. The dummy results for ‘sell rice’ suggest that significantly more adopter farmers cultivate rice for commercial purposes, whereas significantly more non-adopter farmers focus on subsistence purposes only. Additionally, the adopter farmers have significantly better access to water than the non-adopters, possibly because high-yielding rice varieties generally require much more water than traditional rice varieties. Education and age are not statistically significant.

The yield, gross revenue, and profit generated by the adopter farmers from paddy rice farming are 1.23 t/ha, 594.88 USD/ha, and 342.65 USD/ha higher, respectively, than those by the non-adopter farmers. The fixed cost and total cost incurred by the adopter group are significantly higher than the non-adopter group because improved rice varieties require more labor and other inputs. Additionally, improved rice farming serves as their main household income source, with off-farm income accounting for only about 9.4% of their total household income. However, from this simple comparison, we cannot yet conclude that the farmers who adopted any of the improved rice varieties had a positive impact on yields and profits. This is because the better performance of the adopted farmers might have been influenced by certain characteristics that differ from the non-adopter farmers. Hence, it is necessary to control for these differences through propensity score matching.

Propensity Score Matching Results

Table 2 shows the results of the probit regression for factors influencing the probability of adopting any of the 10 high-yielding rice varieties. The results align with the findings from the descriptive analysis. Gender, paddy field size, and distance to paved roads are positively associated with the adoption of improved rice farming. This implies that a unit increase in each of these variables will lead to a higher adoption of the high-yielding rice varieties, as explained in the previous section. Additionally, household size, the number of rice plots owned, the number of cars owned, the number of cows owned, and off-farm job engagement show a significantly negative association with the adoption of improved rice varieties. This suggests that a unit increase in each of these variables will lead to less adoption of the high-yielding rice varieties, as mentioned above.

Table 3 shows the results of the effects of improved paddy rice farming on the economic well-being of farmer households. The adopter farmers obtained significantly higher yields than the non-adopter farmers, with differences ranging from 1.34 t/ha to 1.43 t/ha. This result is consistent with previous studies by Wiredu et al. (2010) in Northern Ghana, and by Saka and Lawal (2009) in Southwestern Nigeria. Regarding the effect on profits (net farm income), the differences are also positive and statistically significant in favor of the adopter farmers for all four matching methods, ranging from 324.27 USD/ha to 333.98 USD/ha. These results suggest that the adopter farmers achieved significantly higher economic well-being from paddy rice farming than the non-adopters. This finding aligns with some previous studies, such as Hossain et al. (2006) and Mendola (2006) in Bangladesh.

Moreover, Nguezet et al. (2011) from Nigeria, Wiredu et al. (2014) from Northern Ghana, and Wang et al. (2012) from six provinces of Cambodia identified relevant results, such as a significantly positive impact of improved paddy rice farming on the gross revenue from it. In contrast, Rahnam (2003) from Bangladesh showed that commercial rice production based on the use of high-yielding varieties exhibited a sheer lack of efficiency, as the profit was little due to a combination of technical and allocative inefficiencies in modern rice production.

Table 2 Results of probit regression for the determinants of adoption

Adoption	Coeff.	Std. Err.	z	P>z
Household size	-0.18***	0.07	-2.66	0.01
Age	0.01	0.01	0.90	0.37
Education	0.04	0.03	1.17	0.24
Gender	0.57**	0.25	2.25	0.02
Paddy field size	0.72***	0.21	3.47	0.00
Number of paddy field plots	-0.50***	0.11	-4.38	0.00
Distance to the paved road	0.20***	0.05	3.97	0.00
Distance to market	0.04	0.06	0.59	0.55
Own cars	-1.21**	0.47	-2.55	0.01
Own motorbikes	0.21	0.22	0.93	0.35
Own cows	-0.13*	0.07	-1.86	0.06
Engage in off-farm job	-1.54***	0.20	-7.71	0.00
Constant	-0.21	0.72	-0.29	0.77
Number of observations				302.00
Log likelihood				-117.93
LR chi^2				182.81
Pro>Chi^2				0.00
Pseudo R^2				0.44

Source: Own survey, 2014
*Note: p < 0.01***, p < 0.05**, p < 0.1**

Table 3 Average treatment effects of technology adoption on yields and profits

Outcome	Matching method	ATT			
		Adopters	Non-adopters	Diff.	t-stat
Yield	NNM (1)	3.25	1.83	1.42	7.84***
	NNM (5)	3.25	1.82	1.43	9.35***
	KBM (0.03)	3.25	1.89	1.35	8.45***
	KBM (0.06)	3.25	1.91	1.34	8.72***
Profit	NNM (1)	374.00	47.06	326.94	6.42***
	NNM (5)	374.00	40.02	333.98	7.81***
	KBM (0.03)	374.00	48.08	324.27	7.25***
	KBM (0.06)	374.00	43.69	330.31	7.71***

*Note: p < 0.01***, ATT: average treatment effect on treated; Yield: Paddy rice yield (t/ha); Profit: from paddy rice farming (USD); family labor cost has been included in the calculation; 1USD was equivalent to 4,065 Riel; NNM (1): single nearest neighbor matching with replacement and common support; NNM (5): five nearest neighbor matching with replacement and common support; KBM (0.03): kernel-based matching with bandwidth 0.03 and common support; KBM (0.06): kernel-based matching with bandwidth 0.06 and common support.*

Table 4 presents the results from covariate balancing tests for matching processes. The pseudo-R^2, indicating how well the covariates explain the probability of improved technology adoption, was 44% before matching. After matching, the values decreased by only about 2-4%. The small differences before and after matching suggest no systematic differences in the distribution of covariates between the adopter and non-adopter groups. Additionally, the *p*-values of the likelihood ratio tests consistently indicated that the joint significance of the covariates was rejected after matching.

Furthermore, the results of the overall covariate balancing tests in Table 4 show that the standardized mean differences for the covariates used in the estimation process were 39.40% before matching. After matching, they decreased in the range of 8.30-9.30%. Through the matching process, the total bias was reduced by 76.40-78.93%. Significant bias still exists, and addressing it may require an increase in the sample size. The combination of a low pseudo-R^2, insignificant *p*-values of the likelihood ratio test after matching, low mean standardized bias, and high total bias reduction suggests that the specification of the propensity score estimation process successfully balanced the distribution of covariates between the adopters and the non-adopters.

Table 4 Matching quality indicators before and after matching

Matching method	Pseudo R^2		LR chi^2 (p-value)		Mean standardize bias		Total % bias reduction
	Before	After	Before	After	Before	After	
NNM (1)	0.44	0.04	182.81 (0.000)***	15.56 (0.212)	39.40	9.30	76.40
NNM (5)	0.44	0.02	182.81 (0.000)***	9.70 (0.642)	39.40	9.10	76.90
KBM (0.03)	0.44	0.02	182.81 (0.000)***	9.37 (0.671)	39.40	8.30	78.93
KBM (0.06)	0.44	0.02	182.81 (0.000)***	7.44 (0.828)	39.40	8.70	77.92

*Source: Own survey, 2014; Note: $p < 0.01$***; NNM (1): single nearest neighbor matching with replacement and common support; NNM (5): five nearest neighbors matching with replacement and common support; KBM (0.03): kernel-based matching with bandwidth 0.03 and common support; KBM (0.06): kernel-based matching with bandwidth 0.06 and common support.*

CONCLUSION

The results from the propensity score matching methods revealed that the farmers who adopted high-yielding rice varieties had a positive impact on yields and profits from paddy rice production. We recommend that the Government of Cambodia prioritize rice farmers with smaller households and larger paddy sizes, especially those with limited off-farm opportunities, in their efforts to promote the adoption of high-yielding rice varieties in the nation. Careful support and training should be provided to female-headed farmer households to encourage women's involvement in improved rice farming, addressing issues such as poor access to information, limited skills due to low education, and a shortage of farm labor. Additionally, establishing an agricultural land policy to commercialize agricultural land and improving infrastructure for water access and market connectivity should be considered.

ACKNOWLEDGEMENTS

We extend our sincere gratitude to Professor Hiroshi Isoda for his valuable advice and guidance throughout this study, Professor Kolawole Ogundari for his unwavering technical support, and the JDS program for generously providing the scholarship that facilitated the lead author's master's studies. Also, this study constitutes a master's thesis approved at Kyushu University in September 2015.

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