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Impact of Technical Skill on Potato Production Efficiency in Thailand

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Abstract

As a major cash crop of Northern Thailand, potato has gained much attention from state and agribusiness. Potato is one of the three crops considered as most economically sensitive and being under state intervention for supply control. Over the past 20 years, processing type potato, accounting for 98% of total production, has been produced by contracted growers. Through the contract farming system, growers have received technical advice from government agencies with financial support of processing firms. Due to rapid growth of demand, contract-potato production is currently expanded to other provinces in Northeastern Thailand and neighboring countries. The latter is part of Mekong subregional economic cooperation plan. Obviously rise in total production is the result of expansion of cultivated land. In light of increasingly scarce resources and soaring cost, productivity and production efficiency has become an imperative concern. Stochastic production frontier with seasonal selectivity variable is applied to production data gathered in 2004 crop year in two major production areas in Northern Thailand. This paper reveals the significant effect of experience growers earned from contract farming on inducing alternative season choice. Technical efficiency of potato production and the impact of technical skill growers gained from contract system are apparent.

I Introduction

Potato was introduced as a cash crop to Thailand for over 45 years. The production earlier concentrated mainly in specific locations in Northern Thailand. In Chiang Mai, the first location of lowland potato production has experienced major changes in production and marketing.

Potato is one of three crops in the country which government implemented supply control policy. To ensure no excess supply, the government allows firms to import tuber seeds as required for processing. Like other new industrial crops, potato was planted partly by firms and mostly by contracted growers. Contract farming in potato sector is one of the successful cases of this system for agricultural development of small farmers. Especially, the integration of farm production with processing firms provided market access to farmers and reduced price risk. All of processing type potatoes are grown under contract system. Until recently, experienced growers turned to grow off-or early-season.

Due to rapid increase of demand for French fries and snack chips, the production area has been expanded in the past 10 years and potato has become a major cash crop of the North. The processing firms have extended their contracts to many provinces in the North, 3 provinces in the Northeast and areas in neighboring countries. To seek for better price, experienced growers shifted to cultivate early or off-season potato for the same processing firms. However, there was a signal of declining price caused by rising import supply. Evidently, the price of contract potato reduced by almost 15% in 2007. If price continues to decline, those growers who face high production cost or have low production efficiency might have to switch to off- or early-season cultivation to catch the advantage of good prices during low supply period. However, processing firms will not commit any contracts for early-season potato production to avoid sharing output risk with growers. Therefore growers either under contract with declining price trend or not under contract with production risk all have to protect their economic interest themselves by improving their production efficiency. It is the purpose of this paper to explore factors influencing growers' decision on early cropping (non-contract) and analyze levels and causes of production efficiency such that the growers can remain in the industry.

II Background of Potato Sector in Thailand

Due to the growth of tourism and gradual change in life style in early 1980's, demand for potato increased. In 1976, a factory was set up to produce potato chips to catch early trend of snacks business. However, the firm was faced with unstable and limited supply of raw material. To solve the problem, the firm started to make contract with growers for the first time in Chiang Mai in 1987.

Northern Thailand has been the major production center for potatoes. In 1970's and 1980's it accounted for as much as 80 % of total production. In 2005, the total production area was 12,233 acres. About 95% of planted land was in the North. The national production reached 97,411 tons (in 2005 and processing type accounted for 90% of total production) (OAE, 2007).

Although the Northern Region generally has favorable environment for potato production, its production is limited to certain areas. Potato requires sandy soil, good water condition throughout the growing season and night temperature between 15 and 18 degree Celsius. The crop grown in the cool season (short day length) is harvested faster than that grown in the hot season. With these requirements, potato is found in the lowlands (source of major supply), the uplands and some of the highlands in various provinces in the North and the Northeast.

Experienced farmers in the original site of contract potato (in Chiang Mai) and some other well irrigated districts grow 3 crops a year, i.e. potato after the rice crop (July-October) and then sweet corn/baby corn (April-June) on the same potato land. This cropping system appears most suitable and allows farmers to grow potato year after year without the need to change plots in order to avoid accumulation of pest and disease.

Most of highland potato comes from Tak province (southwest of Chiang Mai) and some districts in Chiang Mai and the northeastern provinces. At the altitude of 800-1,500 meters above sea level, it is possible for potato to grow well in the rain-fed areas. The main season is in the cool season which is set under contract with processing firms. The growers take risk to grow second crop (in rainy season) when climatic condition is not favorable which results in lower yield and poorer output quality. As a consequence, no firms made contract with growers for the rainy or early season crop.

Unlike most contract growers in general, potato growers in Chiang Mai (in San Sai District), the original site of the crop, were not the resource limited farmers.

In the past 40 years they were among those with good irrigated land and apt to take economic opportunity more likely than most Chiang Mai farmers in general as the district is located within 20 km. from the capital city. However, they were lack of technical knowledge in the early days. Among others, Ornberg (1996) Singh (2004) and Wiboonpongse et al. (2005) witnessed growers' knowledge provided by academia and local development agencies being the key to the success of potato contract farming. Wiboonpongse and Sriboonchitta (2007) reveal that growers' success in production and seed storage has innovated early season cultivation in the past few years.

This enables growers to supply the firms 1-2 months earlier in order to enjoy high price up to 65% more than that of the agreed level in contract.

Contract farmers in general cases will get technology transfer from processing firms in terms of detailed knowledge about variety, seed input rate, level and type of chemical fertilizer application, plant protection materials, pest control as well as cultural practice. In the case of potato, growers in Chiang Mai Province have been given the relevant knowledge and technical advice frequently for over 20 years. The accumulated knowledge and experience have paved the basis for growers to develop the technique for tuber seed storage which allows the early-season planting of potato when desired. Potato growers in Lampang Province and other areas having relatively lesser experience are still growing in season potato under contract system and remain following cultural practice advice given by the processing firms.

III Theoretical Framework

To investigate technical efficiency and the impact of other inputs, it is necessary to first estimate a production frontier. Since some farmers choose to grow early season instead of in season crop, the production function of each season should be estimated by taking into account the season chosen. The farmers do not choose planting date randomly. They typically have knowledge which indicates that a particular time will do better than the other. Because of choosing of time by the farmer, a problem called selectivity in the statistical sense may arise. If the problem exists, then failure to model the selectivity problem explicitly will result in biased estimates of the production function parameters.

Since each farmer makes his or her decision about the season to grow, the observed output levels are not sampled randomly from the populations of early-season potato crop. There is a variable $Z_i'\gamma$ such that an observation is drawn from the specified model only when $Z_i'\gamma$ crosses some threshold. This implies that the observation is from the subpopulation of the model associated with the selected values of $Z_i'\gamma$. If the observed data are still treated as having been randomly sampled from the population of the model, it potentially biases the estimated parameters. An auxiliary model generating $Z_i'\gamma$ would lead to the general solution of the selectivity problem. To eliminate biased estimates, information about this auxiliary model is incorporated in the estimation of the model (Maddala, 1983, p222; Greene, 1995, p637). This method is relevant to the switching regression model with endogenous switching to be discussed below.

The conventional approach to incorporate selectivity in a model is the famous two-step estimation procedure proposed by Heckman (1979) which involves the following two steps:

Step 1: Fit the probit model for the sample selection equation.

Step 2: Using the selected sample, fit the second step model (OLS or WLS) by adding the inverse Mills ratio from the first step as an independent variable to correct for selectivity bias and test its significance.

However, Greene (2006) claims that such approach is inappropriate for several reasons in models that are not linear, such as probit and tobit. This is because:

1. The impact on the conditional mean of the model of interest will not necessarily take the form of an inverse Mills ratio. Such an adjustment is appropriate and is specific to linear model only.
2. The bivariate normality assumption needed to justify the inclusion of the inverse Mills ratio in the second model generally does not appear anywhere in the model.
3. The dependent variable, conditioned on the sample selection, is unlikely to have the distribution described by the model in the absence of selection (Greene, 2006).

Hence, Greene (2006) proposes an internally consistent method of incorporating 'sample selection' in a model. Specifically, to incorporate selectivity in stochastic frontier framework, Greene (2006) proposes the following analytical approach.

The model incorporating sample selection takes the form:

$$d^* = \alpha' z + w, d = 1(d^* > 0) \quad (1)$$

$$y = \beta' x + v - u \quad (2)$$

$$u = |U| \ with \ U \sim N[0, \sigma_u{}^2]$$

$$(v,w) \sim bivariate \ normal \ with \ [(0,0),(\sigma_v{}^2, \rho\sigma_v, 1)]$$

$$(y,x) \ \ only \ observed \ when \ d = 1$$

where d is the probit selection equation and y is the stochastic frontier function. The selection operates through the heterogeneity component of the production model and not the inefficiency. In other words, the observation is not viewed as a function of the level of inefficiency. The proposed model, however, has certain restrictions. For example, the assumption of u must be half-normal with no truncation or presence of heteroscedasticity and cannot be used for panel data.

The estimator is developed as follows (Greene, 2006). Write w in its conditional on v form,

$w|v = \rho v + h \ where \ h \sim N[0,(1-\rho^2)]$ and h is independent of v

Therefore, $\quad d^*|v = \alpha' z + \rho v + h, \ d = 1(d^* > 0|v)$

Then, $prob[d = 1 \ or \ 0 \,|\, z, v] = \Phi\left[(2d-1)\left(\frac{\alpha' z + \rho v}{\sqrt{1-\rho^2}}\right)\right]$ (3)

The sample is considered into two parts. For the selected observations, d = 1, conditioned on v, the joint density for y and d is the product of the marginals since conditioned on v, y and d are independent

$$f(y, d = 1|x, z, v) = f(y\,|\,x, v) \ prob(d = 1\,|\,z, v) \quad (4)$$

This is the second part. For the first part,

$$y\,|\,x, v = (\beta' x + \sigma_v v) - \sigma_u u$$

where u is the truncation at zero of a standard normal variable. The conditional density is given by:

$$f(y\,|\,x, v) = \frac{2}{\sigma_u}\phi\left(\frac{(\beta' x + \sigma_v v) - y}{\sigma_u}\right), (\beta' x + \sigma_v v) - y \geq 0 \quad (5)$$

Therefore, the joint conditional density is given by:

$$f(y, d = 1\,|\,x, z, v) = \frac{2}{\sigma_u}\phi\left(\frac{(\beta' x + \sigma_v v) - y}{\sigma_u}\right)\Phi\left(\frac{\alpha' z + \rho v}{\sqrt{1-\rho^2}}\right) \quad (6)$$

The unconditional density is obtained by integrating v out of (6). Since the integral does not exit in closed form, Greene (2006) proposes to compute them by simulation. The final simulated log likelihood is given by (for details see Greene, 2006)

$$\log L_s = \sum_i \log \frac{1}{R} \sum_{r=1}^{R} \left\{ d_i \left[\frac{2}{\sigma_u} \phi\left(\frac{\beta' x + \sigma_v v_{ir} - y)}{\sigma_u} \right) \Phi\left(\frac{\alpha' z + \rho v_{ir}}{\sqrt{1-\rho^2}} \right) \right] + (1-d_i) \left[\Phi\left(\frac{-\alpha' z - \rho v_{ir}}{\sqrt{1-\rho^2}} \right) \right] \right\} \quad (7).$$

The model is estimated using NLOGIT Version 4.0.3 (LIMDEP Inc., 2008).

The Empirical Model

Three sets of variables were prepared for this study, i.e., probit selection equation (or season-choice) model, production frontier models and technical inefficiency effect models. Some of the variables appear in more than one model based on our a priori expectation. The definition of the variables and justification for their inclusion are as follows.

Growers having lengthy experience (EXP) definitely have production skills and self-confidence to produce early-season potato and their skills will have implication for yield and/or production efficiency. This variable, therefore, will be present in both probit and production or Technical Inefficiency models. AGE of growers should imply the accumulated marketing experience which contributes to the bold decision to venture into early season production. Meanwhile, the older the growers, the lower their inefficiency is expected. LAND in the Probit model can reflect the risk taking capability of growers because those who have large land holding size for growing large volume of potatoes are likely to be economically well-off. However LAND in Technical Inefficiency model is the variable associated with production scale in which inefficiency might grow with the diseconomy situation when growers cannot control intensive care for the crop. The PRICE variable is the expected price namely contracted price for in-season crop and previous year’s price for early-season crop. The expected prices appeared rather close to the actual levels received in the year of data collecting for this study.

In the production frontier model all input variables, including preventive chemicals other than disease treatment chemicals, are expected to contribute positively to output level. Presence of blight disease as dummy variables should have negative effect on output but positive sign is anticipated for the dummy variable of Chiang Mai.

The Empirical Model

The probit selection equation (d) is specified as:

d_i	=	1 if early season, i.e., $Z_i'\alpha \geq w_i$	
	=	0 otherwise	
Z_i	=	[*AGE, EXP, LAND, RECEIVED*]	(8)
AGE	=	grower's age (year)	
EXP	=	years of experience in growing potato which represent skill	
LAND	=	potato cultivated area (rai)	
RECEIVED	=	price received by growers (baht/kg)	
α	=	vector of parameters	

The extended Cobb-Douglas functional form of the production frontier for potato for this study is specified as:

$$y = \beta_0 \ln A + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 D_1 + \beta_7 D_2 + \beta_8 D_3 + \beta_9 D_4 + v - u$$

where

y	=	potato output (kg per)
X_1	=	tuber seed (kg per rai)
X_2	=	chemical fertilizer (kg per rai)
X_3	=	labor (man-day per rai)
X_4	=	preventive chemicals/insecticide (baht per rai)
X_5	=	floral-supplement hormone (baht per rai)
D_1	=	1 if using manures or other fertilizers
	=	0 otherwise
D_2	=	1 if Chiang Mai
	=	0 otherwise
D_3	=	1 if apply lime
	=	0 otherwise
D_4	=	1 if there exists late blight disease

= 0 otherwise

β = vector of parameters

Since for policy purposes we are also interested in identifying the determinants of inefficiency, we postulate the following inefficiency effects model for early-season and in-season potato, respectively.

For early season potato :

$$u_{1i} = \delta_{10} + \delta_{11}AGE + \delta_{12}EDU + \delta_{13}EXP + \delta_{14}LAND + \delta_{15}SCORE + \tau_{1i}$$

For in-season potato:

$$u_{2i} = \delta_{20} + \delta_{21}AGE + \delta_{22}EDU + \delta_{23}EXP + \delta_{24}LAND + \delta_{25}SCORE + \tau_{2i}$$

where,

AGE = age of the grower.

EDU = education (years) of the grower

SCORE = knowledge on potato cultivation practice, disease and fertilizer (score)

δ and τ = vector of parameters and error terms respectively. Remaining variables are defined earlier.

IV. Data and variables

Production data of 2006/07 crop year were obtained from interviewing a total 163 potato growers in two provinces, 63 out of which are those pioneer growers in Chiang Mai previously under contract farming system and the remaining 100 are presently the contract growers in Lampang representing those having less skills and experience in potato cultivation.

The length of experience from growing potato under contract farming system varies among individuals. In Chiang Mai, the longest experience is 20 years while the average is 9 years. The growers in Lampang have 4 years experience on the average while 75% of them have 1-5 year experience. The education attainments of growers in both province are at comparable levels (Table 1).

Average planted area in Chiang Mai is 6.00 rai slightly larger than that in Lampang, 5.07 rai

It should be noted that only growers in Chiang Mai applied manure and organic fertilizer to improve soil condition and therefore this input factor is treated as dummy variable for Chiang Mai in the production model.

In case of seed input, Chiang Mai growers used tubers from their own storage or those bought from fellow growers. These tubers are generally the small-sized potatoes unacceptable for processing and thus are utilized on farm as seed using the whole tuber at rather high input rate (240-290 kg/rai).

In the case of in-season cultivation under contract farming, growers are provided with large-sized tuber seeds imported by processing firms and they have to cut them into small pieces for planting at the input rate of 125 kg/rai (Table 1).

Growers applied chemicals as preventive measure rather than for disease treatments. Early-season growers (in Chiang Mai) used almost two times higher herbicide level and more than two times higher insecticide level, as well as 4.5 times higher hormone level for foliage spray than growers in Lampang (descriptive statisties of relevant variables appear in appendices).

Table 1 Average input used in potato production and output and growers' characteristic variables

Input	In season Lampang (N=100)	Off and early season Chiang Mai (N=63)
Tuber seed (kg/rai)	125.00	290.16
Labor (manday/rai)	26.0	25.01
Chemical fertilizer (kg/rai)	201.00	289.68
Manure (kg/rai)	0.00	335.28
Preventive chemicals (baht/rai) • herbicide • insecticide	1,345.02 439.53 905.49	3,003.82 746.38 2,257.44
Late blight	.32	.95
Foral hormone (baht/rai)	442.47	2,006.88
Lime	.0	.51
Cultivated land (rai)	5.07	6.06
Yield (kg/rai)	1,963.4	2,387
Age (year)	45.9	48.75
Education (year)	7.58	6.13
Knowledge (score)	65.81	73.22
Experience (year)	4.48	10.90
Price received (baht/kg)	8.00	9.01

Source: survey, 2004
Note: 2.5 rai = 1 acre

V. Empirical Results

Estimation of separate models for early-and in-seasons production frontiers performs poorly relative to an intregated model. Thus 163 observations from both seasons are combined. The estimations from application of probit, production frontier and technical inefficiency model equations (using NLOGIT version 4.0.3) yield the following results.

(1) Early-season production decision model

The best fitted-model is obtained from inclusion of the following 4 variables and structural form:

d = -9.2211- .0171AGE+.3990***EXP+.00047***RECEIVED-.1169LAND

This model can provide 89% predictive accuracy for early-season production decision and 99% in the case of in-season decision, with experience (EXP) and price (RECEIVED) being the most significant determinants.

(2) Stochastic production frontier

The presence of multicolinearity among many variables led to the removal of certain variables from the model such as tuber seed (X_1) which has rather high simple correlation with fertilizer (X_2) (r =.52) and extremely high with dummy for Chiang Mai (r =.75) as well as correlation between late blight and Chiang Mai (r=.93). The production frontier model in translog form has failed to pass the test for goodness of fit thus the Cobb Douglas form was chosen as alternative and it proved to provide the best specification as presented in Table 2.

Table 2: Maximum-likelihood estimates for parameters of the preferred stochastic production frontier and Inefficiency models

Variables	Model 1 coefficient	Model 2 coefficient
Production Function		
Constant	6.33652***	6.67061***
Fertiliser	0.15022***	0.09754*
Labour	0.01483	0.01100
Chemicals	0.05447*	0.04301
Foliage hormone	0.04191***	0.04139***
Experience		0.01041***
Mills ratio	-.04596*	-0.02927
Inefficiency equation		
constant	0.89607***	0.87034***
Education	0.00093	0.00174
land	0.00214**	0.00195
score	0.000054	0.000005
Variance parameter		
σ_{ε}^{2}	0.02566	0.03142
γ	0.92352***	1.48287***

Source: NLOGIT, version 4.0.3, 2008.

Notes: $\sigma_{\varepsilon}^{2} = \sigma_{v}^{2} + \sigma_{u}^{2}$ and $\gamma = \dfrac{\sigma_{u}^{2}}{\sigma_{v}^{2} + \sigma_{u}^{2}}$

: ***, **, * denote statistically significant at the 1, 5 and 10 per cent levels

Mills ratio is significant (model 1) demonstrating that production frontier of early- season growers differs from that of in- season growers. However, experience of growers has significant impact on decision making in probit function model and is the a component of mills ratio. As a consequence, the inclusion of EXP in the second model means to reduce significance of mills ratio. However, the inclusion of EXP in model 2 was intended to reflect the impact of the skills of Chiang Mai growers, who had long previous experience from being contract farmers, on potato growing productivity.

Major production inputs except labor have the effects on yield level as expected. Due to similar levels of labor input employed between the two groups of growers (coefficient of variation =.20), labor becomes insignificant determinant.

(3) Technical Inefficiency model

The best model concerning IT equation from the empirical findings contains only three variables[a]. As γ is statistically significant, it is implicit that production frontier exists in this functional form. The results indicate the larger the planted area, the lower the efficiency. Knowledge variable (SCORE) having low coefficient of variation = .16 thus becomes insignificant. The low coefficient of variation might come from the fact that critical knowledge was not clearly addressed in the questionnaire. Meanwhile, schooling attainment has no part to play in efficiency improvement.

Technical efficiency of growers in both groups is not different much on the average in the 0.89-0.92 range (Table 1). It is noteworthy that Lampang growers were able to produce potato at high efficiency level even though they obtained lower yield per rai from using input less intensively than Chiang Mai growers (Figure 1). The proportion of Lampang growers performing at very high efficiency level (TE = .91-1.00) was slightly lower than the case of Chiang Mai counterpart (findings from model 1). The difference in TE levels is greater when model 2 is applied. Another interesting notion is that contract growers generally adhere quite closely to advice and receive close supervision from extension workers of processing companies, helping make their technical efficiency levels less varying than otherwise case.

Table 3: Percentages of technical efficiencies

Interval	Model 1		Model 2	
	Lampang	Chiang Mai	Lampang	Chiang Mai
0.61-0.70	0(0)	0(0)	0(0)	3(4.76)
0.71-0.80	0(0)	3(4.76)	0(0)	3(4.76)
0.81-0.90	25(25)	10(15.87)	58(58)	20(31.75)
0.91-1.00	75(75)	50(79.37)	42(42)	37(58.73)
Mean technical efficiency	0.92	0.92	0.89	0.89

Source: From estimation.
Note: Number in the parentheses are the percentage.

[a] To ensure estimation of production equation to also yield goodness of fit (If specified in a different way, the parameter values become negative and some even insignificant)

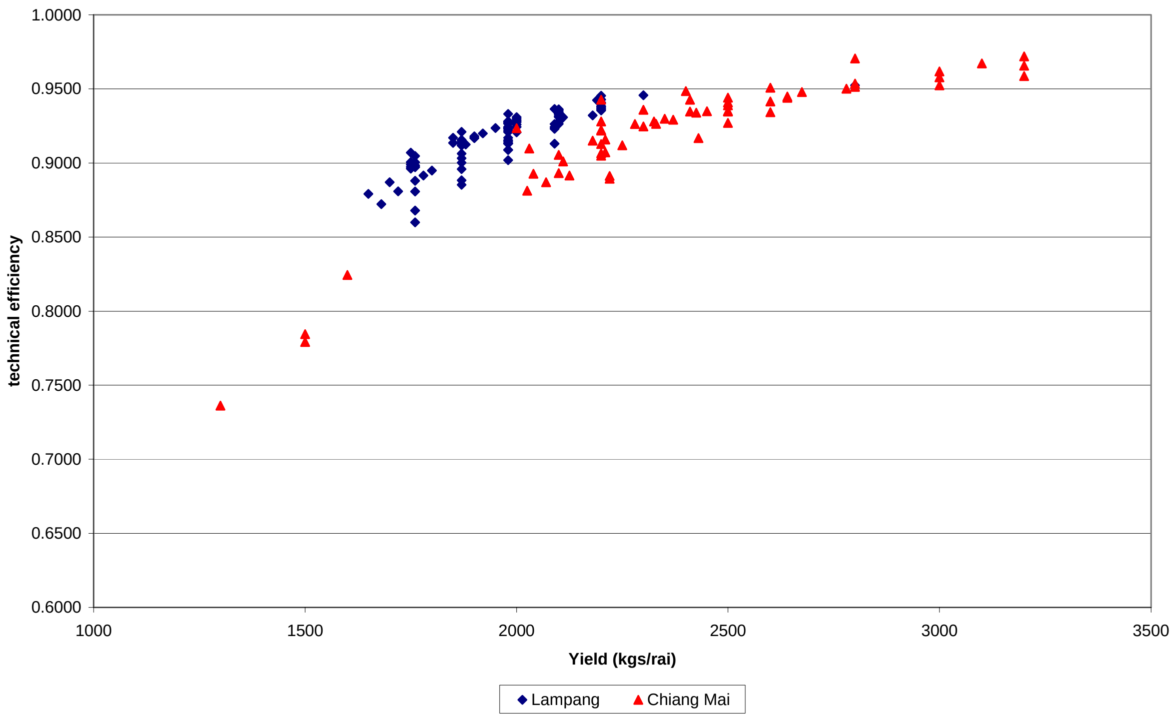

Figure1 Technical efficiency in relation to yield (model 1)

It seems safe to say that close supervision and control by the contract companies in terms of production inputs and cultural practice quality can help reduce production risk of growers who have not much experience. This can be verified by the content in figure 2 showing in the less than 5 year experience group, Chiang Mai growers have TE level lower than the Lampang growers who do farming according to contract arrangement. However, in the 6-10 year experience group, there is tendency for Lampang growers to perform poorer than their Chiang Mai counterpart.

The underlying reason for Chiang Mai growers to apply higher rate of chemical fertilizers, foliage hormone, and preventive chemicals and thus get higher productivity than Lampang levels partly comes from their confidence in making investment decision due to their relatively more lengthy production experience.

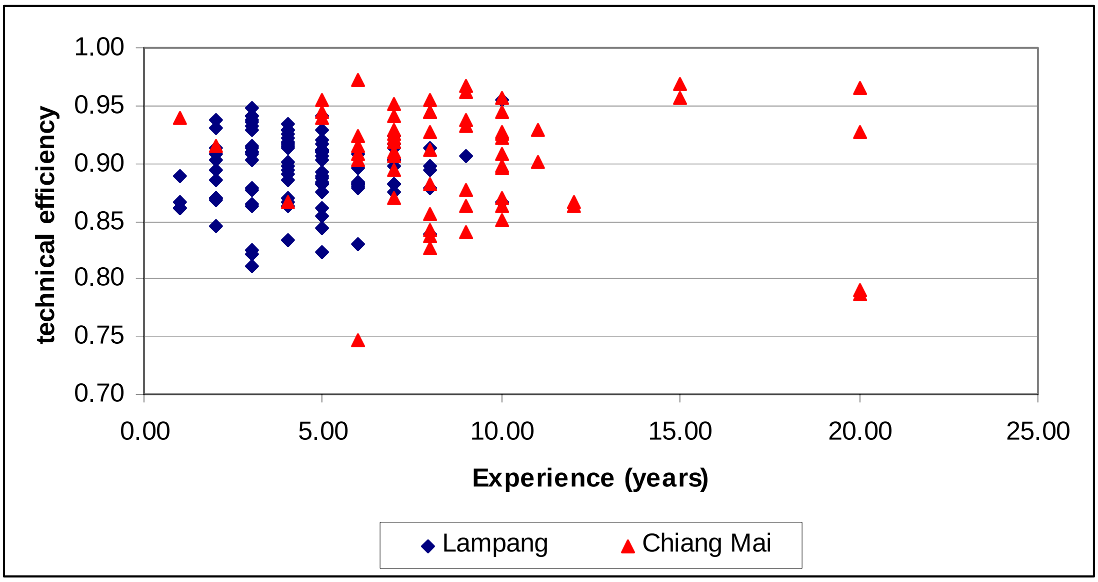

Figure2 Technical efficiency in relation to Farmer's experience (model 2)

Conclusion

In developing countries where small farmers have limited resource and lack adequate access to market and technical knowhow, contract farming is expected to be an instrument to overcome these constraints by means of technological transfer and input use efficiency improvement. This study found potato growers who have received technological transfer for no more than 5 years from contract processing firms can perform equally well in comparison to independent growers who have previous lengthy experience in contract farming. Their relatively short experience can be best augmented by the close production supervision from processing companies' extension workers. Once they become more experienced growers, they will have higher confidence and investment capability much enough to decide on alternative plan, eg. early-season potato cultivation based on their accumulated knowledge and skills to manage for greater yield and secure better market price. This case study on potato contract farming in Thailand portrays the benefit of using contract farming system to help improve productivity and technology in a country whose agricultural sector is in the transition onto agro-industrial platform.

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Appendix

Table 1: Summary statistics of key variables for the sample Lampang

Variable	Maximum	Minimum	Mean	Std. Dev.
Yield (kgs/rai)	2800.00	1650.00	1963.10	168.42
Fertiliser (kgs/ rai)	300.00	200.00	201.00	10.00
Labour(man-hour/rai)	53.00	14.00	26.07	7.12
Chemical (kgs/ rai)	1255.00	166.00	387.24	191.28
Supplementary food (kgs/ rai)	170.00	34.00	75.73	32.76
Experience (years)	10.00	1.00	4.48	1.98
Education (years)	18.00	4.00	7.58	3.31
LAND (rai)	10.00	1.00	5.07	2.08
SCORE	95.00	32.00	65.81	14.41

Table 2: Summary statistics of key variables for the sample Chiang Mai

Variable	Maximum	Minimum	Mean	Std. Dev.
Yield (kgs/rai)	3200.00	1300.00	2387.38	394.75
Fertiliser (kgs/ rai)	650.00	150.00	289.68	83.72
Labour(man-hour/rai)	38.00	16.00	25.10	5.71
Chemical (kgs/ rai)	1388.00	470.00	782.08	199.79
Supplementary food (kgs/ rai)	767.00	1.00	348.33	157.76
Experience (years)	20.00	1.00	10.90	13.97
Education (years)	18.00	4.00	6.13	3.31
LAND (rai)	14.00	1.00	6.06	3.18
SCORE	95.00	36.00	73.22	11.85