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THE IMPACT OF CLIMATE CHANGE ADAPTATION RESPONSE ON RICE FARMERS' LIVELIHOOD IN SOC TRANG PROVINCE OF VIETNAM

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Abstract

This study uses the propensity score matching approach to empirically analyze farmers' preference for adaptation to climate change in rice production and the impact of adaptation response on their livelihood, more specifically on household income. Observational data were obtained from interviews with 80 Soc Trang rice farmers in the Mekong Delta, Vietnam. The findings indicate that 74% of farmers typically decided to adapt their rice farming to climate change with respect to salinity intrusion while 26% of farmers did not. The choice of adaptation response is significantly influenced by education, social norm, location at district level and micro-level (e.g. access to water sources). Furthermore, the study demonstrates that adaptation response to climate change at the farm level has a positive impact on household income. Specifically, farmers who have adapted their rice farming to salinity intrusion have a higher annual income (about 34 million Vietnamese Dong) than those who have not adapted.
Key words: *climate change, adaptation, rice farmers, income, propensity score matching.*
Jel Codes: *Q12, Q15, Q19, Q54, R11*

1. Introduction

Agriculture is one of the main sources of livelihood for vulnerable rural people who face lots of challenges that hamper agricultural productivity. In recent years, climate change is considered as a major challenge to agriculture, particularly in developing countries. Poor and marginalized communities in these countries are expected to be the most vulnerable to climate change and its impacts, due to their limited capacity for adaptation and heavy dependence on natural resources. Approximately 2.5 billion people who derive their livelihood in partly or in totally from agricultural production are affected by climate change (Ali & Erenstein, 2017).

The Mekong Delta is the biggest area of rice production in Vietnam, occupying approximately 55% of the total national area. According to Vietnam Food Association (2018), Vietnamese rice exports reached 5.7 million tons in volume and 2.54 billion U.S dollars in value in 2017. Moreover, approximately 60% of Vietnamese communities in the Mekong Delta primarily live based on agriculture (MARD, 2011). According to the IPCC (2007), the Mekong Delta is also expected to be one of the most vulnerable regions to climatic variability in the world. A large portion of this region is forecasted to be flooded and incur accelerated salinity intrusion by a scenario of 30 cm sea level rise by the year 2050 (Smajgl et al., 2015). Particularly, the rice yield potential is forecasted to decline by up to 50% by the year 2100

(ICEM, 2008). According to Mekong Commons (2017), economic losses resulting from salinity intrusion and drought in 2015 were estimated at 45 million U.S. dollars (or 1.5% of the annual rice production) in the Vietnamese Mekong Delta. These risks pose serious impacts on both production and rural livelihood, especially to the rice farmers in Soc Trang province, which is located in the coastal region of the Mekong Delta.

To mitigate climate change and its adverse impacts, adaptation is considered to be an important response at the individual, group, and government scales. As agricultural production remains the main source of income for most rural communities, adaptation is therefore imperative to enhance the resilience of the agricultural sector, protect the livelihoods of the poor, and ensure food security (Bryan et al., 2013). It is also demonstrated that agricultural production will be severely affected by climate change with farmers not making use of adaptation being more vulnerable (Smit & Skinner, 2002). Therefore, smallholder farmers performing adaptation responses are more likely to secure their income and livelihood compared to those not adapting. There have been previous studies analyzing the impacts of climate change on agriculture (Kidane, Abebe, and Degefie, 2006, Deressa, 2007) and determining factors that affect adaptation choices (Deressa, Hassan, Ringler, Alemu, and Yesuf, 2009, Gbetibouo, 2009, Below et al., 2012, Ndamani & Watanabe, 2016).

A decision to implement adaptations by rural farmers was significantly influenced by a variety of factors including socio-economic characteristics (e.g. education level, household size, age, and gender) and access to resources (e.g. access to market, extension service, credit service, and climatic information) (Hassan, 2008, Deressa et al., 2009, Hisali, Birungi, and Buyinza, 2011, Below et al., 2012, Dang, Li , Nuberg, and Bruwer, 2014a). In addition, risk perception and social norms were found to be significantly associated with adaptation intention and actual behavior to cope with climate change (Pelling & High, 2005, Wolf, 2011, Dang, Li, Nuberg, and Bruwer, 2014b). In terms of its effectiveness, there are few studies reporting that adaptation practices have significantly positive impacts on crop productivity, income, food security level, and significantly negative impacts on the level of poverty by using propensity score matching approach (Khonje, Manda, Alene, and Kassie, 2015, Abid, Schneider, and Scheffran, 2016, Rahut & Ali, 2017, Ali & Erenstein, 2017). To the best of the authors' knowledge, no previous studies have explored the impacts of adaptation strategies to climate change on rice production. Therefore, the fundamental aim of this study is to empirically investigate the key determinants influencing adaptation choice and assess the impact of adaptation response on household income among rice farmers in Soc Trang province of the Vietnamese Mekong Delta.

2. Climate Change Adaptation Response and Rural Livelihood

Adaptation is defined as an adjustment in ecological, social or economic systems to respond to actual or expected climatic phenomena and its impacts (IPCC, 2007). It refers to changes in processes or structures to minimize the potential damages related to climate change. Adaptation types have been differentiated according to various items including purposefulness, timing, or temporal scope, etc. According to Adger, Arnell and Tompkins (2005), intentional adaptation was described as responses or strategies that are triggered by climate change and occur naturally without interventions by public agencies. Those are intentionally conducted according to the process of perception based on experience or information and responding to climate change. Nevertheless, some other adaptations can also occur as results of other non-climate-related social or economic changes. Those unintentional adaptations may not be primarily motivated by climate change but rather by other social or economic benefits.

In the study site, local adaptation practices including changing rice varieties, fertilizer and chemical uses, total area of farming land, and irrigation schedule as well as diversifying their crops (i.e. farming rice and shrimp, or rice and cash crop in rotation) and incomes (i.e. by shifting from farming to non-farming activities, and partially or totally shifting from rice farming to livestock or shrimp farming) were intentionally and unintentionally employed by rice farmers (Ho & Ubukata, 2018). Some adaptation practices referred to as intentional adaptation responses were undertaken through a two-step process of perceiving climate change and its impacts. Other unintentional adaptation practices were primarily motivated by economic benefits or social effects (e.g. access to markets, social norms, and reliance on public adaptations), rather than climate change and its impacts.

Moreover, rural livelihood mainly referred to household incomes from both agriculture and non-agriculture sources. And, it was directly affected by the adverse impacts of climate change associated with salinity intrusion (e.g. shortage of water for irrigation, salinization, and loss of rice yield) (Ho & Ubukata, 2018). Thus, the performance of adaptation responses not only help rural farmers reduce potential losses in crop productivity but also sustain their income and food security (Khonje et al., 2015, Abid et al., 2016, Manda, Alene, Gardebroek, Kassie, and Tembo, 2016, Rahut & Ali, 2017, Ali & Erenstein, 2017). In details, the more adaptation practices that were adapted by Pakistani farmers, the higher food security levels were (8 – 13%) and the lower levels of poverty were (3 – 6%). In wheat production, adaptation practices to climate change might lead to increase net income by 1,658 – 2,610 Pakistani rupee per month and to raise wheat yield by 42 – 65 kg per hectare.

3. Methodological Framework

Recently, there has been increasing interest in methods based on the propensity score to reduce or eliminate the problems of selection bias or hidden bias[i] when using observational data (Austin, 2011). Examples of recent use of these methods include assessments of the effects of kindergarten retention on children's social-emotional development (Hong & Yu, 2008), the effectiveness of Alcoholics Anonymous (Ye & Kaskutas, 2009), the effects of small school size on mathematics achievement (Wyse, Keesler, and Schneider, 2008), and the effect of teenage alcohol use on education attainment (Staff, Patrick, Loken, and Maggs, 2008). Even in climate change and the agricultural sector, this approach is also employed to analyze the impacts of adaptation practices on household food security and poverty in Pakistan (Ali & Erenstein, 2017), the impacts of adaptation practices on wheat productivity, income and poverty in the Himalayan region of Pakistan (Rahut & Ali, 2017), the impacts of adoption of improved maize varieties on crop incomes, consumption expenditure, and food security in Eastern Zambia (Khonje et al., 2015), and the impacts of adaptation on wheat productivity and net crop income in Pakistan (Abid et al., 2016). In addition, it is used to investigate the impacts of export horticulture farming on per capita calorie intake among smallholder farmers in Eastern and Central provinces in Kenya (Chege, Nyikal, JMburu, and Murrithi, 2015). Our objective in this study is to explore the key determinants of adaptation choice and evaluate the impact of adaptation response on household income among Soc Trang rice farmers in the Vietnamese Mekong Delta using the propensity score matching (PSM) approach.

The propensity score was defined by Rosenbaum and Rubin (1983a) to be the probability of treatment assignment conditional on observed baseline covariates. The PSM entails forming matched sets of treated and control (or untreated) subjects who share a similar value of the propensity score. Conceptually, it is defined as a three-step analytic process (Guo & Fraser, 2015). The best conditioning variables that are speculated to be causing an imbalance between treated and control group are examined in the first step. Matching or resampling in the second step and post-matching analysis based on the matched samples in the third step, are included.

Firstly, the estimated propensity score is the predicted probability of treatment derived from the fitted regression model or propensity score model. In this study, the propensity model of binary logistic regression is used to investigate the choice of climate change adaptation response by Soc Trang rice farmers. Some previous studies also used the binary logistic model as the appropriate econometric model to identify the factors that affect farmers' choice of adaptation strategy to climate change (Bryan et al., 2013, Mabe, Sienso, and Donkoh, 2014, Ndamani & Watanabe, 2016). A binary logistic regression describes the conditional probability of receiving treatment as follows:

$$P\ (D_i/X_i = x_i) = \frac{e^{\beta iXi}}{1+e^{\beta iXi}} = \frac{1}{1+e^{-\beta iXi}} \quad (1)$$

where, D_i denotes adaptation response to climate change with respect to salinity intrusion in rice farming, with 1 representing adaptation (treated group) and 0 no adaptation (control group). X_i is the observable vector of explanatory variables.

After propensity scores are estimated, the next step of analysis often entails matching treated and control subjects based on the estimated propensity scores. The most common matching algorithm is greedy matching [ii] which includes Mahalanobis metric matching, Mahalanobis metric matching with propensity scores, nearest neighbor matching, caliper matching, nearest neighbor matching within a caliper, and nearest available Mahalanobis metric matching within a caliper defined by the propensity score (Guo & Fraser, 2015). In this study, nearest neighbor matching is selected to be the main matching method. One individual is matched with another individual from the other treated subjects (one-to-one pair matching) which have similar values of propensity scores.

The effect of treatment for each observation can be expressed as follows:

$$Y_i\,(1) - Y_i\,(0) \quad (2)$$

where, Y_i is denoted as an outcome for the subject *i*, especially $Y_i\ (1)$ is an outcome for the treated group and $Y_i\ (0)$ is an outcome for the control group.

The average treatment effect (ATE) is the average effect, at the population level, of moving an entire population from untreated to treated (Imbens, 2004). The ATE is defined to be:

$$E\ [Y_i\ (1) - Y_i\ (0)] \quad (3)$$

A related measure of treatment effect is the average treatment effect for the treated (ATT) which is the average effect of treatment on those subjects who ultimately received the treatment (Imbens, 2004). It represents the average difference between the observed outcome of the treated and untreated groups. In this study, the ATT is specified as the mean difference in the outcome of farmers who performed adaptation response and farmers who performed no adaptation. The ATT is defined as:

$$E\ [Y_i\ (1) - Y_i\ (0)/D_i=1] \quad (4)$$

In estimating the effectiveness of an incentive or intervention with potentially high barriers to participation, the ATT may be of greater interest than the ATE. In contrast, the ATE may be of greater interest than the ATT in assessing the impact of an incentive or intervention with the low barriers, cost, and effort for participation (Austin, 2011).

Finally, sensitivity analysis and matching quality checking are employed to check the robustness and adequacy of the results. According to Angrit and Pischke (2008), the goal of most empirical economic research is to overcome hidden bias. In terms of sensitivity analysis, it is reported that observational studies vary markedly in their sensitivity to hidden bias: some are sensitive to very small biases while others are insensitive to quite large biases (Rosenbaum & Rubin, 1983b). Therefore, various methods of sensitivity analysis including McNemar's test, Wilcoxon's signed rank test, and the Hodges-Lehmann point and interval estimates, were developed by Rosenbaum for correcting hidden bias and sensitivity analysis evaluating matched pair studies (Guo & Fraser, 2015). The aim of sensitivity analysis is to specify several possible values of Γ – a measure of the degree to be free of hidden bias – and consider how the inference might change at a given significant level. According to Rosenbaum (2002b), a study is sensitive if values of Γ close to 1 while a study is insensitive if extreme values of Γ are required to alter the inference at a given significant level. Furthermore, the p value of the Wilcoxon's signed rank test depicts how significant the treatment is. If the p value is less than the usual significant level of 0.05, we can reject the null hypothesis of no treatment effect.

To check the matching quality, the balance test for PSM is entailed. Conceptually, the test was first described in Rosenbaum and Rubin (1985) to check the balance between the treatment group and the control group. For simplicity, the balance test is to check whether the propensity score is an adequate balancing score, or the overall quality of estimation is robust. Among the variety of balance tests, the standardized test of differences is employed in this study. The standardized difference is considered as the size of the difference in means of a conditioning variable X_i before and after matching. They also suggest that the matching quality can be evaluated by a reduction in the standardized difference and a constancy in variance ratio. Particularly, standardized differences and the variance ratio might take on values close to zero and one, respectively. If the differences remain, then either the propensity score model should be estimated using a different approach, or a different matching algorithm should be used, or both.

4. Materials and Variable Description

4.1. Study Site and Data Collection

4.1.1. Study Site

The Long Phu and Tran De district of Soc Trang province were selected as the case study area in the Mekong Delta because it has experienced frequent and severe salinity intrusions in recent years, particularly in the years of 2006 and 2013. Moreover, villagers' occupation in the study site is mainly agriculture (e.g. rice production). The total area of land use in Long Phu and Tran De district in 2013 is shown in Table 1. The 2013 salinity intrusion was severe, resulting in a dramatic reduction of the rice yield, particularly in the third rice crop harvested from February to July (STDARD, 2015). In terms of geographical settings, Long Phu is bordered by the Hau river in the north and the East Sea in the east. Long Phu rice farmers have been directly affected by low and moderate levels of salinity in the Hau river and other small ones. Meanwhile, Tran De is a coastal district which is located at the estuaries of the Hau river and along the My Thanh river (a river with a high level of salinity and considered to be a saline river used mainly for aquaculture and salt production). Tran De rice farmers have been directly affected by high levels of salinity from the estuaries of the Hau river and the My Thanh river. Since 2010, salinity has become a serious issue in some inland parts of Long Phu (e.g. up to Dai Ngai town). Both the study sites are located within the region of the Long Phu – Tiep Nhat project, which is a system of irrigation canals, sluice gateways, and embankments providing irrigation water for agricultural production and a minimum protection against flood-induced inundation and salinity.

Table 1. Total Area of Land Use in 2013 in the Study Site

Land use (ha)	Long Phu	Tran De
Total area	26,382.27	37,822.70
Rice production	15,484	22,600
Fruit trees	2,500	200
Vegetables or cash crop	4,500	4,500
Aquaculture farming	155	5,700

Source: Soc Trang Department of Agriculture and Rural Development, 2015

4.1.2. Data Collection

The study uses the observational data collected in March and September 2015 via in-depth interviews with 80 rice farmers in Long Phu and Tran De districts of Soc Trang province. They were selected based on the official household list of each commune guided by village leaders. This implies that the interview, which was assigned by administration selection or local leaders, was defined as a quasi-experiment or observational study with the lack of random assignment (Guo & Fraser, 2015).

The structured questionnaire was used to collect information about farmers' perceptions of climate change over a ten-year period (1995 – 2015), their intention and actual behavior to adapt, their rice production in the year of 2015, and household characteristics. Only the heads of farm households were surveyed in an hour interview. The household interviews were held in four communes of Long Phu and three communes of Tran De. These respondents have various degrees of access to water sources[iii]. The description of surveyed households with location and access to water sources is shown in Table 2.

Table 2. Description of Location and Access to Water Sources of Study Site

District	Commune/ Town	Location	Access to water sources (Number of households)		
			Near	Medium	Far
Long Phu	*Directly affected by Hau river*				
	Long Phu Town	Located along Hau river and Saintar river (a small one)	-	12	-
	Long Phu		10	-	-
	Tan Thanh	Located along Saintar river	-	-	14
	Tan Hung		-	-	14
Tran De	*Directly affected by My Thanh river and the estuary of Hau river*				
	Dai An 2	Located along the estuary of Hau river with high salinity level	3	5	-
	Thanh Thoi An	Located along My Thanh river	10	-	-
	Lieu Tu		9	3	-

Apart from farm level data, secondary data from agricultural reports, statistical records, and local officers are included based on expert interviews. Four key informants (e.g. agricultural officers) were individually involved in an hour in-depth interview. They provided essential information regarding observed changes in climatic conditions over the last ten years, changes in land uses and agricultural production, and public adaptation strategies and incentives at community level.

4.2. Variable Description

The following variables in the logistic model were chosen based on literature on the choice of climate change adaptations in agricultural sector: education, perception, social norm, farm area, sources of information (e.g. public media, social networks, and institutional information) and geographical locations (e.g. district and access to water sources). For instance, Deressa et al. (2009) and Ndamani and Watanabe (2016) reported that more educated farmers were more likely to adapt their farming to cope with climate change. They also showed that the probability of adaptation choice was positively affected by access to information (e.g. agricultural extension services). Additionally, perception of climate change was found to be significantly influencing the choice of adaptation practices (Dang et al., 2014a, Mabe et al., 2014, Shongwe, Masuku, and Manyatsi, 2014). Regarding to farm characteristics such as geographical locations, different farmers living in different geographical locations generally employed different adaptation practices (Deressa et al., 2009, Hisali et al., 2011). Moreover, the size of farm was found to be negatively influencing the choice of adaptation (Arimi, 2014).

Table 3. Description of Variables in the Binary Logistic Model

Variables	Description	Mean	Standard deviation
Adaptation	Dependent variable – dummy variable, 1 denotes farmer performs adaptation, 0 farmer performs no adaptation	0.7375	0.4428
Perception[iv]	The level of perception – categorical variables, 1 denotes farmer has low perception, 2 denotes farmer has moderate perception and 3 denotes farmer has high perception	1.7250	0.7791
District	Location at district level, dummy variable, 1 denotes farm locates in Tran De district, 0 denotes farm locates in Long Phu district	0.3750	0.4872
Education	Number of years of formal schooling	6.8125	3.4387
Farm area	Total area of rice farming, measures in hectare	1.6080	1.2805
Social norm[v]	Using 1-5 Likert scales, from strongly disagree to strongly agree with the statement "I should perform adaptation practice or not perform any adaptation practice because my friends, relatives, and neighbors do that."	1.8000	0.9195
Access to water sources	Distance to water sources intuitively estimated by rice farmer – categorical variable, 1 denotes farm locates in far, 2 denotes farm locates in medium and 3 denotes farm locates in near to water sources	2.0500	0.8700
Public media	Dummy variable, 1 denotes farmers have access to information of climate change adaptation from public media, 0 denotes otherwise	0.7000	0.4611
Institutional information	Dummy variable, 1 denotes farmers have access to information of climate change adaptation from institutional sources, 0 denotes otherwise	0.3750	0.4872
Social networks	Dummy variable, 1 denotes farmers have access to information of climate change adaptation from social networks, 0 denotes otherwise	0.3125	0.4664

The statistical description and measurement of these variables are shown in Table 3. The average years of formal schooling were about 7 years. The average farming area was approximately 1.6 hectares. Particularly, respondents with farming area from 1 to 3 hectares are the majority (59%), followed by respondents with farming area under 1 hectare (33%) and respondents with farming area more than 3 hectares (8%). In terms of access to water sources, 40% of respondents were located near to water sources while 25% of respondents were located at medium distance and 35% were located at a far distance to water sources. Majority of respondents (53%) perceived change in climatic condition with respect to salinity intrusion, including 20% of respondents perceiving a high level of change and 33% perceiving a moderate level of change. Meanwhile, about 47% of respondents had a low perception level of change in salinity intrusion. The surveyed data also reported that local farmers have access to various sources of information associated with climate change adaptation practices which involved public media (e.g. television, radio, and newspaper) (70%), local government and institutions (e.g. agricultural officers, technical training, and extension services) (38%), and social networks (e.g. heard or seen from their neighbor, friends, or relatives) (31%) (Table 4).

Table 4. Sources of Information of Climate Change Adaptation Practices

Sources of information	Long Phu (hhs[a])	Tran De (hhs)	Total (hhs)
Public media	36 (72.00)	20 (66.67)	56 (70.00)
Institutional information	22 (44.00)	8 (26.67)	30 (37.50)
Social networks	14 (28.00)	11 (36.67)	25 (31.25)
No information	8 (16.00)	6 (20.00)	14 (17.50)

Note: [a] hhs denotes number of surveyed households. Percentage is in parentheses.

5. Results and Discussion

5.1. Adaptation Practices and Smallholder Rice Farmers' Income

5.1.1. Adaptation Practices

To cope with the adverse impacts of salinity intrusion, some rice farmers employed one or a combination of adaptation responses. More specifically, 74% of farmers typically decided to perform their adaptation by changing rice crop varieties, adjusting the fertilizer and chemical use, reducing the scope of their rice farming, and diversifying crops as well as their sources of income (treated group). Meanwhile, 26% of the others did not perform their adaptation (control group) (Table 5).

Table 5. Adaptation Practices in Long Phu and Tran De District

Local adaptation practices	Long Phu(hhs[a])	Tran De (hhs)	Total (hhs)
Changing rice variety	15 (30.00)	2 (6.67)	17 (21.25)
Changing fertilizer and chemical use	19 (38.00)	7 (23.33)	26 (32.50)
Changing irrigation schedule	12 (24.00)	4 (13.33)	16 (20.00)
Changing area of farming land	8 (16.00)	8 (26.67)	16 (20.00)
Crop diversification	3 (6.00)	9 (30.00)	12 (15.00)
Income diversification	9 (18.00)	0 (0)	9 (11.25)
No adaptation	12 (24.00)	9 (30.00)	21 (26.25)

Note: [a] hhs denotes number of surveyed households. Percentage is in parentheses.

In details, Long Phu farmers have an easy access to institutional or formal information (from agricultural officers and extension services) and diverse rice varieties which have been introduced by the provincial seed hatchery in Long Phu district (e.g. IR 50404, OM 4900, and OM 5451). These result that Long Phu farmers (30%) were more likely to employ adaptation practices related to changing their rice varieties to cope with salinity intrusion compared to Tran De farmers (7%). Furthermore, Long Phu farmers (occupying 18%) preferred to diversify their incomes than Tran De farmers (no farmers).

Meanwhile, Tran De farmers tended to reduce the third rice crop, and/or incorporating shrimp farming (with rotation practice) based on the recommendation from local government and institutions on shifting land use from agriculture to aquaculture in areas where salinity intrusion became serious. Consequently, adaptation practice associated with crop diversification (farming an integrated rice-shrimp) was more likely to be employed by Tran De farmers (30%) than Long Phu farmers (6%). Additionally, a reduction in the scope of rice farming was commonly implemented by Tran De farmers (27%) than Long Phu farmers (16%).

5.1.2. Smallholder Rice Farmers' Income

As previously noted, the household income of Soc Trang rice farmers comes from both agriculture and non-agriculture sources. Table 6 presents the annual income of smallholder rice farmers in Soc Trang province. On average, the total household income of rice farmers was about 94.91 million Vietnamese Dong (VND) per year. Particularly, the annual income of farmers who adapted and farmers who did not adapt having an average of 100.32 million VND and 79.70 million VND, respectively.

Table 6. Average Household Income by Adaptation Response

Adaptation response	Total income (million VND per year)
Adaptation	100.3173
No adaptation	79.7002
Average	94.9053

5.1.3. Test of Difference in Means

To simply estimate the differences between the adaptation and no adaptation groups, the difference test in means is used. The calculation of t-statistics from Table 7 indicates that farmer characteristics including level of perception, and education, access to institutional information, and farm characteristics such as access to water sources are significantly different between farmers who perform adaptation response and those who do not. However, the effect of adaptation response on household income does not reach statistical significance ($t = 1.24$, $p > 0.10$).

Table 7. Farmer and Farm Characteristics of Adaptation and No Adaptation Groups

Variables	Control group (n = 21)	Treated group (n = 59)	C-T	p-value		
	Mean	Mean		H: Diff < 0	H: Diff ≠ 0	H: Diff > 0
Perception	1.8136	1.4762	-0.3374** (0.1955)	0.0442	0.0884	0.9558
District	0.4286	0.3559	0.0726 (0.1243)	0.7197	0.5607	0.2803
Education	5.1905	7.3898	-2.1994*** (0.8434)	0.0055	0.0109	0.9945
Farm area	1.7257	1.5661	0.1596 (0.3269)	0.6866	0.6268	0.3134
Social norm	2.1905	1.6610	0.5295** (0.2274)	0.9888	0.0225	0.0112
Access to water sources	1.8095	2.1356	-0.3261* (0.2194)	0.0706	0.1413	0.9294
Public media	0.6190	0.7288	-0.1098 (0.1173)	0.1761	0.3522	0.8239
Institutional information	0.2381	0.4237	-0.1856* (0.1228)	0.0673	0.1347	0.9327
Social networks	0.3333	0.3051	0.0282 (0.1192)	0.5933	0.8133	0.4067
Income	79.7002	100.3173	-20.6171 (16.6336)	0.1094	0.2189	0.8906

Note: Standard errors are in parentheses. *, **, and *** means significance with confidence interval at 90%, 95%, and 99%.

5.2. Impact of Adaptation Response on Total Household Income

The PSM approach is employed to assess the impact of adaptation response on total household income. In the first step of PSM, the binary logistic model is used to provide the propensity score estimates. The result of the model also indicates the influential factors driving the choice of climate change adaptation response. The goodness-of-fit is reflected in the Pseudo R^2 (20.15%) at the 0.05 significance level suggesting the model is relatively fitted (Table 8). The parameter estimates of education level, social norm, location at district level, and access to water sources are statistically significant at either 0.05 or 0.10 significance level.

As expected, education has a positive influence on the choice of adaptation. This implies that farmers with more years of formal schooling prefer to perform adaptation response. Particularly, an additional year of education can increase the probability of adaptation response by 3%.

In terms of geographical location at district level, the coefficient in the logistic model is negative associated with the performance of adaptation response, which suggests that Long Phu farmers are more likely to adapt to climate change related to salinity intrusion than Tran De farmers. More specifically, the probability of Long Phu farmers performing adaptation is 28% higher than the probability of Tran De farmers performing adaptation. In practice, Long Phu farmers who have previously had fewer issues with salinity levels were very sensitive to changes in salinity intrusions and the impacts those intrusions had on their production and livelihoods. Hence, unlike Tran De farmers, who had previously experienced saltwater intrusions and had previously taken steps to protect their livelihoods, Long Phu farmers were more likely to perform adaptation response to risks associated with changes in salinity.

With respect to access to water sources, the result indicates that farmers with a short distance to water sources tend more to adapt compared to farmers with a far distance to water sources, the latter of whom are not affected directly by salinity intrusion. Particularly, farmers with a shorter distance to water sources are 19% more willing to adapt than farmers with a far distance to water sources.

Table 8. The Propensity Score Model

Variables	**Coefficient**	**Marginal effects**	**p value[a]**	**p value[b]**
Perception	0.2165 (0.5643)	0.0326 (0.0849)	0.7010	0.7010
District	-1.8346** (0.9223)	-0.2764** (0.1274)	0.0470	0.0300
Education	0.2049* (0.1051)	0.0309** (0.0146)	0.0510	0.0340
Farm area	-0.0952 (0.2269)	-0.0143 (0.0341)	0.6750	0.6740
Social norm	-0.5955* (0.3282)	-0.0897** (0.0457)	0.0700	0.0490
Access to water sources	1.2655** (0.5270	0.1906*** (0.0691)	0.0160	0.0060
Public media	-0.2731 (0.7133)	-0.0411 (0.1069)	0.7010	0.7000
Institutional information	0.1741 (0.8397)	0.0262 (0.1262)	0.8360	0.8350
Social networks	-0.4747 (0.6464)	-0.0715 (0.0966)	0.4630	0.4590
Constant	-0.7447 (1.4212)	-	0.6000	-
Number of observations	80			
LR $chi^2(9)$	18.56			
Pseudo R^2	0.2015			
Probability > chi^2	0.0292			

Note: Standard errors are in parentheses. *, **, and *** means significance with confidence interval at 90%, 95%, and 99%; [a] p value for coefficient; [b] p value for marginal effects.

As previously mentioned, local adaptation practices were both intentionally and unintentionally conducted by local rice farmers. More specifically, unintentional adaptation responses might be explained by some economic or social effects such as social norm. The result of the model reflects the social pressures can negatively influence an individual's adaptation choice to cope with salinity intrusion. More specifically, the more pressures, or opinions they heard or seen from their neighbors, relatives, or friends, the less they decided to perform adaptation response by 9%. In practice, there are seven farmers decided to give up their adaptation performance due to collective effects. For instance, five farmers would perform no adaptation related to changing planting dates (e.g. early planting or harvesting, shortening the growing season) due to the impact of various diseases in the case of different stage of rice growth if their neighbors did not change planting dates. Two other farmers would perform no adaptation like their neighbor while their intention to cultivate a salt-tolerant rice variety to cope with salinity intrusion because of the problem of a collective purchase by middle-men at the same time in this area. It was reported as one of constraints or barriers to farmers' adaptation response in the study site.

After propensity scores are estimated, the next step of analysis entails choosing a matching algorithm for treatment effect estimation and checking overlap or the common support. The treatment effects are estimated in the nearest neighbor pair matching treated and control subjects based on propensity score estimates. Table 9 presents that both the ATE and ATT are statistically significant at the significance level of 0.01. It implies that adaptation response has a positive impact on the total annual household income. An average ATT of 34.09 indicates that farmers who have adapted to climate change related to salinity intrusion have higher total household income from agriculture (about 34 million VND per year) compared to those who have not adapted. These results are consistent with those reported by Khonje et al. (2015), Abid et al. (2016), and Rahut and Ali (2017) for wheat crop income. More specifically, some adaptation practices related to changing rice varieties, changing fertilizer and chemical use, changing irrigation schedule, reducing the size of rice farming, and diversifying their income were not costly for implementing. Only adaptation practice associated with crop diversification (e.g. rice and shrimp integrated farming in rotation) had a high initial cost but gained high revenue from shrimp production. This confirms that adaptation response may bring more beneficial for rice farmers.

Table 9. Treatment Effects on Total Household Income with Nearest Neighbor Matching

Income	Coefficient	p value
ATE Adaptation (1 vs 0)	33.3029*** (6.1861)	0.000
ATT Adaptation (1 vs 0)	34.0914*** (8.0459)	0.000

Note: Standard errors are in parentheses. *, **, and *** means significance with confidence interval at 90%, 95%, and 99%.

Taken together, Figure 1 shows that the distribution of the propensity scores between the groups of adaptation and no adaptation in Soc Trang province are within the region of common support[vi]. This means that there is a substantial overlap in the distribution of propensity scores for the treated and control groups.

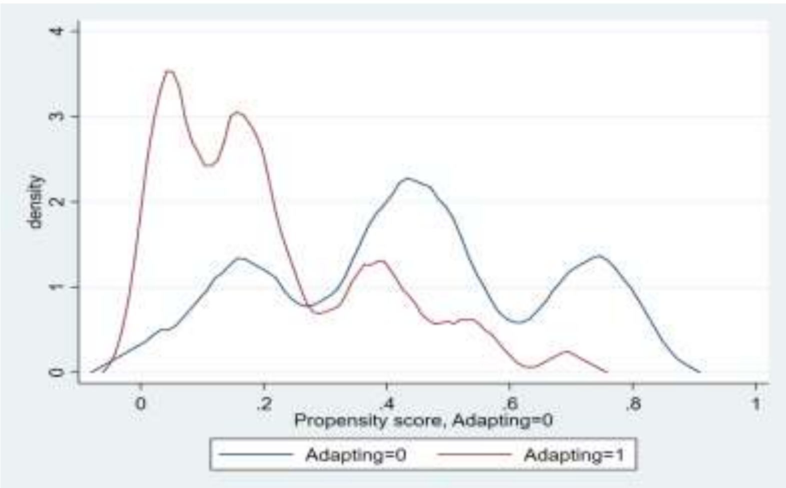

Figure 1. Distribution of Propensity Scores

The final step of PSM is checking the hidden bias and the matching quality of the study. In terms of sensitivity analysis, the result in Table 10 provides several possible values of gamma Γ, the minimum and maximum values of the p value (sig+ and sig-) using Wilcoxon's signed rank test, the minimum and maximum values of the Hodges-Lehmann point estimate (t-hat+ and t-hat-), and the lower and upper bounds of the 95% confidence interval of the Hodge-Lehmann interval estimate. As depicted, Γ = 22 is the value at which the significance interval becomes uninformative. Because of an extreme value of Γ = 22, it can be concluded that the study is insensitive to or robust against hidden bias. Moreover, the p value of Wilcoxon's signed rank test at Γ = 22 is less than the significant level of 0.05, the null hypothesis of no treatment effect is, therefore, rejected. This suggests that even a considerable amount of unobserved heterogeneity would not alter the inference about the estimated effects.

Table 10. Result of The Rosenbaum Sensitivity Analysis

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	3.90E-15	3.90E-15	84.8075	84.8075	71.2562	101.1720
3	3.60E-06	0	60.3669	121.7050	50.2565	143.8900
5	0.0003	0	52.4113	138.7630	42.6979	166.8300
7	0.0017	0	48.5320	148.0400	37.1308	194.8750
9	0.0048	0	45.6087	155.0370	31.7698	216.3470
11	0.0096	0	43.7123	162.3840	28.1485	227.9430
13	0.0156	0	42.4424	168.0310	25.2804	250.2280
15	0.0224	0	40.8062	174.0080	21.0065	299.5270
17	0.0298	0	39.1573	178.5990	-99	99
19	0.0373	0	38.4992	184.1290	-99	99
21	0.0450	0	37.8365	189.2420	-99	99
22	0.0488	0	37.3712	190.4000	-99	99
22.5	0.0507	0	37.2115	191.5830	-99	99
23	0.0526	0	37.1666	194.8660	-99	99

Note: Gamma: log odds of differential assignment due to unobserved factors, sig+: upper bound significant level of the Wilcoxon's signed rank tests, sig-: lower bound significant level of the Wilcoxon's signed rank test, t-hat+: upper bound Hodges-Lehmann point estimate, t-hat-: lower bound Hodges-Lehmann point estimate, CI+: upper bound confidence interval (α = 0.95), CI-: lower bound confidence interval (α = 0.95)

To check matching quality, the test of standardized differences is used to illustrate the standardized differences and variance ratio before and after matching (Table 11). Before matching, there are large differences in the covariates between the adaptation and no adaptation farmers. These differences are significantly reduced after nearest neighbor matching, with many of the covariate differences receiving values close to zero (e.g. district, education, farm area, access to water sources, and social networks) (Figure 2, 3, 4, 5, and 6). But some other covariate differences (e.g. social norm, public media, perception, and institutional information) are slightly change (Figure 7, 8, 9, and 10). Additionally, the variance ratio of some covariates after matching becomes close to one except covariates of perception, public media, and institutional information. In this sense, the propensity score model may provide relatively adequate balancing scores. Or, the PSM approach reports that the overall quality of estimation and matching are comparatively satisfied because of a slight reduction of standardized differences and the relative constancy of variance ratio. However, the result is not particularly robust. This suggest that, given a larger sample data with enough observations to provide comparator information for PSM, the matching and balance test might become more clearly established and robust.

Table 11. Result of Balance Test

Covariates	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Perception	0.4693	0.4489	1.8556	1.8775
District	-0.1467	0.0353	0.9069	1.0231
Education	0.6860	0.0438	1.3460	0.9439
Farm area	-0.1304	0.0031	1.5506	1.0056
Social norm	-0.5523	0.2304	0.5820	1.0683
Access to water sources	0.3763	0.0000	0.9711	1.1028
Public media	0.2317	-0.1585	0.8119	1.2199
Institutional information	0.3963	0.4422	1.3041	1.4214
Social networks	-0.0596	0.0743	0.9243	1.0727

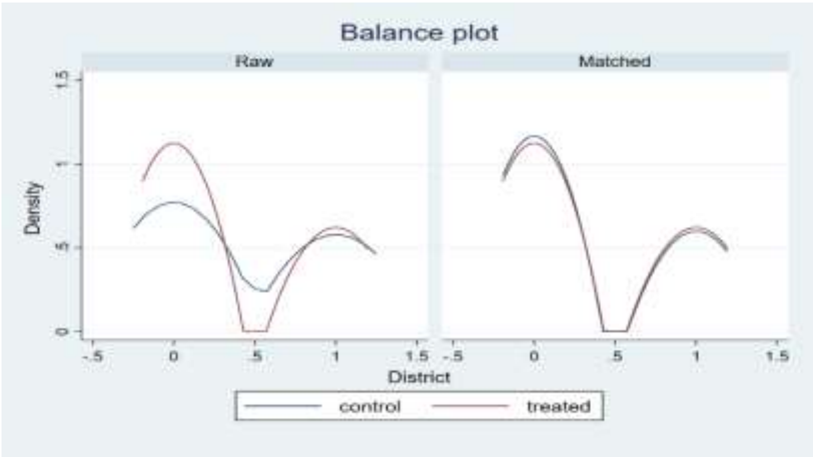

Figure 2. Balance Test of District Covariate

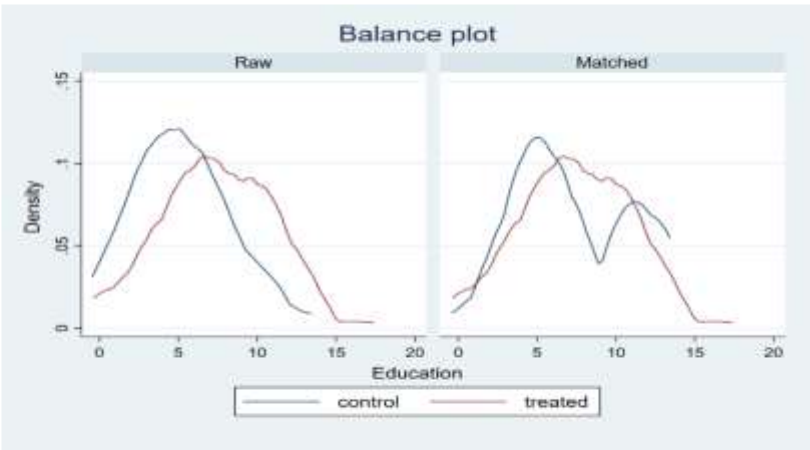

Figure 3. Balance Test of Education Covariate

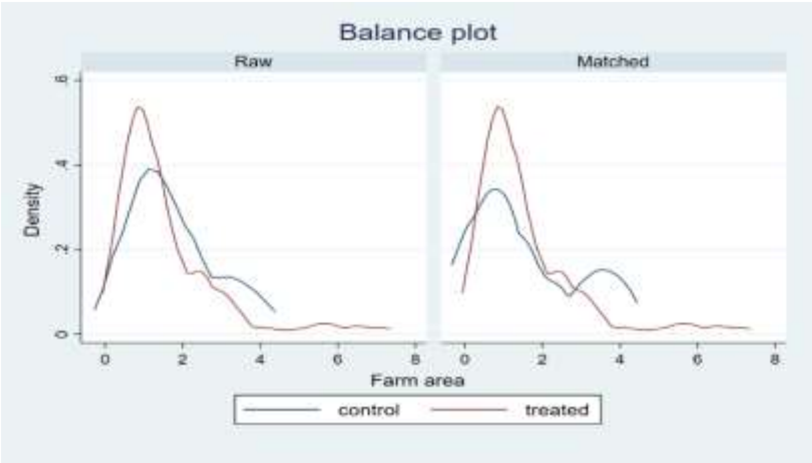

Figure 4. Balance Test of Farm Area Covariate

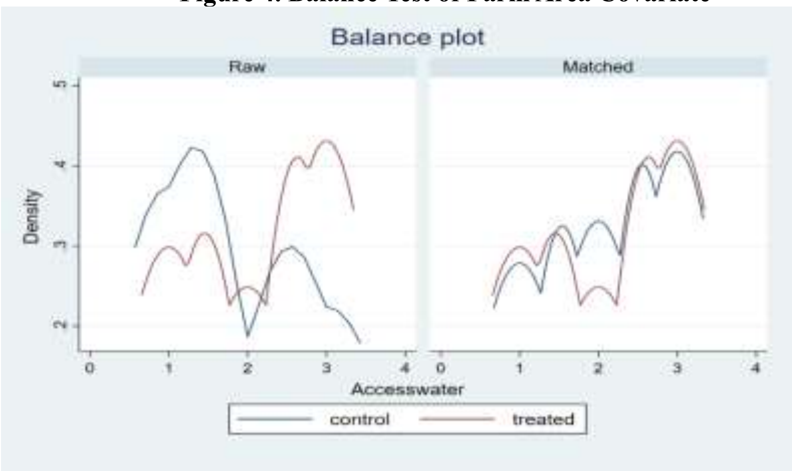

Figure 5. Balance Test of Access to Water Covariate

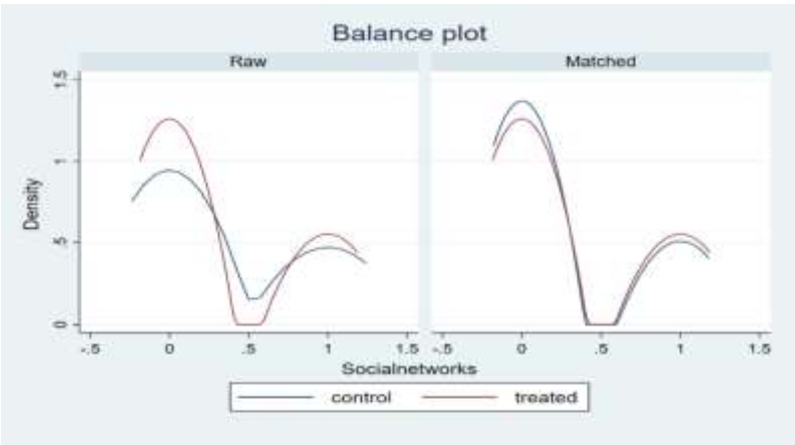

Figure 6. Balance Test of Social Networks Covariate

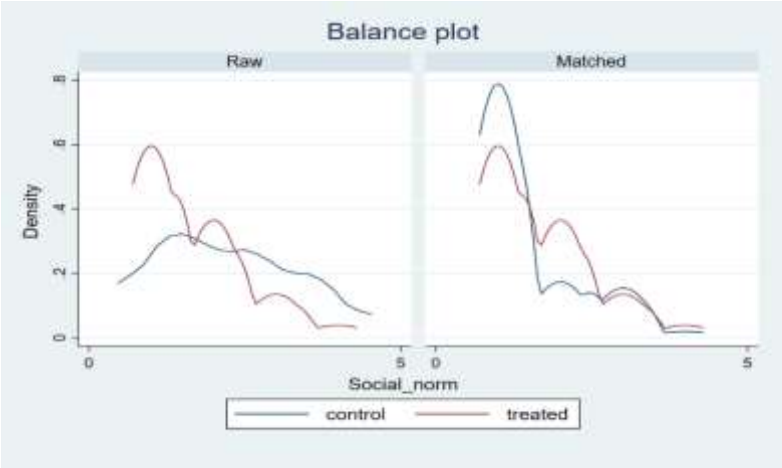

Figure 7. Balance Test of Social Norm Covariate

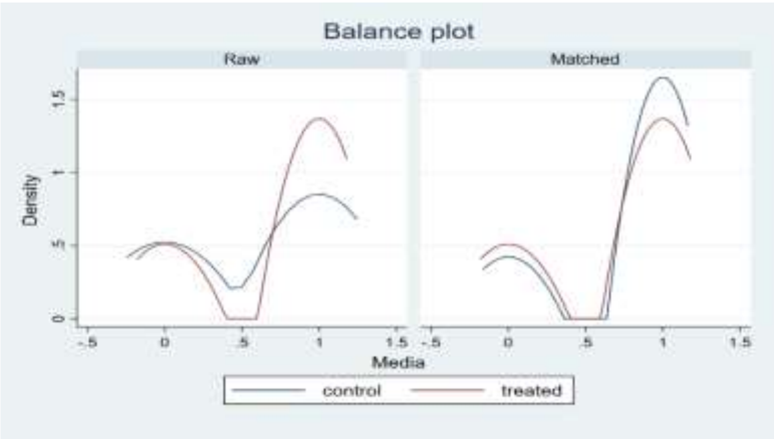

Figure 8. Balance Test of Public Media Covariate

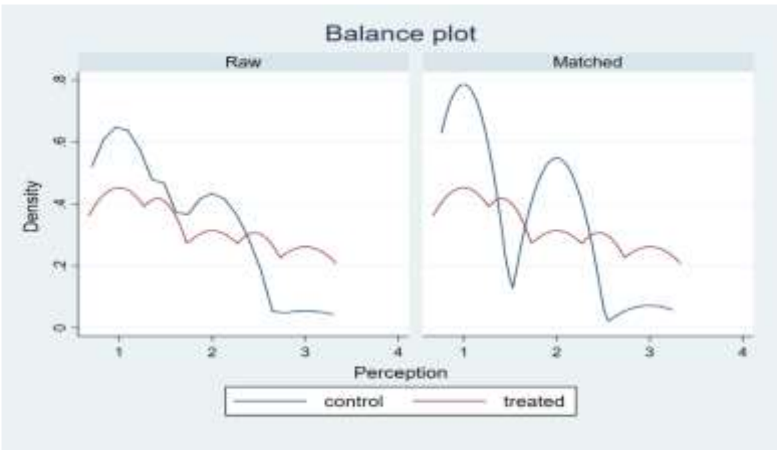

Figure 9. Balance Test of Perception Covariate

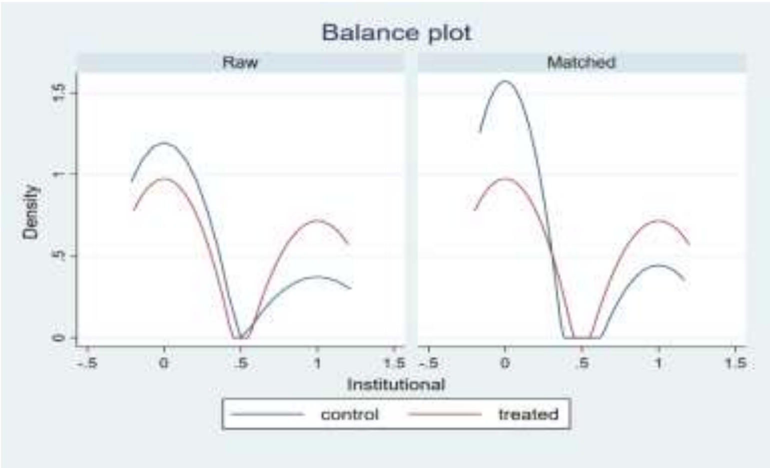

Figure 10. Balance Test ofInstitutional Information Covariate

In summary, the results of PSM ensure that climate change adaptation response can help to improve rural livelihood, especially household income in Soc Trang province.

6. Conclusions

In the combat against climate change, adaptation is considered as an important response to sustain rural livelihood in rice production. The study attempts to investigate the factors influencing the choice of adaptation response to salinity intrusion and the impact of adaptation choice on household income in Soc Trang province.

Results indicated that in response to climate change with respect to salinity intrusion and its impacts on both agricultural production and rural livelihood, majority of farmers (74%) have adapted their rice farming by one or a combination of adaptation practices. Others (26%) decided to perform no adaptation response.

In exploring the decisional factors driving performance of adaptation response and measuring the impacts of adaptation performance on household income, the PSM approach was employed. The results of the binary logistic model revealed that some influencing factors on the choice of adaptation included level of education, social norm, and geographical location at both district level and micro-level (e.g. access to water sources). More specifically, farmers with higher education are more likely to perform adaptation response. At the district level, Long Phu farmers are more likely to perform adaptation response to climate change related to salinity intrusion than Tran De farmers. In terms of access to water sources, more farmers owning their land at a short distance to water sources tend to adapt to salinity intrusion compared to those at a far distance to water sources, who are not directly affected by salinity intrusion. Furthermore, social norm may negatively influence the choice of adaptation response among rice farmers.

This study's finding supports the crucial role of climate change adaptation response in increasing household income. Farmers who have adapted their rice farming to climate change with respect to salinity intrusion have higher income (34 million VND per year) than those who have not adapted. As noted, this finding is line with other studies indicating that adaptation responses to climate change are the effective strategy to increase total household income which helps to sustain rural livelihood.

In the propensity score analysis approach presented here, the impacts on household income are evaluated more powerfully than with traditional techniques (e.g. test of difference in means) within observational studies.

This study also has some specific messages for further policies in (i) improving the perceptions of climate change and climate adaptation practices through educational program, as well as formal sources of information (e.g. public media, agricultural officers, and extension services), (ii) enhancing incentives which can train rural farmers on technical knowledge as well as stimulate adaptation responses suitable for specifically geographical locations to cope with climate change, (iii) supporting local farmers popularize their adaptation activity due to its beneficial achievements, and (iv) concerning on the actual barriers to farmers' adaptation (e.g. social norm) before any policy intervention on adaptation strategies.

The authors acknowledge limitations associated with limited sample size from only one province of the Vietnamese Mekong Delta. However, information of climate change adaptation response and its adapting process in this study is deployed from both local agricultural officers and rural rice farmers through in-depth interviews. Therefore, this empirical study hopes to provide some of the relative merits into the use of propensity score analysis for observational data and research of the process of adaptation strategies in response to climate change related to salinity intrusion in regional rice production in the empirical province of Mekong Delta. Further research with a representative sample will have to be conducted to investigate the effects of adaptation strategies or policy interventions associated with climate change on rice production in the Vietnamese Mekong Delta.

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[i] "Hidden bias is essentially a problem created by the omission in statistical analysis of important variables, and omission renders nonrandom the unobserved heterogeneity reflected by an error term in regression equations." (Guo & Fraser, 2015)(p.357)

[ii] "In greedy matching, a treated subject is first selected at random. The untreated subject whose propensity score is closest to that of this randomly selected treated subject is chosen for matching to this treated subjects. This process is then repeated until untreated subjects have been matched to all treated subjects or until one has exhausted the list of treated subjects for whom a matched untreated subject can be found." (Austin, 2011)

[iii] The definition of access to water source as the distance from farm to various water sources: near, medium, and far was taken from Ho and Ubukata (2018)

[iv] The definition of perception as the level of perceived changes related to salinity intrusion: low, moderate, and high by Soc Trang rice farmers was taken from Ho and Ubukata (2018).

[v] Social norm can be interpreted as how individuals perceive the pressures from other people that make her or him be able or not be able to perform their adaptation behavior (Ajzen, 1991).

[vi] The region of common support is defined as where distributions of the propensity score for treated and control group overlap (Guo & Fraser, 2015) (p.148).