Master's Thesis of Science in Agriculture

Two Essays on Farm Productivity in Rural Cambodia: Low Rice Yield in Tonle Sap Zone and Effects of Land Titling

캄보디아 농업생산성에 관한 두 가지 연구

: 톤레삽 지역의 낮은 쌀 생산성과 토지 증명서 효과

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Abstract

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This thesis are tied to the application of econometrics in agricultural productivity related topics. Two essays incorporate several estimation procedures and modeling techniques to analyze the issues of rice and land in Cambodia.

The first essay, *Why Does Tonle Sap Zone have the Lowest Rice Productivity?*, investigates factors that affect paddy productivity in the Tonle Sap zone, Cambodia using the parcel level data of the Cambodia Socio-Economic Survey (CSES) conducted in 2014. The paddy yield in Tonle Sap zone is very low though its cultivation area is the largest in

Cambodia. Many qualitative studies show that the Tonle Sap zone is a water-rich region, centered on the Tonle Sap Lake, but irregular rain and floods are likely to damage the yield. The findings that the rice productivity in the Tonle Sap zone is greatly affected by the wet and dry season, and especially irrigation, are constant with above the view.

The second essay, *Does Land Titling improve Agricultural Productivity in Rural Cambodia?*, uses CSES 2014 data to analyze the effects of land titling in Cambodia by addressing simultaneous causality bias and selection bias originated by non-experimental data. The findings indicate that the effects of land titling on agricultural productivity and input use are not significant. For credit accessibility, households with land titling was expected to receive cheaper interest rates and larger amount of money from lenders compared to without the titling, but the titling has weak effects on access to credit. These results do not coincide with the hypothesis in the study. In rural Cambodia, the role of land titling may be replaced by social customs and norms.

Keywords: Rice Productivity, Tonle Sap Zone, Land Titling, Simultaneous Causality Bias, Selection Bias, Instrumental Variable, Matching Frontier, Cambodia

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List of Abbreviations

CSES	Cambodia Socio-Economic Survey
MAFF	Ministry of Agriculture, Forestry, and Fisheries
MF	Matching Frontier
NIS	Cambodia National Institute of Statistics
OLS	Ordinary Least Squares
RGC	Royal Government of Cambodia
SIDA	Swedish International Development Cooperation Agency
2SLS	Second Stage Least Squares

1. Introduction

Cambodian agriculture has been at the center of rapid transformation. Average of agriculture growth between 2004-2012 was 5.3%, which was among the highest in the world (Eliste and Zorya, 2015). Agriculture sector contributed about 30% to the GDP and employed over 45% of the labor force (MAFF, 2017).

According to Cambodia National Agricultural Sector Strategic Development Plan (ASDP) 2014-2018, the Royal Government of Cambodia (RGC) defined the development of agricultural sector as a significant element for economic growth and set following goals: improvement of agricultural productivity, diversification, commercialization, land reform, sustainable management of natural resources, and forestry and fisheries reform. Among these goals, improvement of agricultural productivity is the main strategic target for agricultural growth, and the government puts particular priority on increasing agricultural productivity to reach the goal.

Cambodia agricultural gross production grew by around 9% during 2004-2012, mainly due to improvement of rice productivity (Eliste and Zorya, 2015). Rice ecosystem in Cambodia can be divided by main four ecological zones such as Tonle Sap, Plain, Mountain and Coast zone.

Though the Tonle Sap zone has the largest rice cultivation area, the rice productivity is the lowest level compared to others. Therefore, the study attempts to find factors affecting rice productivity in the Tonle Sap zone by using CSES 2014 parcel-level data. The researches on rice productivity in Tonle Sap zone have almost been conducted as qualitative studies, explaining why rice productivity near the Tonle Sap Lake is low with flood and lack of irrigation systems. The results of the study show that factors affecting rice productivity in the Tonle Sap zone are irrigation and wet season. The findings give some support to previous studies as quantitative research.

The researches on the relationship between land property rights and agricultural productivity has been actively studied in many developing countries, because insecure land ownership is likely to provide increased uncertainty for farmers in their agricultural activities. However, the results of the effects of land property rights are still controversial. In terms of property rights to land, Cambodia is a special case because the land law has changed dramatically according to the government. This study investigates the effects of spread of land titling in rural Cambodia. The findings indicate that land titling has a weak impact on agricultural productivity, input use, and credit accessibility in rural Cambodia.

The thesis, therefore, has two types of purposes as follows: 1) finding factors affecting rice productivity in Tonle Sap zone, 2) investigating the effects of land titling in rural Cambodia.

The thesis is organized as follows. Section 2 shows factorial analysis on rice productivity in Tonle Sap zone. Section 3 investigate the effects of land titling on agricultural productivity in rural Cambodia. Section 4 represents conclusion.

2. Why Does Tonle Sap Zone Have the Lowest Rice Productivity?

2.1. Background and Purpose of the Study

Rice is the most important field crop and staple food in Cambodia. Rice dominates Cambodia's remarkably wide agricultural sector. More than 80% of Cambodian live in rural areas, and most of them engage in rice farming, which has a big impact on rural people's livelihoods (Mund, 2011).

Cambodia paddy production has increased dramatically from 2.3 million tons (Mt) in the early 1960s to 9.8 Mt in 2016. During the same period, the yield has increased from 1.09 (t/ha) to 3.42 (t/ha) more than three times (FAOSTAT, 1961-2016). Despite its sharp growth, the paddy yield in 2016 is still 3.42 (t/ha). It is one of the lowest levels compared to neighboring countries such as Vietnam (5.58), Myanmar (3.81), Laos (4.26) and the Philippines (3.86) (FAOSTAT, 2016). If Cambodian paddy yield rises to the Vietnam level, that contributes to increasing household income, improving food security, and lifting living standard of many farm households above the poverty line (Yu and Fan, 2011).

In Cambodia, rice is grown in the various ecosystems such as rainfed lowland, rainfed upland, deepwater, and irrigated land (Maclean et al., 2013). The rainfed lowlands rely entirely on local rainfall and runoff for water supply. They are the largest proportion of the total rice land in Cambodia. The rainfed uplands are generally located in mountainous forested areas. The deepwater rice is cultivated in low-lying areas that are affected by floodwater. Rice farming sequences and practices differ in these ecosystems (Nesbitt, 1997). Therefore, Cambodia can be divided into four major ecological zones: Tonle Sap, Plain, Plateau, and Coast. The Tonle Sap zone is in the northwest area including six provinces: Banteay Meanchey, Battambang, Siem Reap, Pursat, Kampong Thom, and Kampong Chhnang around the Tonle Sap Lake which is the largest lake in Southeast Asia (Figure 2.1). The Plain zone is in the southeast and includes Kampong Cham, Kandal, Prey Veng, Svay Rieng, and Takeo province. The Plateau zone contains Kampong Speu, Kratie, Mondul Kiri, Oddar Meanchey, Pailin, Preah Vihear, Ratanak Kiri, and Stung Treng province, which is characterized by low population density and dense forests. The Coast zone comprises four provinces such as Kampot, Kep, Koh Kong, and Preah Sihanouk in the southeastern coast.

Figure 2.1. Tonle Sap Zone in Cambodia Map

Source: Library of Congress Geography and Map Division
Note: The marked provinces are included in the Tonle Sap zone.

Rice is mainly cultivated in the Tonle Sap and Plain zone, and most of rice farmers are also concentrated along the northwest-southeast corridor (Yu and Fan, 2011). However, according to Ministry of Agriculture, Forestry, and Fisheries (MAFF) annual report conducted in 2014, the paddy yield in Tonle Sap zone is very low though its cultivating rice area is the largest among the four major zones.

The purpose of this research is to find out factors influencing paddy productivity in Cambodia, especially Tonle Sap zone. Accordingly, the relation between paddy yield and determinants that affect the productivity is studied with the direction of how to increase the yield in the Tonle Sap zone, and it uses the parcel level data from Cambodia Socio-Economic Survey (CSES) conducted in 2014.

This paper is organized as follows. Part 2.2 describes previous studies about rice productivity and shows the difference with the previous studies and the meaning of the study. Part 2.3 introduces theory of production function. Part 2.4 gives description of CSES 2014 parcel level data and presents analysis procedure with Cobb-Douglas production function. Part 2.5 verify that the Tonle Sap zone's paddy yield is less than other zones, estimates which factors affect rice productivity by four ecological zones in Cambodia, and analyzes determinants of the productivity by wet and dry season in Tonle Sap zone. Part 2.6 gives discussion and conclusion.

2.2. Literature Review

In developing countries where essential infrastructures of growing rice were not established very well, improvement of infrastructures plays an important role in rice production. Kikuchi and Hayami (1978) demonstrate that improvements of land infrastructure such as irrigation and drainage are needed as preconditions for the development of large rice productivity gains by taking four Asian countries (Japan, Taiwan, Korea, and the Philippines) agricultural histories as an example.

Not only infrastructures but also government policies affect rice production of farmers in developing countries. Danh (2007) estimate the supply response of rice with price expectation in Vietnam, using dynamic adaptive expectations model and the rational expectations supply response model. The findings are that price expectations play an important role in rice farmers' decision making, thus proper price policy is likely to become a way to improve rice production in the country.

In the mid-1990s, some on the efficiency of rice production had been studied in Asia. Rosegrant and Pingali (1994) shows that declining of rice yield is caused by a stagnant technology in Asia, and suggests that improved management and efficiency of use of the resources used in rice production are needed for the future growth in rice yield. For Chinese, Huang and Rozelle (1996) uses data of China's 13 rice cultivating provinces during 1975-90 and emphasizes technology adoption is an effective way to increase rice yield. Xu and Jeffrey (1998) estimates productive efficiency for Chinese hybrid and conventional rice production. The results show that significant technical and allocative efficiency differences between hybrid and conventional rice production, and reveals significant differences in regional efficiency in hybrid rice production.

In Cambodia, there are a lot of qualitative and quantitative studies on rice production in Cambodia. Chhinh and Millington (2015) demonstrates that repeated droughts negatively affect rice production and especially late season droughts cause greater rice damage than early- and mid-season droughts. Moreover, Murphy et al. (2013) suggest that the resilient option of climate change for rice production is to focus on rice management practices including improvement of irrigation systems. On the other hand, Yu and Fan (2011) uses Cambodia Socio-Economic data conducted in 2004 and 2007, and estimates rice production response. The results indicate that rice productivity can be increased by using proper use of modern technology and input factors such as fertilizer and irrigation. Kea et al. (2016) attempts to measure the technical efficiency and establishes main factors affecting rice production. The results show that the most important factors of rice production's technical efficiency in Cambodia are irrigation, production techniques and labor. Wokker et al. (2014) estimates elasticities with respect to water input for rice production in Cambodia, but the elasticities are quite low between 0.057 and 0.069, because of sharing an aquifer system between Cambodia and

Vietnam in the Mekong Delta.

For rice productivity near the Tonle Sap Lake, Varisa et al. (2006) indicates that though forms of rice farming depend on the location of the village in floods of the Tonle Sap Lake, common to all of them has very low productivity because of poor infrastructure and low level of resources to affect rice production. Meanwhile, Nguyen et al. (2013) suggests effective way to increase yield for lowland and floating rice as follows: maintenance of standing water after heading of ears of rice season, increasing fertilizer, and suitable weed management.

Even though there are rich literature reviews on rice production or productivity in Cambodia, only a few economic studies about the Tonle Sap zone's rice productivity have been done. Therefore, it is important to find out factors affecting rice productivity in the Tonle Sap zone by doing data-based economic research.

2.3. Theory of Production Function

The production function is the mathematical representation of the relationship between physical inputs or production factors and physical outputs of the production process. To meet the mathematical definition of a function, a production function is generally assumed to specify the maximum output that can be obtained from a given set of inputs.

Therefore, the production function describes a boundary representing the limit of output obtainable from each possible input combination. The relationship of output to inputs is non-monetary in the production function itself, namely a production function relates physical inputs to physical outputs, while prices and costs are not reflected in the function.

Classically, the main factors in the production function were land, labor, and capital. Primary factors do not become part of the output product and are not primary elements that are modified in the production process. A production function can be expressed in a functional form as the following:

$$Q = f(X_1, X_2, X_3, \dots, X_n), \tag{2.1}$$

where Q is the quantity of output and $X_1, X_2, X_3, \dots, X_n$ are the quantities of factor inputs such as land, labor, and capital.

According to the degree of substitution of one input by the other, production function model can be classified into three different types: 1) Leontief production function, 2) Constant elasticity of substitution production function and 3) Cobb-Douglas production function. Leontief production function uses a fixed proportion of factors having no substitutability among them. Constant elasticity of substitution production function shows constant changes in the output produced due to changes in the factor of production. This function has the homogeneity degree of 1 that implies the output would be increased by n-fold with the increase in input by n-fold. Cobb-Douglas production function has the technical relationship in which one input can be substituted for the other but to a limited extent.

2.4. Data and Procedure

2.4.1. Data

This research uses the national representative CSES 2014 which contains many kinds of information from a total 12,096 households surveyed in four different types of the zone including 24 provinces. It is conducted by Cambodia National Institute of Statistics (NIS) and supported by Swedish International Development Cooperation Agency (SIDA). The CSES 2014 has the following subject matter areas: demography, housing, agriculture, education, labor force, health, victimization, household income and liability, household consumption, and vulnerability.

Multilevel data set which is characterized by a hierarchical structure including paddy production information, parcel and village level characteristics is constructed. A classic instance is that children nested within classrooms and classrooms belong to schools. In this study, 8,527 parcel data nested within 5,488 households that belong to 651 villages. Then, villages nested within four zones. Each household has averagely

1.5 parcels[1] where rice is grew (Table 2.1).

Table 2.1. Hierarchical Structure of Data from CSES 2014

Group	Zone	Village	Household	Parcel
Number	4	651	5,488	8,527

Source: Author's calculation from CSES (2014).

Table 2.2 shows descriptive statistics of the variables used in estimations. In this data set, only parcels cultivating rice in rural area are included. The paddy yield data means quantity of paddy production (kg) per size of paddy cultivation area (ha). The average yield is 3,171 kg/ha. For the production and the cultivation area, the mean values are 2,194 kg and 0.85 ha respectively. 87% of rice parcels are growing rice in the wet season.

In this study, various input variables affecting rice production were used. However, due to lack of the data, there are limitations in applying quantities of input information to analysis. Therefore, costs of input are applied as proxy variables in place of the input quantities. Input variables related to rice production were selected in consideration of the rice production process and prior articles, and the cost of seedling, fertilizer (chemical, organic), irrigation, and hiring (human, machine, animal)

[1] Each of the parcels has different land size. Table 2.2 will show average size of rice cultivated parcel area that is around 0.8 ha.

were used. The average parcel input cost of seedling, fertilizer, hiring and irrigation are 124,600, 301,884, 315,808 and 6,032 riel[2] respectively.

For irrigation use, since majority of the rice crop in Cambodia is aquatic rice, irrigation facilities that intentionally supplies the necessary amount of water over the period of growing rice, are very crucial for rice farming. In this data, average percent of parcels that can add water with irrigation facilities is 54%.

Land ownership is a prerequisite for secure agriculture activities. Therefore, parcels held with certified paper are used as dummy explanatory variable. 62% of parcels have papers to certify its ownership.

For household characteristics, the number of household members is from 1 to 15, and the average is 4.7. The proportion of male household head is 83%. The youngest household head is 16 years old and the oldest is 88. The mean of household head age is 47.2. Above 70% of household heads can at least read or write a simple simple message. The percentages of households dwelling in each of the four ecological zones are the following: the Tonle Sap zone (31%), the Plain zone (43%), the Mountain zone (21%), and the Coast zone (5%).

[2] Exchange rate of Cambodia riel is 1 dollar equal to 4,040 riel (NBC, 2018).

Table 2.2. Descriptive Statistics

Variable	Definition	Obs	Mean	Min	Max
Output					
Productivity	Paddy yield in kg/ha	8,519	3,171	0	495,050
Parcel Characteristics					
Output	Quantity of paddy production (kg)	8,525	2,194	0	150,250
Cultivation_area	Size of paddy cultivation area (ha)	8,521	0.85	0.004	30
Season_wet	Dummy variable, Season_wet = 1 if wet season, 0 if dry season	8,527	0.87	0	1
Cost_seedling	Input cost of seedling in a parcel (riel)	8,349	124,600	0	23,000,000
Cost_fertilizer	Input cost of fertilizer (chemical, organic) in a parcel (riel)	8,349	301,884	0	28,000,000
Cost_hiring	Input cost of hiring (human, machine, animal) in a parcel (riel)	8,349	315,808	0	28,000,000
Cost_irrigation	Input cost of irrigation in a parcel (riel)	8,349	6,032	0	3,240,000
Parcel_irrigation	Dummy variable, Parcel_irrigation = 1 if a parcel has irrigation system, 0 otherwise	8,496	0.54	0	1
Parcel_paper	Dummy variable, Parcel_paper = 1 if a parcel has a paper to certify its ownership or rental agreement, 0 otherwise	8,496	0.62	0	1
Household Characteristics					
Household_size	The number of household member	8,527	4.7	1	15
Head_male	Dummy variable, d_malehead= 1 if a household head is male, 0 otherwise	8,527	0.83	0	1
Head_age	Household head ages in years	8,527	47.1	18	88
Head_literacy	Dummy variable, Head_literacy = 1 if a household head can at least read or write a simple message, 0 otherwise	8,527	0.73	0	1
Four Ecological Zones					
Zone_tonlesap	Dummy variable, Zone_tonlesap = 1 if a household belongs to the Tonle Sap zone, 0 otherwise	8,527	0.31	0	1
Zone_plain	Dummy variable, Zone_plain = 1 if a household belongs to the Plain zone, 0 otherwise	8,527	0.43	0	1
Zone_mountain	Dummy variable, Zone_mountain = 1 if a household belongs to the Mountain zone, 0 otherwise	8,527	0.21	0	1
Zone_coast	Dummy variable, Zone_coast = 1 if a household belongs to the Coast zone, 0 otherwise	8,527	0.05	0	1

Note: 1) Only parcels cultivating rice are included. 2) Only parcels belonging to rural area are included.

Table 2.3 indicates average values of major variables which affect rice productivity by the four ecological zones as well as multivariate hypothesis tests of equal means which depends on whether homogeneity of variance is assumed when there are more than two groups (STATA, 2017). The hypothesis that the means of the variables are the same for the four zones is tested under the assumption that the zones have equal covariance matrices. The low p-value signifies that the means of major variables are likely to be different between the ecological zones.

The mean of paddy yield in Tonle Sap zone is 2,558 kg/ha, which is the lowest level among the four zones. The average cultivation area in the Tonle Sap zone is 1.10 ha, which is highest relative to other zones. On the other hand, the Plain zone's cultivation area is the lowest among the zones. For the cost of seedling, the Tonle Sap zone's parcels are invested much higher than other zones. The Plain zone is the most aggressive in investing in fertilizer. Hiring cost is the highest in the Tonle Sap zone followed by the Plain zone, which is similar in mountain zone and coast zone. Compared to other inputs, irrigation cost is very low ,and the average cost in the three other areas, except in the Plain zone, is less than 1 $. For the percentage of parcels that can add water with irrigation for agriculture, the Tonle Sap zone is 53% that is low level compared to the other zones (the Mountain zone where irrigation is the least utilized

(42%) should be considered due to geographical limitations).

Table 2.3. Means of Major Variables by Ecological Zones

Variable	Tonle Sap	Plain	Mountain	Coast	P-Value
Productivity (kg/ha)	2,558 (3,203)	3,759 (9,366)	2,944 (4,446)	2,870 (2,213)	0.0000
Cultivation_area (ha)	1.10 (1.33)	0.66 (0.66)	0.88 (0.90)	0.74 (0.69)	0.0000
Cost_seedling (riel)	160,912 (499,974)	120,526 (250,516)	91,766 (445,769)	66,134 (113,667)	0.0000
Cost_fertilizer (riel)	274,335 (502,264)	388,196 (768,442)	166,088 (196,555)	293,716 (401,820)	0.0000
Cost_hiring (riel)	384,268 (891,959)	313,580 (620,186)	235,570 (388,169)	234,135 (231,418)	0.0000
Cost_irrigation (riel)	1,765 (27,865)	11,919 (114,555)	1,125 (10,801)	2,618 (19,450)	0.0000
Parcel_irrigation (%)	0.53 (0.499)	0.59 (0.492)	0.42 (0.494)	0.63 (0.482)	0.0000

Source: Author's calculation from CSES (2014).
Note: 1) The hypothesis of multivariate tests is equal means by the group. 2) Numbers in parentheses are standard error.

2.4.2. Procedure

For this study, Cobb-Douglas production function is used to represent the relationship between the paddy yield and production factors (land, labor, rice production inputs). The model is as following Equation (2.2):

$$yield_{zvhp} = \boldsymbol{X^{\beta}}_{zvhp} e^{\gamma_z + \delta_v + \theta_h + \varepsilon_{zvhp}}, \qquad (2.2)$$

where $yield$ is the paddy yield in kg/ha measured at parcel levels, the subscript, *z*, *v*, *h*, and *p* indicate the zone, village, household, and parcel level, respectively, $\boldsymbol{X}$ is a vector of explanatory variables including parcel characteristics (season dummy, cultivation area, costs of various production inputs, irrigation dummy, certified paper dummy) and household characteristics (household size, head gender, head age, head literacy). $\boldsymbol{\beta}$ is a vector of coefficients to be estimated, and e is the base of exponential function. γ_z is zone effect, δ_v is village effect, and θ_h is household effect. Zone, village, and parcel effects are applied to handle each hierarchy characteristics. For example, village effect can control for village level characteristics, such as graphical differences in market conditions, soil quality, and infrastructure. ε_{zvhp} is error term.

The natural logarithm of Equation (2.2) can be written as follows:

$$\ln yield_{zvhp} = \ln\boldsymbol{X}_{zvhp}\boldsymbol{\beta} + \gamma_z + \delta_v + \theta_h + \varepsilon_{zvhp}, \qquad (2.3)$$

where ln *yield* is the natural log of paddy yield in kg/ha , ln $\boldsymbol{X}'$ includes the natural log of parcel characteristics and household characteristics.

2.5. Estimation Results

2.5.1. Determinants of Paddy Productivity in Cambodia

The Cobb-Douglas production function in Equation (2.3) is estimated for paddy productivity. Table 2.4 shows the results of estimating the model for paddy production (kg) per cultivation area (ha).

In the agricultural production function, land is one of the most important factors along with labor and capital. A 1% increase in cultivation area decreases paddy yield by 0.381%. The paddy yield equals paddy production divided by rice cultivation area. That is why expanding of cultivation area negatively affect the yield.

The wet season has a large and negative impact on Cambodian paddy yield and the yield in the wet season is decreased by 35.1% compared to the dry season. There are many different reason for that. Nesbitt (1997) claims that erratic rainfall during wet season induces substantially lower paddy productivity because it causes insufficient or excessive rains during some important period for paddy. In July and August, lack of rains delays transplanting which plays an important role in vegetative growth. From September to October, excessive rains cause flash floods that can reduce plant density. Inadequate rains in October and November can adversely affect paddy yield during its reproductive stage. In addition, traditional varieties which have lower yield than modern ones are mainly grown in the wet season while modern high yielding varieties like IR 66 are dominant in the dry season (Wang et al., 2012). The traditional ones are photoperiod sensitive, which means they have an adaptive characteristic responsive to Cambodia unstable rainfall patterns in the wet season. Their tall height is also a good trait to endure wet season floodwaters. On the other hand, the modern varieties are not photoperiod sensitive, are not as tall, and have short growing periods, meaning they can be grown throughout the year, but these varieties tend to be grown in the dry season with irrigation as cash crops for foreign buyers (Milne and Mahanty, 2015). Also, Maclean et al. (2013) suggest that paddy productivity of wet season is much lower than that of the dry season, mainly due to low use of higher yield seeds and worse water management in Cambodia.

For input cost of seedling, it reveals that the cost of seedling does not affect the paddy productivity. Likewise, Wokker et al. (2014) argue that Cambodia rice productivity is not affected by investment in paddy seedling. The use of fertilizers has a huge impact on the productivity of rice. However, continuing to increase the use of fertilizers does not increase rice productivity indefinitely. Therefore, the square value of the fertilizer variable is used to obtain the point at which the value falls in this analysis. A 1% increase in the fertilizer cost decreases the yield by

0.189%, but the coefficient of squared cost is a positive sign. It means that paddy yield increases when the cost reach a certain level. The certain point is 67,348 riel. Therefore, the paddy yield starts to increase when a household puts the costs of chemical fertilizers for paddy on their parcel more than 67,348 riel. The cost of hiring in this study includes human, machine, and animal. When hiring cost increases by 1%, the rice yield increases by 0.009%. Cost of irrigation is not a significant effect on paddy productivity in Cambodia. On the other hand, use of irrigation has a positive impact on rice productivity. If parcel can add water with irrigation system, the productivity increases by 10.4%. Since land property rights may affect farm productivity, in Cambodia where rice farming is a major part of agriculture, land held with formal titling is expected to be high rice productivity compared to land without the titling. However, the variable, parcel with certified paper, does not significantly affect the paddy yield in the study.

The household characteristics include household size, household head characteristics such as gender, age, and literacy. The labor is also an important element in agriculture production function. Labor force is substituted for the number of household member in this study since most of the labor forces in developing countries' rural area come from within the households. However, household size has not a significant effect on the paddy yield in Cambodia. For the gender of household head, if the household head is male, the yield increases by 5.5%. However, the age and literacy rate of the household head have not significantly effect on the paddy productivity.

Finally, the paddy productivity might differ between the four zones since rice production is more vibrant in some zones of Cambodia than others. To test this hypothesis, dummy variables of the four zones is applied. The omitted category for the four ecological zones is the Tonle Sap zone. The dummy effect of the ecological zones are significant (the effect of the Coast zone is not significant), and the coefficients are as follow: Plain (0.086), Mountain (0.162). That means if households are in the Plain zone, the paddy yield is 8.6 % higher than the Tonle Sap zone. Likewise, for the Mountain zone, the paddy yield increases by 16.2%. The hypothesis of a strong effect of difference between the zones provides some support for low rice productivity in the Tonle Sap zone. So, what factors affect low rice productivity in the Tonle Sap zone?

Table 2.4. Determinants of Paddy Productivity in Cambodia

Independent variables	Paddy production per cultivation area , *kg/ha* (log)
Parcel characteristics	
Cultivation area, *ha* (log)	-0.381***
	(0.017)
Wet season (1 = yes, 0 = dry season)	-0.351***
	(0.034)
Cost of seedling, riel (log)	0.007
	(0.012)
Cost of fertilizer, riel (log)	-0.189***
	(0.007)
Ln_Cost of fertilizer^2, riel	0.017***
	(0.001)
Cost of hiring, riel (log)	0.009***
	(0.003)
Cost of irrigation, riel (log)	0.005
	(0.003)
Parcel with irrigation (1 = yes, 0 = no)	0.100***
	(0.033)
Parcel with paper (1 = yes, 0 = no)	-0.017
	(0.023)
Household characteristics	
HH size	0.008
	(0.005)
Male HH head (1 = yes, 0 = female)	0.055**
	(0.022)
Age of HH head	-0.000
	(0.000)
Literacy of HH head (1 = yes, 0 = no)	0.023
	(0.020)
Four Ecological Zones	
Plain zone	0.086**
	(0.040)
Mountain zone	0.162***
	(0.051)
Coast zone	0.057
	(0.050)
Constant	7.251***
	(0.118)
Zone Fixed	Yes
Village Random	Yes
Household Random	Yes
Log pseudolikelihood	-9,149.2
Wald chi2	816.2
Prob > chi2	0.0000
Obs	8.490

Note: 1) *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%, 5%, 10%, respectively. 2) Numbers in parentheses are robust standard error. 3) The omitted category for the four ecological zones is the Tonle Sap zone.

2.5.2. Paddy Productivity and Four Ecological Zones

To verify the determinants on the paddy productivity in the four zones, the paddy productivity model is estimated separately for each of the four main, geographical zones in Cambodia. Table 2.5 shows estimation results of the determinants of paddy production by the four ecological zones.

In the Tonle Sap zone, a 1% increase in cultivation area decreases paddy yield by 0.338%. The effect of the wet season on the paddy productivity is greatly high. Compared to the dry season, paddy productivity decreases by 40.3% in wet season. Excessive rains in the wet season, connected with the high floodwater level in the Tonle-Bassac and Mekong rivers, bring about great damage to the crop (Nesbitt, 1997).

The paddy yield starts to increase if a household invests the cost of chemical fertilizers on a parcel more than 17,487 riel. When the hiring cost increases by 1%, the paddy yield increases 0.016%.

In where crop fields are often overflowed by high floodwater in the wet season like the Tonle Sap zone, irrigation is one of the most important elements to grow rice well. The irrigation system includes draining unnecessary water from farmland when the water is more than necessary as well as intentionally supplying the necessary amount of water during the growing season. One thing to focus on is that only in the Tonle Sap zone, the irrigation cost significantly affects paddy yield. When irrigation cost increases by 1%, the paddy yield increases 0.021%. In particular, the use of irrigation system has a greatly positive impact on rice productivity. If a parcel uses irrigation system for rice production, the productivity increases by 15.8%.

In the Plain zone, the paddy yield decreases by 0.381% when cultivation area increases by 1%. For the wet season, the coefficient of the variable is -0.290. The effect of the wet season on the paddy yield is less than other zones. The yield starts to increase when the cost of chemical fertilizer is more than 261,367 riel. The impact of the irrigation system on the paddy yield is significant. Parcels held with irrigation facility are 7.9% more productive than parcel without irrigation system. If the household head is male, the yield increases by 4.3%.

In the Mountain zone, a 1% increase in the cultivation area decreases the paddy productivity by 0.444%. During the wet season, rice productivity is 64.7% less than in the dry season. The productivity elasticities with respect to the seedling cost is 0.024. The paddy yield increases when the fertilizer cost reaches 109,097 riel. A 1% increase in the cost of hiring increases the paddy yield 0.012%. Household male head has a large impact on the yield compared to other zones, and the yield increases by 12.9%.

In the Coast zone, a 1% increase in the cultivation area decreases the paddy yield by 0.476%. The season variable is not significant. The investment effect of seedling in the Coast zone on the paddy yield is much higher than other zones; the coefficient is 0.305. The elasticities of the yield concerning the fertilizer cost is -0.411, and that of the squared variable is 0.021.

Certified paper or rental agreement and many household characteristics such as household size, household head age, and literacy rate of the head have not a significant effect on the paddy yield in all the four zones.

Table 2.5. Determinants of Paddy Yield by Ecological Zones

Independent variables	Paddy production per cultivation area , *kg/ha* (log)			
	Tonle Sap	**Plain**	**Mountain**	**Coast**
Parcel characteristics				
Cultivation area, ha (log)	-0.338***	-0.381***	-0.444*	-0.476***
	(0.032)	(0.027)	(0.032)	(0.052)
Wet season (1 = yes, 0 = dry season)	-0.403***	-0.290***	-0.647***	-0.062
	(0.084)	(0.032)	(0.363)	(0.131)
Cost of seedling, riel (log)	-0.024	0.013	0.024**	0.305***
	(0.024)	(0.013)	(0.010)	(0.087)
Cost of fertilizer, riel (log)	-0.127**	-0.237***	-0.174***	-0.411***
	(0.055)	(0.030)	(0.031)	(0.082)
Ln_Cost of fertilizer^2, riel	0.013***	0.019***	0.015***	0.021***
	(0.003)	(0.001)	(0.002)	(0.004)
Cost of hiring, riel (log)	0.016**	0.002	0.012***	-0.000
	(0.006)	(0.003)	(0.004)	(0.012)
Cost of irrigation, riel (log)	0.021***	0.004	-0.007	0.008
	(0.006)	(0.004)	(0.009)	(0.010)
Parcel with irrigation (1 = yes, 0 = no)	0.158*	0.079**	0.042	-0.029
	(0.083)	(0.033)	(0.042)	(0.079)
Parcel with paper (1 = yes, 0 = no)	-0.044	-0.019	0.032	0.000
	(0.045)	(0.030)	(0.054)	(0.094)
Household characteristics				
HH size	0.014	0.008	0.004	-0.003
	(0.010)	(0.007)	(0.010)	(0.029)
Male HH head	0.011	0.043*	0.129***	0.060
	(0.057)	(0.024)	(0.046)	(0.064)
Age of HH head	-0.000	-0.000	-0.000	-0.002
	(0.001)	(0.000)	(0.001)	(0.003)
Literacy of HH head (1 = yes, 0 = no)	0.022	0.017	0.006	0.085
	(0.039)	(0.026)	(0.046)	(0.051)
Constant	7.343***	7.491***	7.516***	6.155***
	(0.270)	(0.099)	(0.384)	(0.601)
Village Random	Yes	Yes	Yes	Yes
Household Random	Yes	Yes	Yes	Yes
Log pseudolikelihood	-3,467.5	-3,246.6	-1,609.8	-369.3
Wald chi2	203.3	345.9	274.9	171.3
Prob > chi2	0.0000	0.0000	0.0000	0.0000
Obs	2,666	3,660	1,741	423

Note: 1) *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%, 5%, 10%, respectively. 2) Numbers in parentheses are robust standard error.

2.5.3. Paddy Yield in Tonle Sap Zone by Wet and Dry Season

The season variable is one of the biggest impact on paddy productivity in Tonle Sap zone. Rice farming method is different in the seasons with rice ecosystems. Depending on climatic conditions, it is possible to cultivate triple rice cropping for a year, but there is commonly a single cropping in the wet and the dry season due to lack of repair facilities. The wet season starts in May and ends in October and the dry season is from November to April of next year in Cambodia. For this reason, I assume that there is double rice cropping for a year in Cambodia. Table 2.6 shows estimation results of the paddy production model in the Tonle Sap zone by the wet and dry season.

In the wet season, a 1% increase in cultivation area decreases the paddy yield by 0.341%. The paddy yield of wet season starts to increase when the fertilizer cost is more than 9,718 riel. A 1% increase in hiring cost increases the paddy yield by 0.017%. For the irrigation variables, Yu and Fan (2011) represent that investment in irrigation does not affect Tonle Sap zone's paddy yield in the wet season. However, in this result, a 1% increase in irrigation cost produces a huge increase in wet season paddy productivity by 0.026%. In addition, the productivity is 13.1% much higher when parcels apply irrigation facilities. Since sudden downpours cause floods and damage many crops in the wet season, irrigation investment and use of the system are crucial for rice cultivation in the Tonle Sap zone.

Similarly, a 1% increase in cultivation area decreases the dry season paddy yield by 0.328%. The cost of fertilizer in the dry season make the productivity decrease before to reach 116,618 riel. After then, the yield increases faster than in the wet season. Investment of irrigation has a small impact on the productivity by 0.006%.

To accurately analyze factors affecting the rice productivity by the wet and dry season, some climate variables such as rainfall, temperatures, and disaster are necessary. Those kind of variables, however, are not included in this study due to the data limitation. Moreover, the number of plot observations varies greatly in the wet and the dry season in the Table 2.6 because majority of Cambodia farm households commonly grow rice in the wet season, while other crops and vegetables are mostly cultivated in the dry season instead of rice. Accordingly, there are some limits to interpretation of variables by the both season in Tonle Sap zone. However, this results might generally help to understand which factors are important in the rice productivity in the wet and dry season in the Tonle Sap zone.

Table 2.6. Paddy Yield in Tonle Sap Zone by Wet and Dry Season

Independent Variables	Paddy production per cultivation area, *kg/ha* (log)	
	Tonle Sap Zone	
	Wet Season	Dry Season
Parcel characteristics		
Cultivation area, ha (log)	-0.341***	-0.328***
	(0.037)	(0.078)
Cost of seedling, riel (log)	-0.012	-0.045*
	(0.027)	(0.027)
Cost of fertilizer, riel (log)	-0.101*	-0.245***
	(0.060)	(0.067)
Ln_Cost of fertilizer^2, riel	0.011***	0.021***
	(0.003)	(0.005)
Cost of hiring, riel (log)	0.017**	0.006
	(0.007)	(0.012)
Cost of irrigation, riel (log)	0.026***	0.006*
	(0.009)	(0.003)
Parcel with irrigation (1 = yes, 0 = no)	0.131*	-0.007
	(0.076)	(0.093)
Parcel with paper (1 = yes, 0 = no)	-0.056	0.052
	(0.050)	(0.076)
Household characteristics		
HH size	0.015	-0.013
	(0.011)	(0.015)
Male HH head	0.020	-0.044
	(0.060)	(0.085)
Age of HH head	-0.000	-0.001
	(0.001)	(0.002)
Literacy of HH head (1 = yes, 0 = no)	0.018	0.022
	(0.042)	(0.069)
Constant	6.773***	8.276***
	(0.272)	(0.253)
Village Random	Yes	Yes
Household Random	Yes	Yes
Log pseudolikelihood	-3,231.0	-100.1
Wald chi2	164.8	44.6
Prob > chi2	0.0000	0.0000
Obs	2,436	230

Note: 1) *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%, 5%, 10% respectively. 2) Numbers in parentheses are robust standard error.

2.6. Discussion and Conclusion

Cambodia's rice productivity has increased rapidly since the 1960s until now, but is still lower than its neighboring countries. To increase overall productivity in Cambodia, improvement of paddy yield in the Tonle Sap zone is necessary since the Tonle Sap zone has the lowest paddy productivity though it has the largest paddy cultivation area among the other zones. This research focuses to find out determinants affecting low paddy productivity in the Tonle Sap zone by using parcel level data of CSES conducted in 2014.

Many previous studies suggest the reasons why rice productivity is low in the Tonle Sap area as following: the extreme rain in the rainy season which damages rice production, use of traditional varieties in the wet season that have lower yield, and bad water management.

According to the first estimation results, the low paddy yield in the Tonle Sap zone is indicated (the Plain zone is 8.6% higher and the Mountain zone is 16.2% higher than the Tonle Sap zone). In Table 2.5, the paddy production model is estimated separately for each of the four main zones in Cambodia. Table 2.5 shows that the rice productivity in the Tonle Sap zone is greatly affected by the wet and dry season, and irrigation. The yield of wet season is 40.3% lower than that of dry season. For the irrigation variables, a 1% increase in the irrigation cost increases the rice yield by 0.021%, and parcels with irrigation facilities produce huge impact on the paddy yield in the Tonle Sap zone by 15.8%. Nevertheless, the irrigation investment cost and the ratio of irrigation usage those in the Tonle Sap zone are significantly lower than in other zones (Table 2.3). Table 2.6 represents estimation results of the paddy production model in the Tonle Sap zone by the wet and dry season since rice farming method is different by seasons with rice ecosystems in Cambodia. The results show that in the wet season the paddy yield of parcels with irrigation facilities is 13.1% higher than parcels without irrigation system.

These results are consistent with the previous views that rice productivity in the Tonle Sap zone is low due to flood, use of low yield varieties in the wet season, and worse water management. However, due to the data limitation, the inability to apply climate variables and types of rice varieties, and lack of observations in the dry season make it difficult to clearly interpret the results, but these results may help us to understand the factors that generally affect rice productivity in the Tonle Sap zone, away from the earlier qualitative studies. In addition, the findings could have important implications for discussions on how to promote Cambodia rice productivity in the future.

3. Does Land Titling Improve Agricultural Productivity in Rural Cambodia?

3.1. Background and Purpose of the Study

The vulnerability of property rights is considered a crucial barrier to economic development (Acemoglu et al., 2001; De Long and Shleifer, 1993; Johnson et al., 2002; Douglass Cecil North, 1981; Douglass C North and Thomas, 1973). The evolution of property rights and their effect are central issues in the political economy of development. The securing of property rights, therefore, has long been advocated as a good policy for economic growth.

In the livelihoods of farmers around the world, secure land rights as a productive resource are critical. Secure access to land allows farmers to work and invest in their agricultural activities with the expectation that they will benefit without fear that their land may be confiscated arbitrarily. Therefore, land rights are seen as the key to enhancing the conditions of farmers in many developing countries where agriculture is the predominant sector in terms of agriculture. Nevertheless, the effects of land property rights on agricultural productivity have still been controversial in many countries for a long time.

Regarding land property rights, Cambodia is a special case due to its distinctive historical circumstances. In the past, all private property was abolished, and even the ownership records were destroyed during the Khmer Rouge regime period in Cambodia. In 1989, after the fall of the Khmer Rouge regime, private property rights were officially reintroduced, and the Land Laws that were enacted by 1992, which prompted many farm households to obtain formal land titles. In this context, the study investigates whether the spread of formal land titling leads to improve agricultural productivity in a farming-based country, Cambodia.

However, land rights might have simultaneous causality bias with agricultural productivity and selection bias problems originated by non-randomized survey data. Simultaneous causality bias means that land property rights might affect agricultural productivity at the same time as the productivity have a potential effect on the land rights. The bias has been much addressed in many studies relative to property rights effects analysis. However, for selection bias, many previous studies have not conducted randomized control trials in terms of tenure rights, and leave uncertainty as to why certain households or land parcels received land recognition while others did not (Lawry et al., 2017). Therefore, the study is an attempt to investigate the impact of land titling on agricultural productivity by mitigating simultaneity causality bias and selection bias.

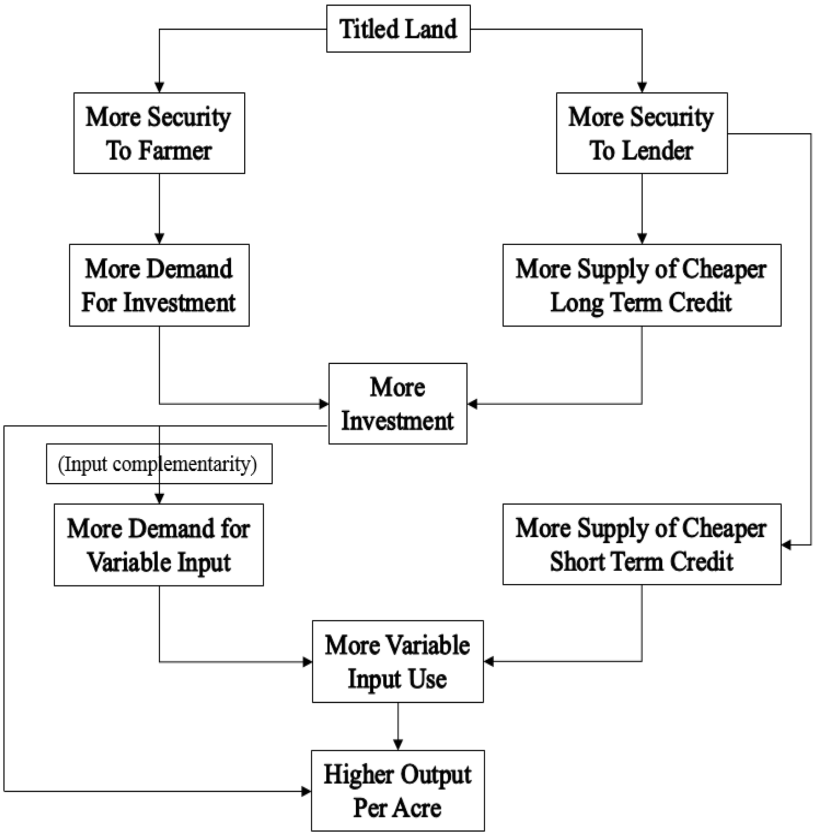
The remainder of the paper is organized as follows. Part 3.2 introduces a theory of this study. Part 3.3 describes the history of land property rights in Cambodia. Part 3.4 provides literature review. Part 3.5 presents the data set to be used in this study and provides descriptive statistics. Part 3.6 shows model and estimation strategies. Part 3.7 investigates the effect of land titling on agricultural productivity, input use, and access to credit. Part 3.8 gives discussion and conclusion.

3.2. Theory of the Study

Feder (1987) suggested two main channels that titled land have potential impacts on the increase of agricultural productivity. First, titled land can increase incentives to invest with the confidence of the landowner. Farmers without the secure property rights to land have little incentive to plant because there is no reasonable assurance that one will possess the land at the time of harvest. In other words, the effect of secure land ownership is increased certainty by the farmers as to whether they will be able to benefit from the investments that they make to improve the farm's productive capacity. Second, secure land property rights facilitate farmers to increase agricultural productivity by easing access to credit. Possession of a land titling is often an essential precondition for commercial or official bank loans as collateral (Dorner and Saliba, 1981;

Sacay, 1973; Wai, 1957). Farmers without the secured land property rights face obstacles in access to low-cost credit. Constrained and more expensive credit might make farmers invest low input use on their land. On the other hand, secure land ownership is more likely to give farmers easier access to cheaper, longer-term, and more extensive credit. Farmers applying these benefit of credit on their farmland as the investment of agricultural input are expected to increase agricultural productivity. Figure 3.1 summarizes the causal relationship of the preceding discussion.

Figure 3.1. Land Titling and Agricultural Productivity : A Conceptual Framework



Source: Feder (1987)

In a quantitative study, however, it is difficult to demonstrate whether all the two theories work in Cambodia. This is because, to substantiate confidence of the farmers and lenders, subjective assessments of property rights effect of the survey respondents is required. However, the data to be used in this research does not contain such subjective information. Therefore, this study establishes agricultural productivity, input use and credit accessibility (monthly interest and amount of debt) as dependent variables, and aims to investigate the effects of land titling in rural Cambodia.

3.3. History of Land Property Rights in Cambodia

In pre-colonial times, the sovereign formally owned all land, but land actually was freely occupied since population density was low. During French colonization (1863-1953), modern system of property rights and the concept of fully private property in land was first introduced by Civil Code in 1920. However, only 10% of landowners (especially the rice growing plains) received land ownership titles because of lack of bureaucratic capacity. After independence in 1953 and up to the Khmer Rouge takeover in 1975, the colonial property rights system was continued. During the Khmer Rouge reign (1975-1979), all private properties in the land were abolished, and all records of ownership were destroyed. After the fall of the Khmer Rouge, land continued to be used by solidarity groups and owned by the state. Families were allowed small plots, but there existed no effort to restore private ownership.

Private property rights to land were officially reintroduced in 1989, and the Land Laws were enacted in 1992. Many households submitted applications for formal land titles by the government, and more than four million applications have been submitted. However, the only small amount of these applications have actually resulted in certificates being issued because of the limited administrative capacity of the governments.

Furthermore, when households applied for a land title, they needed to pay substantial costs in terms of informal registration fees. The official fee of registration was 3-4$ while the actual fee was sometimes as much as 300-400$ (Markussen, 2008). The poor did not even register for official land titles because they could not afford the informal fee.

The Land Laws of 2001 with the goals for the provision of greater tenure security to average Cambodians created LMAP (Land Management Administration Project). LMAP aimed to facilitate a comprehensive reform of land management policies in Cambodia, and one of its purposes is a systematic land titling, issuing 1 million titles in 11 provinces during 2003-2007. As of 2010, these processes had collected data on more than 2 million parcels and had issued around 1.5 million title certificates (Trzcinski and Upham, 2014).

3.4. Literature Review

This part examines the relevant literature based on the dependent variables set in Part 3.2 such as agricultural productivity, input use, and access to credit.

3.4.1. Agricultural Productivity

Feder (1987) who suggested a classic framework between secure land ownership and agricultural productivity found that property rights to land in Thailand have a positive effect on farm productivity since they lead to decrease the uncertainty of farmers and lender. Agricultural tenancy laws offering the security of tenure to tenants in the Indian state of West Bengal in the late 1970s had a positive impact on agricultural productivity (Banerjee et al., 2002). Hayes et al. (1997) showed that tenure security had a positive effect on agricultural productivity in peri-urban areas of the Gambia, by applying a feasible generalized least squares Amemiya's generalized probit to handle both continuous and discrete endogenous variables. For Cambodia, Markussen (2008) used Cambodia socio-economic survey data conducted in 2004 to estimate the effects of land property rights with instrumental variable estimation. The finding was that plots with formal paper in rural Cambodia have higher productivity than other plots. Melesse and Bulte (2015) investigated the effect of Ethiopian land registration and certification program on farm productivity by employing propensity score matching method (PSM), and found that the land program has robust positive effects on the productivity.

On the contrary, Place and Hazell (1993) showed that land rights were not found to detect any effect on agricultural productivity in Ghana, Kenya, and Rwanda. Also, F. Place and S. E. Migot-Adholla (1998) stated land registration in Kenya had a weak impact on crop yield of smallholder farms. Furthermore, Atwood (1990) and Sjaastad and Bromley (1997) cast doubt on the positive relationship between land rights and agricultural productivity in Africa. Bellemare (2013) showed that while formal land rights had no significant effect on agricultural productivity, informal land rights such rights to lease out had a negative impact on the productivity by using precise soil quality measurements data to control unobserved heterogeneity between plots.

3.4.2. Investment and Input Use

Migot-Adholla et al. (1994) used Ghana data collected by the World Bank and estimated the effect of tenure security on investment in farming. The results were that property rights have a positive impact on the investment in the region of Anloga but not in Wassa. Besley (1995) who re-used the same Ghana data developed three theoretical models to imply the link between property rights and investment incentives in Ghana by addressing endogeneity issue. The finding was that better land rights facilitate agricultural investment in Wassa but a less noticeable impact in Anloga. These show that results may vary depending on estimation methodology even if two studies use the same data. Goldstein and Udry (2008) demonstrated the positive effect of secure tenure rights on agricultural investment in the Akwapim region of Ghana. Low-cost land certification implemented in Ethiopia had strong significant impacts on the maintenance of soil conservation structures and land investment (Holden et al., 2009). Likewise, Deininger et al. (2011) found that land certification increases land investment and rental market participation in Ethiopia. Property documentation in Zambia had a positive effect on fixed investment and increased productivity in the long run (Smith, 2004). In Gambia, the effect of tenure security was found to enhance long-term investment (Hayes et al., 1997). In Vietnam, the 1993 land law, which allows land rights to be secure, guaranteed and traded, had a positive impact on long-term agricultural investment (Do and Iyer, 2008).

On the other hand, land tenure system in sub-Saharan Africa such as Ghana, Kenya, and Rwanda was not found to be a significant factor in determining investment and input use (F. Place and S. E. Migot-Adholla, 1998). Brasselle et al. (2002) found that improved land rights do not stimulate investment for farmers in Burkina Faso. Land title in Madagascar also had no significant effect on plot investment, so little effect on productivity (Jacoby and Minten, 2007). Those results bear out the skepticism about the existence of a positive causal relationship between secure land tenure and investment in sub-Saharan Africa.

3.4.3. Access to Credit

For Thailand, the positive effects of land property rights mainly work through credit accessibility (Feder, 1987).

However, several other studies found that land property rights do not improve access to agricultural credit by the use of land as collateral. Government land titling in rural Peru did not positively affect secure property such as access to credit (Kerekes and Williamson, 2010). Formal land titles in Cambodia were also found to have weak effects on credit accessibility (Markussen, 2008). The reason is likely to be explained by the fact that credit markets in Cambodia were less developed than in Thailand. Atwood (1990) questioned the conventional link that land registration has a positive impact on credit accessibility by providing collateral for agricultural loans, and suggested that empirical economic assessment is required for many African situations. Place and Hazell (1993), using household survey data in sub-Saharan Africa, found no effect of informal land rights on access to credit in Ghana, Kenya, and Rwanda. F. Place and S. E. Migot-Adholla (1998) showed no effect of registration and titling program on the use of formal credit in Kenya.

3.5. Data and Descriptive Statistics

The research uses the national representative Cambodia Socio-Economic Survey (CSES) parcel-level data surveyed from January 2014 until December 2014, which was conducted by Cambodia National Institute of Statistics (NIS) and supported by Swedish International Development Cooperation Agency (SIDA). This survey data includes around 12,000 households and more than 15,000 parcels information surveyed in 24 provinces in Cambodia.

To clearly verify the effects of land titling, we created two levels of data sets: parcel level and household level. The data set of the parcel level includes variables used for analysis of agricultural productivity and input use. In the data set at the parcel level, only parcels growing crops in rural areas and owned by the households are included, whereas rented parcels are excluded. On the other hand, variables used for estimations related to credit are contained in the data set of the household level, because CSES 2014 only has data on average monthly interest and a total amount of debt taken by households. In the data set at the household level, only rural households that owned land and only the households that have debt are included.

Table 3.1 shows descriptive statistics of parcel level, and Table 3.2 shows descriptive statistics of household level. The first line of Table 3.1

shows the percentage of parcels with land titling. Among the total parcels, 64% of the parcel has land titling. The average crop yield is 4,055 kg/ha. For total inputs cost, the mean value is 879,402 riel[3]. 94% of parcels are used as collateral for loan. The mean of parcel value is 31,600,000 riel/ha, and the average parcel area size is 0.98 ha. Of that, cultivation area occupies 0.87 ha. 79% of parcels are growing crops in the wet season. On average, 52% of parcels can add water with irrigation. Types of crops include cereal (79%), tuber crop (6%), leguminous crop (less than 1%), industrial crop (2%), vegetable (2%), fruits and nuts (8%), and other crops (3%). Land consists of six types of lands: wet season land (67%), dry season land (9%), wet and dry season land (8%), kitchen garden land (10%), permanent crops land (6%), and other types of land (less than 1%). The percentages of four modes of land acquisition are the following: given by the government (34%), inheritance or given by relatives (46%), bought (13%), and other modes of acquisition (7%). The second and third columns indicate the average value of parcels with titling and without titling. Compared to parcels without titling, parcels with titling have higher value of productivity, higher cost of total inputs, more likely to be used as collateral, and higher value of parcel. For the above variables, the results of two-sample *t*-tests for equality of means

[3] Exchange rate of Cambodia riel is 1 dollar equal to 4,040 riel (NBC, 2018).

of the two parcel groups indicate that the mean for parcels with titling are significantly greater than that for parcels without titling except value of productivity. Parcels with titling were also more likely to acquire land from the government and by bought, while parcels without tiling were more likely to acquire land from inheritance or given by relatives.

In Table 3.2, the percentage of household with land titling is 65%. The mean of the total amount of debt is about 5,200,000 riel, and the outstanding loan is around 3,800,000 riel. Monthly interest is from 0% to 20%., and the average interest is around 2.52%. The average of total land size is 1.67 ha. Land value and total expenditure are used as proxy variables for income level. The average land value is 26,200,000 riel/ha, and the mean of total expenditure is over around 4,300,000 riel. The mean of household size is 4.8. Male household head is 82%, and the average of household head age is 45.5. The percentage of household head who can at least read or write a simple message is 73%. The results of t-tests for the total amount of debt and average interest show that the mean for households with titling are significantly greater than without titling.

However, such differences between those groups with titling and without titling should not necessarily be ascribed to land titling. Detailed econometric analyses, therefore, are needed to verify the causal inference.

Table 3.1. Descriptive Statistics of Parcel Level

Variable	All parcels	N	Parcels with titling	N	Parcels without titling	N	*t*-test (P-value)
Parcels with land titling (dummy)	0.64	10,655					
Productivity, kg/ha	4,055	10,639	4,192	6,864	3,806	3,775	0.149
Total inputs cost for cultivation, *riel*	879,402	10,397	956,858	6,691	739,558	3,706	0.000
Parcel as collateral (dummy)	0.94	10,655	0.97	6,873	0.91	3,782	0.000
Parcel value, *riel / ha*	31,600,000	10,655	34,800,000	6,873	25,900,000	3,782	0.000
Parcel area size, *ha*	0.98	10,655	1.01	6,873	0.93	3,782	0.008
Cultivation area size, *ha*	0.87	10,642	0.90	6,865	0.83	3,777	0.005
Wet season (dummy)	0.79	10,655	0.79	6,873	0.79	3,782	0.797
Irrigated in at least one season (dummy)	0.52	10,655	0.57	6,873	0.43	3,782	0.000
Crop type							
Cereal (dummy)	0.79	10,655	0.79	6,873	0.79	3,782	0.957
Tubers crop (dummy)	0.06	10, 655	0.05	6,873	0.07	3,782	0.000
Leguminous crop (dummy)	0.00	10, 655	0.00	6,873	0.00	3,782	0.537
Industrial crop (dummy)	0.02	10, 655	0.02	6,873	0.01	3,782	0.053
Vegetable (dummy)	0.02	10, 655	0.02	6,873	0.02	3,782	0.016
Fruits and Nuts (dummy)	0.08	10, 655	0.09	6,873	0.07	3,782	0.000
Other crops (dummy)	0.03	10, 655	0.03	6,873	0.04	3,782	0.216
Land type							
Wet season land (dummy)	0.67	10,638	0.66	6,865	0.69	3,773	0.003
Dry season land (dummy)	0.09	10, 638	0.08	6,865	0.10	3,773	0.009
Wet and dry season land (dummy)	0.08	10, 638	0.09	6,865	0.07	3,773	0.000
Kitchen garden land (dummy)	0.10	10, 638	0.11	6,865	0.09	3,773	0.039
Permanent crops land (dummy)	0.06	10, 638	0.06	6,865	0.05	3,773	0.033
Other types of land (dummy)	0.00	10, 638	0.00	6,865	-	-	0.026
Mode of land acquisition							
Given by the government (dummy)	0.34	10,655	0.36	6,873	0.28	3,782	0.000
Inheritance or given by relatives (dummy)	0.46	10, 655	0.41	6,873	0.54	3,782	0.000
Bought (dummy)	0.13	10, 655	0.17	6,873	0.08	3,782	0.000
Other modes of acquisition (dummy)	0.07	10, 655	0.06	6,873	0.10	3,782	0.000

Note: 1) Only parcels cultivating crops are included. 2) Only parcels owned by rural households are included. 3) Rented parcels are excluded. 4) The null hypothesis of *t*-test assumes that there is no difference between the two groups.

Table 3.2. Descriptive Statistics of Household Level

Variable	All households	N	Households with titling	N	Households without titling	N	*t*-test (P-value)
Households with land titling (dummy)	0.65	2,095					
Total amount of debt, *riel*	5,190,657	2,095	5,863,982	1,361	3,913,620	734	0.000
Outstanding loan, *riel*	3,790,307	2,095	4,139,192	1,361	3,143,398	734	0.000
Average interest, %	2.52	2,090	2.47	1,357	2.63	733	0.033
Land size, *ha*	1.67	2,095	1.69	1,361	1.64	734	0.041
Land value, *riel / ha*	26,200,000	2,095	30,200,000	1,361	18,600,000	734	0.000
Total expenditure, *riel*	4,311,188	2,095	4,453,241	1,361	4,047,788	734	0.110
Household size	4.78	2,095	4.9	1,361	4.7	734	0.005
Male household head (dummy)	0.82	2,095	0.81	1,361	0.83	734	0.282
Age of household head	45.5	2,095	46.3	1,361	44.1	734	0.000
Literacy of household head (dummy)	0.73	2,095	0.75	1,361	0.70	734	0.019

Note: 1) Only rural households that owned land are included. 2) Only the households that have debt are included. 3) The null hypothesis of *t*-test assumes that there is no difference between the two groups.

3.6. Procedure and Estimation Strategies

3.6.1. Procedure

To analyze the relationship between agricultural productivity and land titling, Cobb-Douglas form is used. The model begins as Equation (3.1):

$$\ln\left(\frac{production_{vhp}}{culti\_area_{vhp}}\right) = \alpha_0 + \alpha_1 T_{vhp} + \sum_{k=2}^{n} \alpha_k \boldsymbol{X}_{vhp} + \gamma_v + \varepsilon_{vhp}, \qquad (3.1)$$

where $production_{vhp}$ is crop production quantity on parcel p in household h in village v, $culti\_area_{vhp}$ is cultivation area, $\frac{production_{vhp}}{cult\_area_{vhp}}$ means crop production quantity (kg) per cultivation area (*ha*), T_{vhp} is parcel held with land titling (dummy variable), α_k is coefficient to be estimated, $\boldsymbol{X}_{vhp}$ is a vector of explanatory variables that are exogenous, γ_v is village fixed effect, and ε_{vhp} is error term. Explanatory variables include total input cost, parcel as collateral, parcel sales value, wet season, cultivation area, irrigation, crop type, and household characteristics. Due to the data limitation, "total input cost" is used as substitute for the quantity of input use, which is measured as the cost of cultivation crops (seeds, fertilizers, manure, electricity, hired labor, irrigation, *etc.*). "Parcel as collateral" is entered as a proxy for accessibility of credit. "Parcel sales value" is used as a proxy for income level. Cambodia's climate is dominated by monsoons, which are known as tropical wet and dry. "Wet season" is entered, because these climatic conditions affect farm productivty. Cultivation area is used as a basic element of the production function. Irrigation status is important factors of future productivity. Crop type is appiled to control for crop characteristics. Household characteristics (household size, head gender, head age, and head literacy) are included. Measures of them are available only at the household level, thereby they are applied at this level. Village fixed effects are used to control for village level characteristics, such as agro-climatic conditions, soil quality, market conditions, and infrastructure.

Equation (3.2) shows the relationship between land titling and input use.

$$\ln(input\_cost_{vhp}) = \alpha'_0 + \alpha'_1 T_{vhp} + \sum_{k=2}^{n} \alpha'_k \boldsymbol{X}'_{vhp} + \gamma'_v + \varepsilon'_{vhp}, \quad (3.2)$$

where $input\_cost_{vhp}$ represents total input cost, α'_k is coefficient to be estimated, $\boldsymbol{X}'_{vhp}$ is a vector of explanatory variables that include parcel as collateral, parcel sales value, cultivation area, years since parcel acquisition, crop type, and household characteristics, γ'_v is village fixed effect, and ε'_{vhp}, is error term. In this model, "parcel as collateral" is used because loans can be taken out through land collateral and invest in farming input. "Parcel sales value" is entered, a proxy for income level, because farmers with a higher income are more likely to invest in farm input. The total input cost depends on cultivation area, so cultivation area is entered. Smith (2004) showed that “years since farm acquisition” has a positive impact on fixed investments of farmers. Therefore, “years since parcel acquisition” which is expected to increase total input cost is entered. Crop type is entered to control farm input use from each crop. Finally, household characteristics are included as before the agricultural productivity model.

To investigate the relationship between land titling and access to credit, average monthly interest and total amount of debt are used as dependent variables, since the study investigates whether the effects of land titling affects lower interest rate and larger amount of debt. For interest rate and amount of debt, those variables are household level data, thus those models can be written as follows:

$$interest_{vh} = \alpha''_0 + \alpha''_1 T_{vh} + \sum_{k=2}^{n} \alpha''_k \boldsymbol{X}''_{vh} + \gamma''_v + \varepsilon''_{vh}, \qquad (3.3)$$

where $interest_{vh}$ means average monthly interest rate in household h in village v, α''_k is coefficient to be estimated, $\boldsymbol{X}''_{vh}$ is a vector of explanatory variables including total amount of debt, total land sales value, total expenditure, and household characteristics, γ''_v is village fixed effect, and $\varepsilon''_{vh},$ is error term. In this model, “total amount of debt” is entered, since interest rate is usally determined by the amount of loan. Also, it is necessary to include measures of household assets, because the ability to repay affected by household assets is an important factor of interest rate of loan. Therefore, “total land sales value” and “total expenditure” are entered as a proxy variable for household assets. Household characteristics are also entered.

$$\ln(total\_debt_{vh}) = \alpha'''_0 + \alpha'''_1 T_{vh} + \sum_{k=2}^{n} \alpha'''_k \boldsymbol{X}'''_{vh} + \gamma'''_v + \varepsilon'''_{vh}, \qquad (3.4)$$

where $total\_debt_{vh}$ is total amount of debt in household h in village v, α'''_k is coefficient to be estimated, $\boldsymbol{X}'''_{vh}$ is a vector of explanatory variables such as total land sales value, total expenditure, and household characteristics, γ'''_v is village fixed effect, and ε'''_{vh}, is error term. As before the model, “total land sales value”, “total expenditure” and household characteristics are included.

3.6.2. Instrumental Variables Model

The land titling variable is likely to have endogenous to agricultural productivity and input use. For example, parcels with land titling can affect agricultural productivity at the same time as agricultural productivity have a potential effect on land titling variable. Because households with higher agricultural productivity or income have a better opportunity for obtaining land paper. That means ordinary least squares (OLS) estimation may suffer from simultaneous causality bias. In order to overcome this bias, an instrumental variables estimator is used, using two-stage least squares (2SLS). The below equations show how to reduce simultaneous causality bias, citing an example of the agricultural productivity model. The first stage is as the following Equation (3.5):

$$T_{vhp} = \beta_0 + \beta_1 \sum_{i=1}^{4} Z_{ivhp} + \sum_{k=2}^{n} \beta_k \boldsymbol{X}''''_{vhp} + \delta_v + \sigma_{vhp}, \qquad (3.5)$$

where Z_{ivhp} is the four modes of parcel acquisition used as instrument variable such as land given by the government, inheritance, bought, and other modes of acquisition. For an instrument variable to be valid, it must satisfy two condition: The instrument variable (Z) should explain the variance of T_{vhp} and be independent of the variance of $\ln\left(\frac{production_{vhp}}{cult\_area_{vhp}}\right)$ in Equation (3.1). Following Besley (1995), Brasselle et al. (2002), and Markussen (2008), the mode of land acquisition as instruments for land titling is used in this study since the mode of land acquisition is correlated with land titling and uncorrelated with the productivity. For instance, if a parcel is given by the government, there is a chance that obtaining an official document was part of the process of acquiring the parcel. There is also no reason why choices related to agricultural productivity should be linked to the mode of land acquisition.

When dealing with endogenous dummy variables, we must be careful not to fall into “forbidden regression”[4] that means replacing a

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[4] A forbidden regression occurs when researchers apply 2SLS reasoning directly to nonlinear models. A common scenario is a dummy endogenous variable.

nonlinear function of an endogenous variable with the same nonlinear function of fitted values from a first-stage estimation (Wooldridge, 2010). Therefore, Angrist et al. (2013) suggested that we should plug in the fitted values of T_{vhp} derived from Equation (3.5) into Equation (3.1):

$$\ln\left(\frac{production_{vhp}}{cult\_area_{vhp}}\right) = \alpha_0 + \alpha_1\widehat{T_{vhp}} + \sum_{k=2}^{n}\alpha_k \boldsymbol{X}_{vhp} + \gamma_v + \varepsilon_{vhp}. \qquad (3.6)$$

Through these 2SLS, we can solve the potential simultaneous causality bias between land titling and agricultural productivity and avoid forbidden regression from endogenous dummy variables.

3.6.3. Matching Frontier

Appropriate randomization eliminates selection bias by balancing both known and unknown predictors in the experimental group assignments (Moher et al., 2001). However, the CSES data is observational survey data that was conducted for a comprehensive set of indicators on living conditions in Cambodia, which is not experimental survey data for land titling. Therefore, land tilting information from the CSES data was not surveyed by randomized control trials. Therefore, the research is likely to have selection bias problem, and the results of its effects may be overestimated.

Matching methods has been often applied to mitigate the selection bias when randomization is infeasible (Bai, 2011). Matching is a statistically powerful and conceptually simple approach to estimate causal treatment effect in observational data analysis. A successful matching application requires both reduced imbalance (increased similarity between treatment groups and control groups) and a sufficiently large matched sample. However, existing matching approaches usually satisfy one of these two factors with manual (human) optimization of the other. These attempts to optimize by hand are time-consuming and rarely yields the optimal solution, because data analysis by human is incapable of evaluating all possible matching solution.

To remedy this problem, King et al. (2017) introduced a new matching method, Matching Frontier (MF), which satisfies jointly optimizing balance and sample size by allowing to evaluate how much balance is achieved by pruning observations and simultaneously fully characterize the trade-off between imbalance and the matched sample size.

Matching Frontier is largely divided into two types of imbalance metrics such as continuous and discrete metrics. However, the difference between these metrics is commonly not large in most data analysis problems (Imbens, 2004; Zhao, 2004). Therefore, among those metrics, a continuous imbalance metric is used in this study. The core component of a continuous imbalance metric is a distance between two-dimensional vectors. The following equation is an example of calculating the distance using Mahalanobis frontier.

$$\mathrm{D}(X_i, X_j) = \sqrt{(X_i - X_j)S^{-1}(X_i - X_j)}, \qquad (3.7)$$

where $\mathrm{D}(X_i, X_j)$ is a distance between two k-dimensional vectors X_i and X_j, corresponding to observations i and j, S is the sample covariance matrix of the original data X.

Therefore, the estimates using Matching Frontier can be relatively free from selection bias by the observational data.

3.7. Estimation Results

3.7.1. Land Titling and Agricultural Productivity

Table 3.3 shows the results of estimating the model for crop production quantity per cultivation area (kg / ha). The first and second columns show the results of estimating the equation (3.1) and (3.6) by OLS and instrument variable estimator (2SLS). The third column represents the estimation results of the model by using Matching Frontier that is expected to reduce selection bias. The impacts of land titling are not significant in both OLS and 2SLS as well as Matching Frontier model. The interesting thing about the results, however, is that the coefficient of OLS is higher than that of 2SLS. Since, if a binary variable is suspected of having endogeneity issue, the instrument is correlated with the measurement error, and then the correlation brings about upward bias in the estimation of the endogenous variable effect (Kane et al., 1999). Plus, in the second column, for the testing for weak instruments, the null hypothesis is that all instruments are weak. In this model, the result rejects the null hypothesis, which means at least one instrument is strong. Under the testing for overidentification, called Sargan test, the null hypothesis is that the covariance between the instrument and the error term is zero, and the p-value is 0.000, thus at least one of the extra instruments is not valid. Finally, the Wu-Hausman tests fail to reject the null hypothesis of no endogeneity. Therefore, it is expected to be no endogeneity between agricultural productivity and land titling.

One thing to take notice is that total inputs cost that is used as a substitution variable for agricultural productivity is significant in the model. That shows the probability that land titling might indirectly affect the productivity if it affects input cost in the following estimations.

Table 3.3. Land Titling Effects on Agricultural Productivity

Independent variables	**Production quantity per cultivation area, *kg / ha* (log)**		
	OLS	**2SLS**	**MF**
Parcel held with land titling (1 = yes, 0 = no)	-0.003	-0.276	-0.010
	(0.051)	(0.270)	(0.044)
Total inputs cost for cultivation crops, *riel* (log)	0.130***	0.129***	0.244***
	(0.017)	(0.016)	(0.030)
Parcel as collateral (1 = yes, 0 = no)	0.098	0.144	-0.111
	(0.089)	(0.097)	(0.259)
Parcel sales value, *riel /ha* (log)	0.118***	0.124***	0.085**
	(0.025)	(0.025)	(0.038)
Wet season (1 = yes, 0 = dry season)	-1.033***	-1.030***	-0.098
	(0.081)	(0.078)	(0.102)
Cultivation area size, *ha* (log)	-0.425***	-0.416***	-0.378***
	(0.028)	(0.028)	(0.039)
Parcel with irrigation (1 = yes, 0 = no)	-0.034	-0.028	-0.010
	(0.051)	(0.049)	(0.050)
Crop Types			
Tuber crop (1 = yes, 0 = no)	-0.373**	-0.368**	2.445***
	(0.156)	(0.151)	(0.311)
Leguminous crop (1 = yes, 0 = no)	-1.688***	-1.670***	
	(0.245)	(0.238)	
Industrial crop (1 = yes, 0 = no)	-1.160***	-1.164***	-0.564*
	(0.194)	(0.187)	(0.318)
Vegetable (1 = yes, 0 = no)	-0.912***	-0.902***	0.535
	(0.170)	(0.165)	(0.494)
Fruit and Nuts (1 = yes, 0 = no)	-2.694***	-2.686***	0.005
	(0.191)	(0.185)	(0.636)
Other crops (1 = yes, 0 = no)	-1.996***	-2.006***	-0.522*
	(0.261)	(0.251)	(0.285)
Household Characteristics			
Household size	-0.009	-0.007	0.012
	(0.010)	(0.010)	(0.014)
Male household head (1 = male, 0 = female)	0.095**	0.091**	0.102
	(0.045)	(0.043)	(0.083)
Age of household head	0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)
Literacy of household head (1= yes, 0 = no)	0.019	0.031	-0.090
	(0.039)	(0.039)	(0.054)
Constant	4.311***	4.835***	3.359***
	(0.564)	(0.470)	(0.858)
Village Fixed Effect	Yes	Yes	Yes
Observations	10,381	10,381	2,001
R-squared	0.447	0.445	0.463
Weak instruments test (P-value)		0.000	
Sargan test for overidentification (P-value)		0.000	
Wu-Hausman test for endogeneity (P-value)		0.277	

Note: 1) *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%, 5%, 10%, respectively. 2) Numbers in parentheses are robust standard error. 3) Only parcels growing crops in rural households are included 4) Rented parcels are excluded. 5 The omitted category for the type of crop is cereal crops. 6) In the 2SLS regressions, instruments are the mode of parcel acquisition. 7) Standard errors are adjusted for clustering at the household and village level.

3.7.2. Land Titling and Input Use

Table 3.4 shows the estimated results of the total cost for crops cultivation to determine the effect of land titling on input use that is expected to increase agricultural productivity. The estimated coefficients on the titling variables in those three methods for total input cost are not significant. That indicates that titling status might increase stability from farmers and lenders, but it does not lead to increased use of inputs for farming. In the 2SLS, the result of the testing for weak instruments rejects the null hypothesis, which means at least one instrument is strong. The result of the Sargan test in this analysis shows at least one of the extra instruments is not valid. According to the below Wu-Hausman test, it is expected to be no endogeneity between the total input cost and land titling.

Table 3.4. Land Titling Effects on Input Use

Independent variables	Total input cost for crops cultivation , *riel* (log)		
	OLS	**2SLS**	**MF**
Parcel held with land titling (1 = yes, 0 = no)	-0.066	0.342	-0.040
	(0.062)	(0.335)	(0.055)
Parcel as collateral (1 = yes, 0 = no)	0.078	0.009	-0.141
	(0.114)	(0.122)	(0.376)
Parcel sales value, *riel /ha* (log)	0.079**	0.071**	0.109***
	(0.033)	(0.033)	(0.040)
Cultivation area size, ha (log)	0.881***	0.869***	0.808***
	(0.031)	(0.032)	(0.033)
Years since parcel acquisition	0.001	0.002	-0.003
	(0.002)	(0.002)	(0.003)
Crop Types			
Tuber crop (1 = yes, 0 = no)	-0.542***	-0.546***	0.111
	(0.147)	(0.143)	(0.315)
Leguminous crop (1 = yes, 0 = no)	-0.183	-0.208	
	(0.149)	(0.145)	
Industrial crop (1 = yes, 0 = no)	-0.299*	-0.291*	-0.341
	(0.165)	(0.162)	(0.355)
Vegetable (1 = yes, 0 = no)	0.025	0.012	0.093
	(0.203)	(0.199)	(0.671)
Fruit and Nuts (1 = yes, 0 = no)	-7.131***	-7.145***	-6.321***
	(0.221)	(0.214)	(0.258)
Other crops (1 = yes, 0 = no)	-4.999***	-4.985***	-4.973***
	(0.338)	(0.327)	(0.314)
Household Characteristics			
Household size	-0.023*	-0.026**	-0.012
	(0.013)	(0.013)	(0.015)
Male household head (1 = male, 0 = female)	0.117**	0.124**	-0.014
	(0.057)	(0.055)	(0.083)
Age of household head	-0.005**	-0.006***	0.000
	(0.002)	(0.002)	(0.002)
Literacy of household head (1= yes, 0 = no)	0.050	0.033	0.024
	(0.050)	(0.050)	(0.059)
Constant	12.421***	12.144***	12.181***
	(0.583)	(0.611)	(0.923)
Village Fixed Effect	Yes	Yes	
Observations	10,380	10,380	2,919
R-squared	0.678	0.676	0.658
Weak instruments test (P-value)		0.000	
Sargan test for overidentification (P-value)		0.016	
Wu-Hausman test for endogeneity (P-value)		0.212	

Note: 1) *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%, 5%, 10%, respectively. 2) Numbers in parentheses are robust standard error. 3) Only parcels growing crops in rural households are included 4) Rented parcels are excluded. 5 The omitted category for the type of crop is cereal crops. 6) In the 2SLS regressions, instruments are the mode of parcel acquisition. 7) Standard errors are adjusted for clustering at the village level.

3.7.3. Land Titling and Access to Credit

To investigate the relationship between land titling and access to cheaper and extensive credit, two types of variables are analyzed: (1) the interest rate paid on loans, (2) the amount debt. In these analyses, titling status is assumed to be no endogeneity. Because feedback link from credit accessibility to land tilting has been weak in Cambodia (Markussen, 2008). In addition, those analyses are separately divided by all credit market and formal lender, because collaterals play a less significant role in the informal credit market. For informal lenders such as relatives, friends, neighbors, and others, the lending decision often relies on personal familiarity.

Table 3.5 and 3.6 show OLS regressions for the average monthly interest and total amount of debt. For interest rates, the results show a negative effect of household with land titling, but not significant even in formal lender. On the other hand, the effects of the titling on amount borrowed are significant in OLS in both all lender and formal lender. If households have land titling, households are able to borrow debt by 18% in all lender and by over 33% in formal lender. However, the results in Matching Frontier are not significant. Though many observations were pruned during the process of matching, the results are expected to be worth because it attempts to reduce selection bias through optimizing the balance between treatment group (households with titling) and control group (households without titling).

Table 3.5. Land Titling Effects on Average Monthly Interest

Independent variables	Average monthly interest, %			
	All Lender		Formal Lender	
	OLS	**MF**	**OLS**	**MF**
Household with titling (1 = yes, 0 = no)	-0.059	-0.160	-0.024	-0.080
	(0.106)	(0.332)	(0.053)	(0.176)
Total amount of debt, *riel* (log)	-0.143***	-0.200	-0.163***	-0.335***
	(0.035)	(0.163)	(0.019)	(0.061)
Total land sales value, *riel /ha* (log)	-0.038	-0.124	0.013	-0.013
	(0.052)	(0.266)	(0.024)	(0.126)
Total expenditure, *riel* (log)	-0.097**	-0.354	-0.053**	0.012
	(0.048)	(0.229)	(0.023)	(0.111)
Household size	0.066***	0.186	0.010	0.071
	(0.023)	(0.142)	(0.011)	(0.052)
Male household head	-0.110	-0.233	-0.027	-0.180
	(0.104)	(0.679)	(0.050)	(0.255)
Age of household head	-0.000	0.006	-0.001	-0.001
	(0.003)	(0.013)	(0.001)	(0.004)
Literacy of household head	-0.166*	-0.206	-0.105**	0.089
	(0.089)	(0.407)	(0.044)	(0.2123)
Constant	7.197***	13.389*	6.235***	6.854***
	(1.823)	(5.334)	(0.710)	(2.392)
Village Fixed Effect	Yes	Yes	Yes	Yes
Observations	2,090	383	1,040	175
R-squared	0.456	0.150	0.654	0.560

Note: 1) *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%, 5%, 10%, respectively. 2) Numbers in parentheses are robust standard error. 3) Only rural households that owned land are included. 4) Only the households that have debt are included. 5) Standard errors are adjusted for clustering at the village level.

Table 3.6. Land Titling Effects on Total Amount of Debt

Independent variables	Total amount of debt, *riel* (log)			
	All Lender		Formal Lender	
	OLS	MF	OLS	MF
Household with titling (1 = yes, 0 = no)	0.180**	0.015	0.333***	-0.578
	(0.075)	(0.185)	(0.109)	(0.464)
Total land sales value, *riel /ha* (log)	0.062*	0.215	0.044	0.230
	(0.037)	(0.147)	(0.050)	(0.339)
Total expenditure, *riel* (log)	0.377***	0.362***	0.378***	0.630**
	(0.033)	(0.123)	(0.045)	(0.282)
Household size	0.053***	0.010	0.011	0.070
	(0.017)	(0.079)	(0.023)	(0.139)
Male household head	0.002	0.524	0.101	-0.264
	(0.074)	(0.375)	(0.105)	(0.688)
Age of household head	-0.006***	0.004	-0.006**	-0.008
	(0.002)	(0.007)	(0.003)	(0.012)
Literacy of household head	0.143**	0.508**	0.152	0.354
	(0.063)	(0.222)	(0.092)	(0.571)
Constant	9.824***	5.303*	10.145***	3.201
	(1.282)	(2.936)	(1.413)	(6.421)
Village Fixed Effect	Yes	Yes	Yes	Yes
Observations	2,090	384	1,040	175
R-squared	0.490	0.168	0.600	0.779

Note: 1) *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%, 5%, 10%, respectively. 2) Numbers in parentheses are robust standard error. 3) Only rural households that owned land are included. 4) Only the households that have debt are included. 5) Standard errors are adjusted for clustering at the village level.

3.8. Discussion and Conclusion

To verify the theory of causal link between land titling and agricultural productivity, the study set input use and access to credit (monthly interest and amount of debt) as dependent variables along with farm yield, and investigate land titling status effects on those variables. This study uses CSES 2014 data, and attempt to control simultaneous causality bias between land property rights and productivity and selection bias originated by non-experimental data, by employing instrumental variable estimation and Matching Frontier method.

Many previous studies have conducted to investigate the effects of land property rights on agricultural productivity. However, the results conducted in farming-based developing countries have still been controversial. The notable thing is that Markussen (2008) used CSES 2004 that is similar to CSES 2014 shows that plots held with formal land titles have a positive effect on agricultural productivity.

However, what we found in this study is that the effects of land titling on agricultural productivity are not significant. For input use, land titling does not lead to increased use of inputs for production. Lastly, though households with land titling was expected to receive cheaper interest rates and larger amount of money compared to without the titling, the titling has a weak impact on credit accessibility such as monthly interest and amount of debt.

These results throw doubt on the positive results of the earlier study in Cambodia and the hypothesis explaining the causal link between land titling and agricultural productivity. Many studies that raised a question the positive effects of land property rights explain the reason for the weak effects of land rights. Place and Hazell (1993) stated that customary restrictions on land rights still prevail in Kenya, thereby titled land has no effect on productivity. Frank Place and Shem E Migot-Adholla (1998) described land registrations are acquired to enhance the security of rights rather than to increase agricultural productivity. Bellemare (2013) explained in the French colony, Burkina Faso, due to unsuccessful efforts to disrupt customary tenure during the colonial period, formal land rights have no significant effect on agricultural productivity. Brasselle et al. (2002) reported traditional village orders of Burkina Faso have provided the basic land rights stimulating small investment. Kerekes and Williamson (2010) stated that due to lack of local knowledge in rural communities of Peru, a top-down approach may not be the best way for securing property such as access to credit. Markussen (2008) argued there is a restriction on credit accessibility regardless of property rights to land since Cambodian financial markets are underdeveloped.

By reviewing these skepticism of the effects of land titling, the results of the study can be predicted that in the rural Cambodia where agricultural development has not progressed much, in practice, the absence of land titling may not imply uncertainty for many farmers, since traditional village order (social customs and norms) may replace or impede the roles of land rights in stimulating agricultural productivity, use of inputs, and access to credit.

4. Conclusion

This thesis incorporates two essays related to agricultural productivity in rural Cambodia. The first essay investigates the factors affecting low rice productivity in Tonle Sap zone, and the second determines the effects of land titling on agricultural productivity in rural Cambodia.

There are many prior studies on rice productivity in Cambodia, but productivity studies based on the Tonle Sap zone are extremely rare, and only a few qualitative studies exist. Those studies suggest the reasons why rice productivity is low in the Tonle Sap area as following: the extreme rain in the rainy season which damages rice production, use of traditional varieties in the wet season that have lower yield, and bad water management. For the first essay, the findings are consistent with the previous views. However, due to the data limitation, the inability to apply climate variables and types of rice varieties, and lack of observations in the dry season make it difficult to clearly interpret the results, but these results may help us to understand the factors that generally affect rice productivity in the Tonle Sap zone, away from the earlier qualitative studies. In addition, the findings could have important implications for discussions on how to promote Cambodia rice productivity in the future.

In the second essay, the findings are that land titling has a weak effect on agricultural productivity, input use, and credit accessibility in rural Cambodia. These show the contrary to the result of the earlier study in Cambodia and the hypothesis explaining the causal link between land titling and agricultural productivity. Many studies that cast a doubt the positive effect of titling on productivity, investment, and access to credit market explain the reason of the weak effects of land titling. That is the role of land titling may be replaced by social customs and norms. Similarly, the results of the study can be predicted that land titling may not affect agricultural productivity, investment in input use, and credit accessibility in the rural Cambodia where agricultural development has not progressed much, since the titling may be substituted for traditional village orders.

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요약 (Abstract in Korean)

본 논문은 캄보디아의 농업 생산성과 관련한 쌀, 토지의 두 가지 연구 주제를 다루고 있으며, 이를 분석하기 위한 몇 가지 추정 절차와 모델링 기법을 포함한다.

첫 번째 연구는 2014년 캄보디아 사회 경제조사(CSES) 데이터를 이용하였으며, 톤레삽 지역의 쌀 생산성에 영향을 끼치는 요인들을 분석하고자 한다. 캄보디아의 쌀 재배지역은 네 가지의 생태학적 지역(톤레삽, 평지, 고원, 해안)으로 나눌 수 있으며, 그 중 톤레삽 지역은 쌀 생산성이 가장 낮은 지역이다. 많은 선행연구에서는 톤레삽 지역이 불규칙적으로 내리는 비와 홍수로 인해 쌀 생산에 피해를 줄 수 있다는 결과를 보였다. 본 연구의 분석 결과는 톤레삽 지역의 쌀 생산성은 우기와 건기, 그리고 관개시설 이용여부에 유의미한 영향을 받는 것으로 나타났다. 이러한 결과는 선행연구와 비슷한 결과를 나타내지만, 양적 연구로서 경제학적인 접근을 통해 톤레삽 지역의 쌀 생산성 요인 분석을 보여준 것에 의미를 둔다.

두 번째 연구는 캄보디아 농촌지역에서 농업 생산성과 토지 증명서 간의 양의 상관관계에 대한 가설의 작용 여부를 2014년 캄보디아 사회 경제조사 데이터를 이용하여 분석하였다. 이전의 많은 연구들은 토지 증명서와 관련한 동시 인과관계 편향(simultaneous causality bias)를 통제해왔지만, 비무작위 시험(non-randomized trial)이나 일반 관측 데이터(observational data)에서 문제시 될 수 있는 선택편향(selection bias)은 거의 고려되어 오지 않았다. 따라서 이러

한 문제들을 해결하기 위해 도구변수 추정방법과 매칭프론티어(Matching Frontier)와 같은 일치 방법(matching method)이 적용되었다. 연구 결과로는 농업생산성, 투입비용, 신용접근성에 대한 토지 증명서의 영향이 유의미하지 않음을 보였다. 이러한 이유로는 캄보디아의 농촌지역에서 토지 증명서의 역할이 사회적 관습과 규범으로 대체될 수 있다는 것이 추측된다.

주요어: 쌀 생산성, 톤레삽 지역, 토지 소유권, 동시 인과관계 편향, 선택 편향, 도구변수, 매칭프론티어, 캄보디아
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