The Empirical Econometrics and Quantitative Economics Letters
ISSN 2286 – 7147
Volume 2, Number 2 (June 2013), pp. 83 – 96.

An analysis of operational efficiency and optimal development for agricultural cooperatives in Chiang Mai

Montri Singhavara[1], Nisachon Leerattanakorn[1],
Aree Cheamuangphan[1] and Kamontip Panyasit[2]

[1]*Faculty of Economics, Maejo University,*
E-mail: montrish@gmail.com

[2]*Faculty of Management Sciences, Chiang Mai Rajabhat University,*
E-mail: Somying1052@gmail.com

ABSTRACT

By employing the Malmquist productivity index, Data Envelope Analysis (DEA) and super-efficiency DEA, this study attempts to analyze the total factor productivity change, find out the optimal size of business and some policy implications are suggested in order to improve efficiency of agricultural cooperatives in Chiang Mai province, Thailand. The results represent that after adopting information technology (Technological change), total productivity change has improved however pure technical efficiency change and scale efficiency change still continue in downward trend. From 55 agricultural cooperatives, there are 19 units (34%) having pure technical efficiency and 18 units of them are extreme efficient DMUs. Moreover 9 agricultural cooperatives (17%) have assets worth approximate 40.69 billion baht and have constant return to scale. The optimal membership and the proper volume of debt are important notices for administrators considering for improving business efficiency.

Keywords: Efficiency, Total Factor Productivity Change, Super-efficiency DEA, Malmquist Index, Agricultural Cooperative.

1. Introduction

Thailand has been well-known as kitchen of the world and has been the world's top exporter of various agriculture products such as rice, rubbers and chickens for many years. Therefore, it is not surprising that agriculture industry has been an important sector which generates income and employment. Since agriculture sector is the biggest part of Thai economy, it has suffered from the tremendous impact of the current global economic crisis. Plenty of Thai

farmers faced with financial problems and because of increasing production costs they needed the bulk of assistance from financial institutions. There are many resources for financial assistance for instance Bank for Agriculture and Agricultural Co-Operative (BAAC), a state enterprise under the jurisdiction of the Ministry of Finance, local banks and private banks. However, agricultural cooperatives which have local branches in almost rural villages are the most important financial institution in term of loans, input supplier and other financial transactions.

Although, there are plenty of financial institutions, the official statistics show that many farmers cannot access these financial resources. According to the Ministry of Finance’s survey, it is reported that in 2008 the amount of illegal debts were approximate one hundred thirty six billion baht (Financial Policy Office, 2008). One of the obstacles in accessing financial capital for the poor and remote farmers occurs from the inefficiency management of each financial institution.

In this study, we focused on the agricultural cooperatives in Chiang Mai province, the largest and most important economic city in northern of Thailand. Moreover, farmers in this area were stuck in a spiral of low incomes and very high debts. The objectives of our study were to study the efficiency of agricultural cooperatives in Chiang Mai province, to find the optimal size of the organization and to give some advice for improve the operational and management efficiency. The results of this study will have a rich implication for agricultural cooperatives, policy makers and government as well.

2. Literature review

In recent years, the concept of efficiency measurement has captured a great deal of attention in agricultural field weather direct or indirect efficiency. The concept of efficiency measurement means that the performance of a decision making unit (DMUs) is measured relative to a "best practice" frontier, which is determined by the most efficient decision making unit in the industry.There are two alternative approaches to estimate frontier models: parametric frontier and the non-parametric mathematical programming.Each of these approaches has its advantages and drawback however in practical studies there are provided the similar result of estimation. (Tim Coelli., D.S. Prasada Rao and Geore E. Battese, 1998)

The parametric frontier rely on econometric technique, commonly referred as Stochastic Frontier Analysis (SFA).The initial framework on parametric frontier analysis commenced with Farell's (1957) where goal programming techniques were used to estimate production function.

The advantage of stochastic production frontier approach over DEA is the random variations can be founded in the model, thus this measurement correspond with the real situation of agricultural activities. However, the disadvantage of this method is that, although it can model multiple outputs technologies, doing so is somewhat more complicated, and raises problems for outputs that take zero values (Paul, Johnson and Frengley, 2000).

Data Envelopment Analysis (DEA) is a mathematical linear programming based on Non-parametric method. The initial DEA model, as originally presented in Charnes, Cooper, and Rhodes (CCR) (1978), built on the earlier work of Farrell (1957). The advantage of this approach over parametric methods is that no assumptions are needed regarding the relationship between the inputs and outputs. Therefore, complex or ambiguous relationships can still be modeled. Moreover, whereas, traditional regression compares DMU's to the average producer, DEA compares DMU's to the most efficient producer. Thus, following DEA method it advises how DMUs evaluatedshould mend its behavior to reach efficiency.

There are two main characteristics differences between SFA and DEA (Kebede, 2001):

1. The SFA as an econometric approach attempts to distinguish noise from inefficiency. The DEA as programming approach is non-stochastic and lumps both effects together. It then calls the result inefficiency.

2. The SFA is parametric, and confounds the effects of misspecification with inefficiency. The DEA is non-parametric and less prone to this type of specification error

When the Cooperatives are estimated and these units not included in the reference set of the envelopement model, this models are called super-efficiency DEA models. Super-efficiency model as follow, Charnes, Haag, Jaska and Semple (1992) use a super-efficiency model to study the sensitivity of classifications. Zhu (1996) and Seiford and Zhu(1998) develop a number of new super-efficiency models to determine the efficiency stability regions. Anderson and Peterson (1993) propose using the CRS super-efficiency model in ranking the efficient DMUs. Also, the super-efficiency DEA models can be used in detecting influential observations (Wilson, 1995). Seiford and Zhu (1999) study the infeasibility of various super-efficiency models developed from the envelopment model.

In this study we applied DEA because the cooperative financial data was difficult to determine the explicit functional form and there are small number of Cooperative that had complete financial data. Moreover we used super-efficiency models to classify pattern of efficiency.

The empirical studies which related to efficiency of agricultural cooperatives in Thailand were scarcity. Rattanawipa (2009) used output oriented DEA for identify the comparative technical efficiency and scale efficiency among various agricultural cooperatives among 26 agricultural cooperatives in Chiang Mai province during 2003-2007. The paper found that the average technical efficiency was 0.996 and the average pure technical efficiency was 0.998 while the majorities were operating at full technical efficiency (1.00). The total factor productivity growth index took place at proper rate of 1.037 as a result of technological progress rather than from improvement in technical efficiency change. Moreover, normal and inverse DEA was applied to predict the performance of Bank for Agriculture and Agricultural Cooperatives. The results confirmed the high efficiency and accuracy of the model (Junjira, 2000)**.**

3. Data and Methodology

3.1 Data

The secondary data is obtained from the annual report of agricultural cooperatives in Chiang Mai province for the period 2006-2010. In 2010 there are 113 agricultural cooperatives located in this study area. Calculating by Taro Yamane method (Yamane, 1967), the proper sample size is 89 agricultural cooperatives, however after detect outlier and missing data the final sample size is 55 agricultural cooperatives.

3.2 The estimate of productivity change with Malmquist TFP index

To determine the productivity of the agricultural cooperatives of this study, based on concept of Caves et al., (1982), who has proposed a distance function d(x, y) can be used in the construction of the Malmquist index and measure the Malmquist index of change between t and t+1 as the ratio

$$d^T(x^{t+1}, y^{t+1})/d^T\,(x^{t+1}, y^{t+1}) \qquad (1)$$

From equation (1) can be divided into two parts according to the guideline of Fare et al., (1994) including the product of technological change and technical efficiency change as:

$$\mathrm{M}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{d^{t+1}(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)}\left[\frac{d^t(x^{t+1}, y^{t+1})}{d^{t+1}(x^{t+1}, y^{t+1})}\frac{d^t(x^t, y^t)}{d^{t+1}(x^t, y^t)}\right]^{1/2} \qquad (2)$$

The ratio outside the brackets is the index of change in technical efficiency between year t and t+1, while the bracketed term is the index of change in technology (or technological change) between two periods evaluated at x^t and x^{t+1}.

The measurement of technical efficiency (the reciprocal of the input or output distance) is used to constructing the Malmquist index, we obtain the productivity growth if M > 1 and productivity downturn when M < 1. In addition, the technical efficiency can be divided into two components such pure technical change and scale technical change (equation 3). The first ratio is based on VRS hypothesis, measuring the pure technical efficiency only. Secondly, the ratio of overall efficiency (CRS) score to pure technical efficiency score (VRS) has provide us with a measurement of scale efficiency. The difference between the CRS scores and the scale efficient change allow us to obtain the pure efficiency change. Thirdly, this term is about the technological change index (Cummins, 1999).

$$\mathrm{M}(x^{t+1},y^{t+1},x^{t},y^{t}) = \frac{d_{VRS}^{t+1}(x^{t+1},y^{t+1})}{d_{VRS}^{t}(x^{t},y^{t})}\left[\frac{d_{CRS}^{t+1}(x^{t+1},y^{t+1})}{d_{VRS}^{t+1}(x^{t+1},y^{t+1})}\Big/\frac{d_{CRS}^{t}(x^{t},y^{t})}{d_{VRS}^{t}(x^{t},y^{t})}\right] \times\left[\frac{d_{CRS}^{t}(x^{t+1},y^{t+1})}{d_{CRS}^{t+1}(x^{t+1},y^{t+1})}\frac{d_{CRS}^{t}(x^{t},y^{t})}{d_{CRS}^{t+1}(x^{t},y^{t})}\right]^{1/2} \quad (3)$$

In order to calculate the total factor productivity (TFP change) between the two periods has been using the distances function that consist of four components namely d_{VRS}^{t+1}, d_{VRS}^{t}, d_{CRS}^{t+1} and d_{CRS}^{t} which are estimated by linear programming models of the frontier production function.

3.3 Efficiency and the improvement of input factors

Data Envelope Analysis (DEA) is used for estimating the relative efficiency of 55 agricultural cooperatives in 2010. The model in this study is based on input-orientation because the model assumption suggested that most of cooperatives pay attention to modifying the inputs factors (constant outputs) for maximizing efficiency (Zhu, 2009). Hence, the DEA model can be representing two-stage DEA express as:

$$Min\ \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^{-} + \sum_{r=1}^{s} s_r^{+}\right)$$

Subject to $\sum_{i=1}^{n}\lambda_j x_{ij} + s_i^{-} \geq \theta x_{io}$, (5) $;m,\ldots,1 = i$

$\sum_{j=1}^{n}\lambda_j y_{ij} - s_r^{+} \geq y_{ro}$, $;s,\ldots,1 = r$

$\lambda_j \geq 0$, $n\ldots,1 = j$

The presence of the non-Archimedean ε in the objective function of equation (5) effectively allows the minimization over θ to preempt the optimization involving the slack, s_i^- and s_r^+. Thus, (5) is calculated in a two-stage process with maximal reduction of inputs being achieved first, via the optimal θ^*; then, in the second stage, movement onto the efficient frontier is achieved via optimizing the slack variables in (5)

where n is amount of agricultural cooperative, m is amount of factor inputs, s is amount of output, λ_j is weighted value of the agricultural cooperatives j, y_{ij} is amount of output i from agricultural cooperatives j, x_{kj} is amount of input k from agricultural cooperatives j, θ is efficiency score of agricultural cooperative based on input-orientation, s_i^- is input slacks, s_r^+ is output slacks

In this study, we focused on 2 points: 1) Efficiency change overtime (by using Malmquist index) and 2) Efficiency score of each cooperative in 2010 from traditional DEA and super-efficiency DEA. In studying both points, we used the same input and output variables. Output variable is the annual income of a cooperative. Input variables consist of the following points:

- **Capital stock**: total amount of a firm's starting capital, represented by the value of its issued common and preferred stock. This factor is important because it is form its members' fund which doesn't cost interest from beginning.
- **Working capital**: the amount of current assets and permanent asset that exceeds current liabilities which reserved for the 2 main types of loans: total loan and business loan.
- **Total loan**: the amount of money which is a loan for farmers by agricultural cooperatives. It is not only represents source of business income but also risk because this loan does not require any loan security.
- **Business loan**: the amount of money which is a loan for farmers by agricultural cooperatives which requires loan securities such as land and house. Business loan is lower risk comparing to total loan.
- **Total debt**: an amount deposit from cooperative members and loan from outsources. The higher volume of this factor indicates high risk of a cooperative.
- **Farm supplier**: agricultural cooperatives provided input factors (for example chemical fertilizers, pesticides, fuel oil and seeds) for sale to their members and the general people.
- **The membership of agricultural cooperative:** the number of cooperative's member that represents the business size, the capacity to generate income and risk distribution.

- **Total business volume:** all business activities that create income excluding farm supplier such as deposit and gathering business. The volume in this factor can be used to pay off debt in order to lower the risk.

3.4 Super-Efficiency DEA Models

The super-efficiency DEA models can be used in detecting influential observations (Wilson, 1995) and identifying the extreme efficient DMUs (Thrall, 1996). Seiford and Zhu (1999) study the infeasibility of various super-efficiency models developed from envelopment models. The major difference between the traditional DEA and super-efficiency DEA models is that DMU_0 under consideration is excluded from the reference technology set which constructed from all other DMUs in super-efficiency DEA model. Thus, CRS super-efficiency DEA model can be represent under the Input-Orientation Assumption express as:

$$Min\ \theta^{super}$$

$$\text{Subject to} \quad \sum_{\substack{j=1 \\ j\neq 0}}^{n} \lambda_j x_{ij} \geq \theta^{super} x_{io} \quad i = 1, 2, \dots m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \quad r = 1,2, \dots, s; \qquad (6)$$

$$\lambda_j \geq 0, \quad j \neq 0.$$

For VRS super-efficiency DEA model which applied by add constrain as $\sum_{j\neq 0} \lambda_j = 1$ into equation (6).

As in Charnes, Cooper and Thrall (1991), the DMU can be partitioned into four classes E, $E^{/}$, F and N described as follows. First, E is the set of extreme efficient DMU. The DMU in set $E^{/}$ can be expressed as linear combinations of the DMU in set E. Third, F is the set of frontier points(DMU) with non zero slack(s). The DMU in set F are usually called weakly efficient. Fourth, N is the set of inefficient DMU (Zhu, 2009).

Thrall (1996) show that if the CRS super-efficiency model is infeasible, or if the super-efficiency score is greater than one for input-oriented model(less than one for output-oriented model), then DMU $\in$ E. This result can also be applied to other super-efficiency model. i.e., the extreme efficient DMU can be identified by the super-efficiency models. Note that if a specific $DMU_o \in E^{/}$, F or N and is not included in the reference set, then the efficient frontiers (constructed by the DMU in set E) remain unchanged. As a result, the super-efficiency DEA models are always feasible and equivalent to the original DEA models when $DMU_o \in E^{/}$, F or N. Thus we only need to consider the infeasibility when $DMU_o \in$ E.

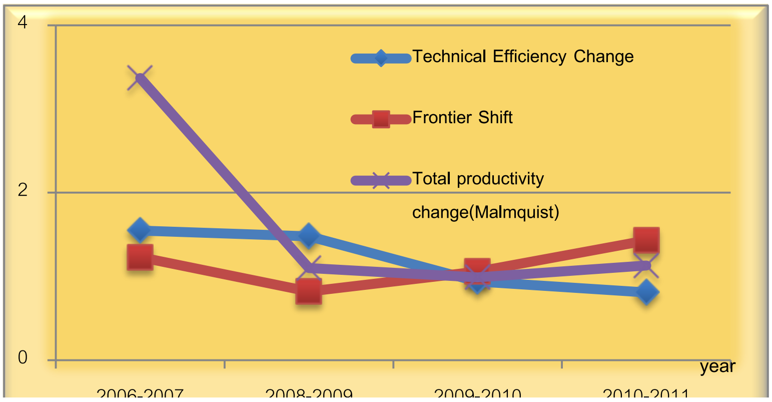
4. Empirical Results

In this part, the analysis is split up into two parts: the first part represents the total factor productivity change (TFP change) and productivity of agricultural cooperatives in period 2006-2010 by using Malmquist index, the second part we apply the DEA technique input-oriented for analyzing the technical efficiency of agricultural cooperatives in 2010 and apply super efficient technique for sensitivity analysis.

4.1 The Total factor productivity change (TFP change) and productivity of agricultural cooperatives in period 2006- 2010.

In this study we analyze the total factor productivity change of 55 agricultural cooperatives and all of them have same inputs and output. TFP change has two components: technical efficiency change or catching up and technological change or changes in the best practice. Figure 1 shows TFP change, technical efficiency change and frontier shift.

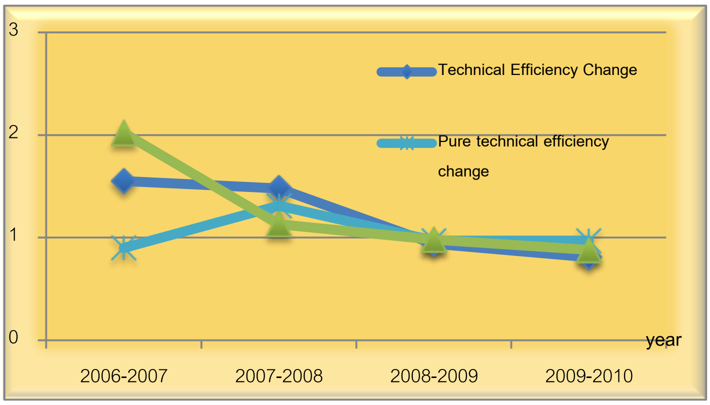
Figure 1: TFP change, technical efficiency change and frontier shift.



From this figure, the total productivity change tends to decrease in the period 2006-2009 and finally equal to 1 because the great decrease in technology change or frontier shift. In the period 2008-2010, each agricultural cooperative implements new technology (new computer software for accounting), so agricultural cooperatives are increasing in total productivity change although at that time technical efficiency change is continuous decrease until less than 1 in period 2009-2010.

When considering the optimal business size from the scale efficiency change which equal to 1. The results show that before 2008, agricultural cooperatives used input factors over than optimal level after that this problem continuously decline. In 2008, study represents that SE = 1, denoting the optimal business size because they use all inputs in full capacity. (Figure 2)

Figure 2: The scale efficiency change.



4.2 The technical efficiency of agricultural cooperatives in 2010 and policy implications.

To analyze the technical efficiency of agricultural cooperatives in 2010, researchers apply DEA approach, one of the main and widely approach for evaluating and improving the performance of business, manufacturing and service operations. DEA is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision making units (DMUs). We calculate DEA by solver command in Microsoft Excel 2010. In addition, it illustrates variation return to scale (VRS) constant return to scale (CRS) and scale efficiency (SE).

Results show that, in fact agricultural cooperatives cannot easily increase output or have various obstacles to do that. Many cooperatives lack good management, some of them use some inputs over than optimal level or impose the management policy focusing on quantitative rather than qualitative growth.

Table 1 shows that there are 19 DMU (34%), pure technical efficiency (PTE) = 1 (based on VRS) representing that all of them rely on efficiency frontier under the variable return to scale assumption. These efficient DMUs are considered as reference DMU in the analysis. 65% of other DMUs are inefficient units and the minimum score of DMU has PTE = 0.26

Following Thall (1996) and Seiford and Zhu (1996) concept, super-efficiency DEA is used in ranking efficient units, identifying outliers, analysis in sensitivity and stability, measuring productivity changes. Based on this approach DMUs are classified into four groups which compose of group E: extreme efficiency group; group $E^{/}$: efficiency DMU which rely on the line connected between DMU in group E; group F: weakly efficiency group; and group N: inefficiency group or group under DEA. It is noteworthy that the efficiency score from super-efficiency DEA approach is not different from this score calculated by traditional DEA in group $E^{/}$, F and N. That means although we ignore or exclude DMUs in group $E^{/}$, F and N, it does not affect efficient frontier; therefore, we focus only on DMU in group E.

Table 1: Technical efficiency and pure technical efficiency and scale efficiency in 2010.

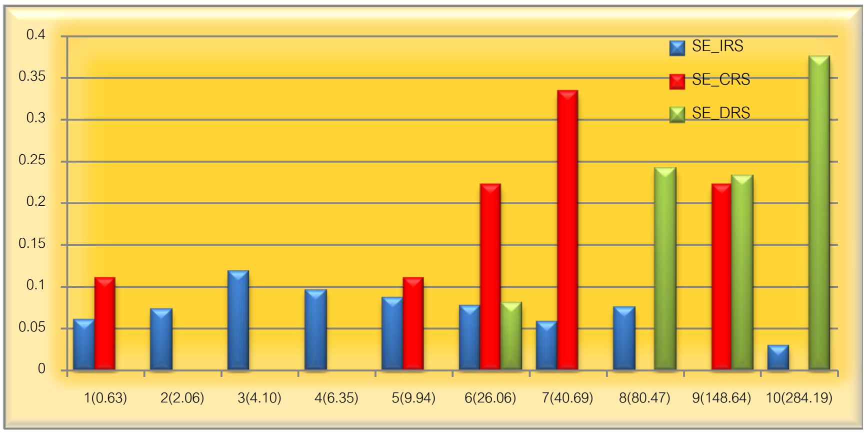
	PTE: VRS	TE: CRS	Return to Scale	SE
The number of efficient DMU (100)	19	9	9	9
The number of inefficient DMU (<100)	36	46	46	46
The number of DMUs exhibits increasing returns to scale	-	-	34	-
The number of DMUs exhibits decreasing returns to scale	-	-	12	-
The number of DMUs which have equal to or greater than average efficient level.	22	16	-	34
Minimum	0.26	0.13	-	0.19
Maximum	1	1		1
Mean	0.64	0.49	-	0.78
Median	0.54	0.34	-	0.92
Standard Deviation	29.34	29.60	-	0.26

The study shows that when considering under assumption of constant return to scale there are 9 agricultural cooperatives are categorized in group E whereas under variable return to scale the number of agricultural cooperative are categorized in group E increased to 18 units and almost all of them are similar in PTE value as shown in table1. Moreover, the super-efficiency scales of these DMUs are more than 1 (Table 1). The higher scale presents that these DMUs can increase the use of input factors whereas it maintains level of efficiency. There is only one DMU that has decreasing return to scale (DRS) and relying on the right endpoint of efficiency frontier. That means this unit can maintain level of efficiency even if it increases the use of input factors infinitely.

After the pure technical efficiency is calculated base on the variable return to scale, we find 9 DMUs (16.36%) that have constant return to scale, 34 DMUs (61.81%) that have increasing return to scale and 12 DMUs (21.81%) that have decreasing return to scale. Then, we calculate scale efficiency (SE) to find out the optimal business size, the scale shows that the mean of scale efficiency (SE) equal to 0.78. There are 9 units (16.36%) that have constant return to scale and SE=1, whereas 46 units (83.93%) are categorized inefficiency units (SE between 0-1). When focusing only on these inefficiency units, 34 units (61.81%) are increasing return to scale and others are decreasing return to scale.

For more detail, we classify agricultural cooperative by asset volume into 10 groups (deciles) for represent the size of business and the distribution of scale economy (Figure 3). The result is consistent with basic microeconomic theory. The constant return to scale is found in agricultural cooperatives having asset equal to 40.69 million baht (D7), the increasing return to scale occurs in small agricultural cooperatives having asset about 4.10 million baht (D3) and tend to continuously decrease. For large-sized agricultural cooperatives, having asset more than 23.63 million baht, they have operated under decreasing return to scale.

Figure 3: The mean of scale economy categorized asset volume.



Indeed, all size of agricultural cooperatives in Chiang Mai province have chance to operate under optimal size but the best size is medium-size (asset between 9.94-40.69 million baht). It is remarkable that the agricultural cooperatives that have asset more than 80.47 million baht may have some problems such as high cost, low revenue or decreasing return to scale.

Table 2: The comparison of input factor improvement between input-oriented and output-oriented

Details	Real value	Input-oriented		Output-oriented	
		Optimum value	% Change	Optimum value	% Change
Capital stock (million baht)	15.87	12.83	-22.67	4.69	-50.31
Working capital (million baht)	71.17	63.04	-18.44	32.80	-42.78
Total debt	46.54	41.79	-17.49	23.08	-40.48
Total loan	37.06	31.17	-26.86	10.78	-67.99
Business loan	21.27	18.53	-22.59	6.18	-67.49
Farm supplier	19.13	19.09	-0.83	16.20	-5.25
Total business value	75.59	74.19	-5.52	69.85	-7.33
The number of membership	1,333	1,151	-9.82	526	-42.58

After analyzing efficiency by using both input-oriented and output-oriented approach, the study shows the same results. No agricultural cooperatives in Chiang Mai province need to increase output (income). Table 2 represents the value of 8 variables in this study compare between input-oriented and output-oriented. Some important policy implications are suggested:

- Agricultural cooperatives should reduce input factors (percentage change from output-oriented greater than input-oriented model).
- Agricultural cooperatives face with high risk from "total loan" business because this loan does not require any loan security.
- Agricultural cooperatives should aware the quality of debtors and the large volume of business does not guarantee high efficiency.
- Agricultural cooperatives should reduce total loan and business loan about 65%. However, this policy may affect the member's satisfaction and inconsistent with the cooperative principle so input oriented approach is more suitable for analyze cooperative efficiency.
- The main advantages of holding high levels of capital stock are decreasing in financial cost, increasing ability to debt, increasing in working capital. However, the high value of capital stock may cause over investment and poor quality loan.

5. Conclusion

After adopting the new technology especially the new accounting software for business with trained staffs, almost agricultural cooperatives in Chiang Mai have increased total productivity change in the period 2008–2010. However, in the period 2007–2010, technical efficiency change had been continuously decreased. The results of this study shows that on the period 2006-2010 there are 10 agricultural cooperatives out of 55 units that have been increasing in 1) technical efficiency change 2) frontier shift 3) pure technical efficiency change and 4) scale efficiency change. The inefficient agricultural cooperatives are faced with a decreasing in pure technical efficiency change and scale efficiency change.

By employing the Data Envelope Analysis (DEA) input oriented under the assumption of variable return to scale, we find, in 2010, there are 19 DMUs relying on efficiency frontier (PTE=100). After applying super-efficiency DEA approach the results show that there are 18 units out of previous 19 units that can increase input factors in the same time of maintaining operation efficiency.

Moreover, when considering the optimal size of business the results represent that there are 19 agricultural cooperatives (16.36%) that are constant return to scale and hold the asset 40.69 million baht. Almost small-sized agricultural cooperative's asset worth about 9.94 billion baht, are increasing return to scale. They would be better operated if they increase business size until having asset about 9.94 billion baht (optimal size). They face with constant return to scale. The large-sized business, especially the agricultural cooperatives having asset more than 23.63 billion baht, are decreasing return to scale and can be obviously observed for the agricultural cooperatives that have asset about 284.19 billion baht.

Following the Envelope Analysis (DEA) Input-oriented approach, the inefficient agricultural cooperatives in Chiang Mai province should deal with debt carefully, control risk, invest in optimal scale and concern the quality of debtors more than turning up business volume policy.

REFERENCES

Ali, Karamat. 2001. Pakistan: The Political Economy of Human Resource Development. Vanguard Books (Pvt.) Limited, Lahore.

Atkinson, S. E. & Wilson, P. W. 1995. "Comparing Mean Efficiency and Productivity Scores from Small Samples: A Bootstrap Methodology". Journal of Productivity Analysis 6, 137- 152.

Aigner, D., C.A.K. Lovell & P. Schmidt. 1977. "Formulation and Estimation of Stochastic Frontier Production Models." Journal of Econometrics. 6: 21-37.

Banker, R.D., A. Charnes & W.W. Cooper. 1984. "Some Models for Estimating Technical and Scale inefficiencies in Data Envelopment Analysis." Management Science. 30: 1078-1092.

Caves, D. W., Christensen, L. R. & Diewert, W. E. 1982. "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity". Econometrica 50(6), 1393-1414.

Charnes, A.,W.W. Cooper & E. Rhodes. 1978. "Measuring the Efficiency of Decision Making Unit." European Journal of Operational Research. 2: 429-444.

Coelli, T.J., D.S. Rao & G.E. Battese. 1998. An Introduction to Efficiency and Productivity Analysis. Massachusetts: Kluwer Acadamic Publishers.

Coelli, T.J., D.S. Rao, C.J. O'Donnell & G.E. Battese. 1998. An Introduction to Efficiency and Productivity Analysis Second Edition. New York: Springer.

Coelli, T.J., D.S. Rao, C.J. O'Donnell & G.E. Battese. 2005. An Introduction to Efficiency and Productivity Analysis Second Edition. Berlin, Springer.

Farrell, M.J. 1957. "The Measurement of Productive Efficiency." Journal of Royal Statistical Society.120(3): 253-281.

Färe,R., S. Grosskopf, B. Lindgren & P. Roos. 1992. "Productivity Change in Swedish Phamacies 1980-1989: A Non-parametric Malmquist Approach." Journal of Productivity Analysis, 3(1): 85-101.

Färe,R., S. Grosskopf, & C.A.K. Lovel. 1985. The Measurement of efficiency of Production. Boston: Kluwer Academic Publishers.

Pramuanpisut Junjira. 2000. "Performance Prediction of Bank for Agriculture and Agricultural Cooperatives in the upper North Using Data Envelopment Analysis

Approach". Master of Science, Department of Agricultural Economics, Chiang Mai University. (in Thai).

Kebede. T.A. (2001). Farm Household Technical Efficiency: A Stochastic Frontier Analysis – A Study of Rice Producers in Mardi Watershed in the Western Development Region of Nepal, A Master Thesis.

Meeusen, W. & Van den Broeck. 1977. "Efficiency Estimation from Cobbdouglas Production Functions with Composed Error", International Economic Review 18(2), 435-444.

Paul, C.J.M., Johnson, W. & Frengley, G. 2000. Efficiency in New Zealand sheep and cattle farming: the impacts of regulatory reform. *Rev. Econ. Statist.,* 82(2): 325-337.

Sangtawan Rattanawipa. 2009. "Efficiency of Agricultural Cooperatives' Business operations in Chiang Mai Province". Master of Science(Agribusiness), Department of Agricultural Economics, Chiang Mai University. (in Thai).

Simak C. Paul. 2000. Inverse and Negative DEA and their Application to Credit Risk Evaluation. Thesis for Doctor of Philosophy, Department of Machanical and Industrial Enginerring University of Toronto 2000.

Simar, L. 1992. "Estimating Efficiencies from Frontier Models with Panel Data: A Comparison of Parametric, Non-parametric and Semiparametric Methods with Bootstrapping". Journal of Productivity Analysis 3, 167-203.

Simar, L. & Wilson, P. W. 1998. "Sensitivity Analysis of Efficiency Scores: How to Bootstrap in Nonparametric Frontier Models". Management Science 44(1), 49-61.

Yamane, Taro. 1967. Statistics, An Introductory Analysis. 2nd Ed., New York: Harper and Row.

Zhu, J. 2003. Quantitative Models for Performance Evaluation and Benchmarking. Boston: Kluwer Academic Publishers.