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The impact of age structure on technical efficiency in Thai agriculture

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Abstract

The purpose of this paper was to estimate the age structure effect of agricultural labor on technical efficiency by using stochastic frontier analysis. The translog stochastic frontier production function with the technical inefficiency model was estimated simultaneously using maximum likelihood methods. Panel data of agricultural production at the provincial level from 76 provinces for 2009–2013 were used for estimating the model. The estimated results of the technical inefficiency model identified that the labor force aged 60 years and over increased the technical inefficiency, while the labor force aged 15–59 years reduced the technical inefficiency in Thai agricultural production. Therefore, the public sector should be determined in establishing policy options to encourage young people to become young, smart farmers. The use of agricultural mechanization that is easily used by older farmers should also be promoted, along with financial support to enable them to increase production efficiency.

Introduction

One of the tendencies of major change around the world includes the encountering of aging societies. In Thailand, an increasing proportion of the elderly population is more evident in rural areas, where the proportion of elderly people was up to 58.92 percent while in urban areas, the figure was 41.08 percent in 2016 (National Statistical Office, 2017). As most of the rural population works in the agricultural sector, the rapid rise in the proportion of older people affects the changing age structure of the labor force in the Thai agricultural sector. The agricultural labor force of aged 60 years and over rose rapidly from 4.33 percent in 1986 to 18.82 percent in 2016 (Table 1).

The increasing proportion of the aging labor force of the agricultural sector affects agricultural production and is an interesting issue. Stloukal (2004) studied the potential impact of rural population aging on agriculture in developing countries. It was found that aging leads to changes in both the quantity and quality of agricultural labor, while the proportion of the aging labor force who have physical disabilities increased. This situation is a possible cause of problems in expanding agricultural production and existing production patterns. However, the research did not apply quantitative methods for assessing the aging effects.

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Table 1
Age structure of the Thai agricultural labor force, 1986–2016 (%)

Age (years)	1986	1991	1996	2001	2006	2011	2016
15–59	95.67	94.76	92.83	91.13	89.12	87.07	81.18
60 and over	4.33	5.24	7.17	8.87	10.88	12.93	18.82
Total	100	100	100	100	100	100	100

Source: Calculated from the NSO labor force survey (National Statistical Office, 2017)

Regarding the quantitative empirical research studies on the impact of an aging labor force in the agricultural sector, Tauer (1995) analyzed the relationship between age and farmer productivity in the United States. It was found that farmer productivity differed across age groups. Some studies applied the efficiency approach to measure the impact of aging on technical efficiency (Abdulai & Eberlin, 2001; Battese & Coelli, 1995; Battese, Malik, & Gill, 1996). These works studied the relationship between the age of the primary decision-maker in the farming operation and inefficiency in India, Pakistan, and Nicaragua. Moreover, Battese and Broca (1997) estimated the relationship between age of the farmers and inefficiency in Pakistan. However, the variables used an "average age" in those studies and therefore could not represent the aging effect clearly.

The issue of an explanatory variable that represents the aging effect on technical efficiency was considered in the work of Li and Sicular (2013) analyzing the relationship between aging in the agricultural labor force and inefficiency in China. The explanatory variable of aging effect was the number of aged members of the labor force, which was separated from the total number in the labor force in order that the aging effect might be measured more accurately. However, according to the literature review, there is no study on the inefficiency effects of aging on the agricultural sector in Thailand, which is still an issue requiring empirical research. Therefore, this article studied the aging effect on technical efficiency in Thai agriculture to answer the question of whether or not the aging of agricultural labor affects technical efficiency in Thai agriculture. Understanding regarding this issue will be beneficial for planning to alleviate inefficiency and to improve the agricultural production efficiency in Thailand.

Literature Review

Productive efficiency refers to the capacity of an economic unit to increase output with constant resources and technology (output-orientated), or the capability to reduce the use of resources with a constant quantity of output (input-orientated). The idea in measuring the efficiency of production started from the work of Farrell (1957) using the ideas from Koopmans (1951) and Debreu (1951). The approach to measuring efficiency by Farrell (1957), which is called the frontier approach, is a comparative measure of efficiency between the obtainable output and the possible maximum output on the production frontier. The possible maximum output of each economic unit is the value estimated from the frontier function. Therefore, if the obtainable output of each economic unit is below the possible maximum output, it means that the production process of an economic unit is inefficient. Farrell (1957) divides efficiency into two features: technical efficiency and allocative efficiency. Technical efficiency is the capacity of an economic unit to increase output as much as possible with limited productive resources, while allocative efficiency is the capacity of an economic unit to use the inputs in the appropriate proportion with the condition of input prices and technology available.

The approach for estimating technical efficiency is divided into two methods: the non-parametric method and the parametric method. Recently, the measurement of productive efficiency with the non-parametric approach has used the Data Envelopment Analysis (DEA) method involving linear programming to calculate the frontier of an economic unit to identify the proportion of inputs with the maximum efficiency, or the proportion of maximum output with the limited inputs. However, the DEA method has several disadvantages such as not defining the error term in the model, and the fact that statistical tools cannot be used in testing the hypotheses on parameters. In measuring efficiency with the parametric approach, it is necessary to estimate the production frontier by using regression analysis. At present, the Stochastic Frontier Analysis (SFA) model presented by Aigner, Lovell, and Schmidt (1977), Battese and Corra (1977), and Meeusen and Van den Broeck (1977) is the most popular approach as it can separate the random errors which are out of control (such as measurement error, statistical noise, and random shock) and remove these from the inefficiency effect. Thus, the results of the inefficiency measurements of this model are more accurate. Because of this, the current research used the SFA method for estimating the inefficiency effect of aging.

The estimation of the SFA model can be used with both cross-sectional and panel data. However, using panel data offers an advantage as the increasing number of observations results in more degrees of freedom. Moreover, it also represents the change in efficiency over time. Analysis using the stochastic frontier model with panel data was first proposed by Pitt and Lee (1981), assuming the technical inefficiency of the time-invariant frontier model. Later, other studies such as those of Cornwell, Schmidt, and Sickles (1990), Kumbhakar (1990), and Battese and Coelli (1992, 1995) changed this assumption giving the technical inefficiency to be the time-variant frontier model which offers better correspondence with reality. For this reason, this study used the SFA model published by Battese and Coelli (1995). This model is a time-varying frontier model for panel data that is popularly applied in agriculture.

Empirical research studies applying the SFA model in estimating the relationship between age and inefficiency in agriculture started from Battese and Coelli (1995). The results of the estimation of the inefficiency effects model revealed that the coefficient of age of the primary decision-maker was positive. This signified that aging farmers have more inefficiency than young farmers. On the contrary, the results of estimation of age coefficients in the inefficiency model of Battese and Broca (1997) and Abdulai and Eberlin (2001) show negative values indicating that young farmers have more inefficiency than aging farmers. From reviewing these studies, it was found that the relationship between age and efficiency is different depending on the study. Moreover, the coefficient of age does not measure the effect of aging directly because it is the average age of the total labor force without separating out the age structure of labor force to be analyzed. Later, Li and Sicular (2013) studied the direct effect of aging on technical inefficiency in Chinese agriculture, using the ratio of the labor force aged 50 years and over as the variable for measuring aging effects in the inefficiency model. Nevertheless, no research has been found on the inefficiency effects of aging on the agricultural sector in Thailand. Thus, this article provides empirical research on this issue.

Methods

Data Collection

The data set contained a panel of 380 observations on 76 provinces in Thailand from 2009 to 2013. The panel data of output, input, and inefficiency factor variables were collected to estimate the translog stochastic frontier production function with the technical inefficiency model. Data of all variables used in the estimation were the provincial averages which are not farm unit observations and thus may not be completely consistent. For that reason, the many datasets may lead to some biases in the estimated results.

All monetary variables consisting of the value of agricultural output, capital, credit, agricultural GPP, and irrigation investment, were converted into real terms with 2010 as the base year using the producer price index (PPI) of agricultural products (Bureau of Trade and Economic Indices, 2017). Definitions, sources, and units of variables used in estimating the SFA models are explained in Table 2.

Data Analysis

This paper estimated the age structure effect of the agricultural labor force on technical efficiency by using stochastic frontier analysis. When defining the production functions for analyzing the stochastic frontier model, it was found that most research popularly defines the stochastic production function in the form of the Cobb-Douglas and the translog functional forms. However, the translog functional form is more flexible insofar as it does not have a priori restrictive constraints like the Cobb-Douglas function with the limit to have the constant return to scale and the

Table 2
Definition, source and unit of variables

Variable	Definition	Source	Unit
Translog stochastic frontier production function			
Y : *Output*	Value of agricultural output, calculated as the sum of the sale of agricultural products (measured in constant 2010 values)	Office of Agricultural Economics (2016)	Baht/household
X_1 : *Capital*	Household expenditure on agricultural production (measured in constant 2010 values) which was used as a proxy for capital	Office of Agricultural Economics (2016)	Baht/household
X_2 : *Labor*	Number of agricultural labor force members aged 15 years and older in the household	Office of Agricultural Economics (2016)	Person/household
X_3 : *Land*	Land use in agriculture	Office of Agricultural Economics (2016)	Hectare/household
X_4 : T	Time-trend		–
Technical inefficiency model			
Z_1 :Non-agricultural income	Ratio of non-agricultural income to the total income of the household	Office of Agricultural Economics (2016)	Percent
Z_2 : Credit	Value of credit that banks provide for agricultural sector (measured in constant 2010 values)	Bank of Thailand (2017)	Millions of baht
Z_3 : Agricultural GPP	Gross provincial product of the agricultural sector (measured in constant 2010 values)	Office of the National Economic Development Board (2017)	Millions of baht
Z_4 : Rainfall	Total rainfall	Meteorological Department (2017)	Millimeter
Z_5 : Irrigation investment$_{t\text{-}4}$	Government spending for irrigation investment includes durable goods, land, and construction costs, with a time lag of 4 years (measured in constant 2010 values)	Bureau of the Budget (2017)	Millions of baht
Z_6 : Training	Proportion of the heads of household who were trained in agricultural vocations	Office of Agricultural Economics (2016)	Percent
Z_7 : Ratio of labor force aged 15–59	Ratio of the number of agricultural labor force members aged 15–59 years to the total number of agricultural labor force members in the household	Office of Agricultural Economics (2016)	Percent
Z_7 : Ratio of labor force aged 60+	Ratio of the number of agricultural labor force members aged 60 years and older to the total number of agricultural labor force members in the household	Office of Agricultural Economics (2016)	Percent
Z_8 : Labor force aged 60+ with capital	Proportion of the number of agricultural labor force members aged 60 years and older to the total number of agricultural labor force members in the household multiplied by capital	Office of Agricultural Economics (2016)	–

elasticity of substitution between inputs always equal to one, which does not correspond with reality whereby inputs do not need to be substituted equally.

In this paper, the production equation in the SFA model was thus imposed using the flexible translog function which is the same pattern as that of Battese and Broca (1997), Chen, Huffman, and Rozelle (2009), Puig-Junoy and Argiles (2004), and Tian and Wan (2000). The translog stochastic frontier production function with three inputs for the panel data can be defined as:

$$\ln(Y_{it}) = \beta_0 + \sum_{j=1}^{4} \beta_j \ln(X_{jit}) + \sum_{j \le k}^{4} \sum_{k=1}^{4} \beta_{jk} \ln(X_{jit}) \ln(X_{kit}) + \varepsilon_{it}, \quad \text{where}$$

$$\varepsilon_{it} = V_{it} - U_{it} \tag{1}$$

where for the i province at time t: Y_{it} is output; β_0 is constant; X_{jit} are the j inputs, with coefficients β_j. ε_{it} is the error term which is divided into two parts, $V_{it}$is the random disturbance term which represents the measurement error, statistical noise, or random shock which are out of control in an economic unit and are assumed to be *iid* $N(0, \sigma_V^2)$, and U_{it} are non-negative random variables which are assumed to account for technical inefficiencies in production that are defined by such economic units and are assumed to be independently distributed as truncation at zero as $N(z_{it}\delta, \sigma^2)$. This study uses the inefficiency effects model proposed by Battese and Coelli (1995) which could be specified as:

$$U_{it} = \delta_0 + \sum_{j=1}^{m} \delta_j Z_{jit} + W_{it} \tag{2}$$

where Z_{jit} are the j factors to explain technical inefficiency in the form of a natural logarithm of the i province at the time t, δ_j are the j parameters required to be estimated, W_{it} is the random variable which is assumed to have a normal distribution as truncated distribution with zero mean and variance equal to σ_w^2.

To estimate the impact of the age structure of agricultural labor on technical efficiency, this paper applied two different SFA models. One was the model which captures the impact of the young age group using “the ratio of the labor force aged 15−59”. Another model utilizes “the ratio of the labor force aged 60 and over” to indicate the impact of an aging labor force.

Other efficiency variables in both models consisted of non-agricultural income, credit, irrigation investment, training, and labor force aged 60+ with capital. Following the existing literature, such as Li and Sicular (2013), if the ratio of income from non-agricultural production is high, agricultural laborers in a household may not have the incentive to improve agricultural production. Credit availability may improve technical efficiency because it increases the chances to purchase high quality inputs such as fertilizers and high yielding seeds, or to invest in machinery and equipment (Abdulai & Eberlin, 2001; Battese & Broca, 1997).

Since an irrigation investment can assist in growing crop and livestock, it may be important to include this variable as part of a policy of how agricultural households may obtain assistance from the government. Likewise, training is an investment in human capital, which may improve farm productivity.

There is an effect of the size of the economy by province on the production pattern of agricultural households. Hence, agricultural GPP was included as a control variable to control for the heterogeneity of output and inputs by province. Similarly, to control for the influential effects of the weather, the model also included rainfall as a control variable to examine a climate effect. In addition, labor force aged 60+ with capital is a composite variable created by multiplying the labor force aged 60+ years and capital to investigate the impact of this combinational input on technical efficiency.

The parameters of the translog stochastic frontier model in Eq. (1) with the inefficiency effects model in Eq. (2) were estimated simultaneously using maximum likelihood methods in the FRONTIER Version 4.1 software package. This software was written by Coelli (1996) to estimate the stochastic frontier function.

Results and Discussion

The estimated results of the impact of age structure on technical efficiency in Thai agriculture have been divided into two models (models 1 and 2), which differ in the specification of the age structure of the agricultural labor force. Model 1 is “young” labor force which was defined as labor force aged 15−59 years. The second model is the “older” labor force which was defined as labor force aged 60 years and older.

Hypotheses Tested

Before explaining the age structure effect of agricultural labor force on technical efficiency, this study proved the tests of hypotheses to confirm the appropriateness of the stochastic frontier and the inefficiency models with the generalized likelihood ratio (LR) test, for which the LR test statistic is specified as:

$$\text{LR} = -2[\text{log likelihood}(\text{H}_0) - \text{log likelihood}(\text{H}_1)] \tag{3}$$

The results of the tests of the hypotheses are shown in Table 3. The first hypothesis is to test for selecting the function appropriate for the stochastic frontier production model for the Thai agricultural sector by considering between the Cobb-Douglas and translog functional forms. The result shows that the likelihood ratios (LR) of the two models were 322.12 and 271.18, respectively, greater than the critical values from the Chi-square(χ^2) table (23.21) at a significance level of .01. It can be summarized that this test strongly rejects H_0 for both models. Therefore the translog functional forms are appropriate for use as the stochastic frontier production function.

The second hypothesis tests whether or not there is a technological change in the model at the time of study. It was found that the null hypothesis is rejected at a

Table 3
Likelihood ratio tests of hypotheses

Null hypothesis		Model 1		Model 2		Result
		LR	α	LR	α	
1.	$H_0 : \beta_{11} = \beta_{12} \ldots \beta_{44} = 0$	322.12	23.21***	271.18	23.21***	Reject H_0
2.	$H_0 : \beta_4 = \beta_{14} = \beta_{24} = \beta_{34} = \beta_{44} = 0$	12.50	11.07**	23.14	15.09***	Reject H_0
3.	$H_0 : \gamma = \delta_0 = \delta_1 \ldots \delta_8 = 0$	565.19	22.53***			Reject H_0
	$H_0 : \gamma = \delta_0 = \delta_1 \ldots \delta_9 = 0$			606.97	24.05***	Reject H_0
4.	$H_0 : \delta_1 = \delta_2 \ldots \delta_8 = 0$	427.81	20.09***			Reject H_0
	$H_0 : \delta_1 = \delta_2 \ldots \delta_9 = 0$			605.10	21.67***	Reject H_0

α denotes the critical values; ***, **, and *represents the critical values at 1%, 5% and 10% significance levels, respectively

significance level of .05 in model 1 and at a significance level of .01 in model 2 to represent the technical change occurring at the time of study and should be input in the production variable for both the models.

The third hypothesis is to test the existence of inefficiency effects. The result of the test showed that LR from the calculation of model 1 was 565.19 greater than the critical value (22.53) from Table 1 of Kodde and Palm (1986, p. 1246) at the significance level of .01. In model 2, the LR test was 606.97 greater than the critical value (24.05) at the significance level of .01. Therefore, H_0 is strongly rejected, indicating that both models have inefficiency effects and the inefficiency models should appear in the SFA models.

Another hypothesis is to test the joint effects of independent variables on the inefficiencies of production in which a constant term (δ_0) is not identified. The result showed that LR gained from the calculation of both models was more than the critical value from the opening Chi-square (χ^2) table at the significance level of .01. Therefore, H_0 is strongly rejected so that at least one of the inefficiency variables is significant.

Estimates of the Model

This paper applies two different SFA models to measure the impact of the age structure of the Thai agricultural labor force on technical efficiency. The first one is the model which captures the impact of the young age group using the ratio of the labor force aged 15–59. The other model utilizes the ratio of the labor force aged 60 and over to indicate the impact of aging. Table 4 presents the estimated results of the SFA model which contains the translog stochastic frontier production function with the technical inefficiency model. The results are similar for both models excluding the age structure variables in the technical inefficiency model. In the translog stochastic frontier production function, it is found that the coefficients of all inputs are significant and have positive effects on agricultural output.

The estimated results of the inefficiency model show that the coefficients of the ratio of non-agricultural income are positive and significant, meaning it is the cause of the rising production inefficiency. This may be because the attractiveness of high non-agricultural income may possibly diminish the attention to agricultural production. On the contrary, credit is the factor to reduce the inefficiency because access to credit may possibly result in the rising of liquidity and increase the capacity for loans for agricultural investment. Other coefficients which consist of agricultural GPP, rainfall, irrigation investment$_{t-4}$, and training are negative and significant. These factors result in decreasing technical inefficiency.

The impact of age structure on technical efficiency is explained by coefficients of the ratios of younger and older people in the labor force. In model 1, the coefficient of the ratio of young labor force is negative and significant. In reverse, in model 2, the ratio of older labor force, which is determined to represent the aging effect, has a positive coefficient. This shows that the aging of the agricultural labor force increases the productive inefficiency in accordance with Li and Sicular (2013), who found that the aging of the labor force has a negative effect on production efficiency in farm households in one province of China. In addition, this study reveals that “labor force aged 60+ with capital” is negative and significant which means that if the older labor force is used as an input with capital, they would transpose from the factor that increases inefficiency to the factor that decreases inefficiency.

This article does not study the reason why the older labor force in the Thai agricultural sector is a factor that leads to inefficiency. However, some previous papers studied this issue by using descriptive statistics. Those studies noted the various factors possibly causing the older farmers to be inefficient. Stloukal (2004) studied the relationship between aging and the abilities of farmers in developing countries. It is found that the older farmers are less healthy. Bryant and Gray (2005) find that farm management shows several differences between older and younger farmers; for example, the use of credit, competence in technology usage, marketing management, etc. Moreover, Li and Sicular (2013) presented the reason that older farmers possibly lack motivation in improving and expanding farm productivity because they can then avoid the difficulty of accessing bank loans, taking on financial risk, and adapting to new technology. There is also the need to retire.

Conclusions and Recommendations

This article estimated the age structure effect of the labor force on technical inefficiency in Thai agricultural production. The results of estimation on the technical inefficiency model indicated that aging of the labor force exacerbates the production efficiency. Additionally, the results indicated that training regarding agricultural vocations is beneficial in improving production efficiency. Consequently, the government sector should be determined to establish policy options to encourage younger

Table 4
Estimates of the translog stochastic frontier production function with the technical inefficiency model

Dependent variable	Parameter	Model 1		Model 2	
		Coeff.	S.E.	Coeff.	S.E.
Translog stochastic frontier production function					
Constant	β_0	0.7542**	0.3666	0.6436**	0.2881
ln(*capital*)	β_1	1.0287***	0.1684	0.1381***	0.1582
ln(*labor*)	β_2	4.4184***	1.2591	0.2305**	1.0591
ln(*land*)	β_3	0.5099*	0.4816	0.6811*	0.5586
T	β_4	0.1988**	0.0866	0.1973***	0.0742
ln(*capital*)^2	β_{11}	0.0119	0.0139	−0.2332	0.0143
ln(*capital*) × ln(*labor*)	β_{12}	−0.4075***	0.1186	−0.2349**	0.1137
ln(*capital*) × ln(*land*)	β_{13}	−0.1273**	0.0534	−0.1051*	0.0616
ln(*capital*) × T	β_{14}	0.0052	0.0097	−0.4272	0.0094
ln(*labor*)^2	β_{22}	−0.1728	0.4201	0.3442	0.3761
ln(*labor*) × ln(*land*)	β_{23}	0.4282*	0.2304	0.1953	0.2216
ln(*labor*) × T	β_{24}	0.0575	0.0458	0.8379	0.0653
ln(*land*)^2	β_{33}	0.1122**	0.0568	0.7376	0.0749
ln(*land*) × T	β_{34}	0.0242	0.0192	0.2016	0.0224
T^2	β_{44}	0.0073*	0.0043	0.1238**	0.0058
Technical inefficiency model					
Constant	δ_0	−0.5524	0.3928	−0.1472*	0.0891
Non-agricultural income	δ_1	0.0166***	0.0006	0.1709***	0.0007
Credit	δ_2	<−0.0001***	<0.0001	−0.4214**	<0.0001
Agricultural GPP	δ_3	<−0.0001***	<0.0001	−0.2358***	<0.0001
Rainfall	δ_4	<−0.0001***	<0.0001	−0.5878***	<0.0001
Irrigation investment$_{t-4}$	δ_5	<−0.0001**	<0.0001	−0.4248*	<0.0001
Training	δ_6	−0.0035**	0.0018	−0.9104*	0.0059
Ratio of labor force aged 15−59	δ_7	−0.0073***	0.0022		
Ratio of labor force aged 60+	δ_7			0.1288***	0.0049
Labor force aged 60+ with capital	δ_8			−0.1509***	<0.0001
T	δ_9	−0.0055***	0.0874	−0.4371***	0.0157
sigma-squared	σ^2	0.0171***	0.0013	0.1629***	0.0017
gamma	γ	0.3916***	0.0430	0.3215**	0.1436
log likelihood function		237.36		258.24	
LR test of the one-sided error		565.19		606.97	

***, **, and * represent significant at 1%, 5% and 10% levels, respectively

entrants into the agricultural sector as well as to foster them to become young, smart farmers, such as by awarding scholarships to people studying agriculture in both colleges and universities, or providing agricultural training and knowledge of operations for young farmers who are interested in precision farming or agribusiness. In addition, consideration should be given to supporting a low interest loan for those who want to invest in agricultural investment, and applying tax incentives, among other options.

The results from the parameter estimation of credit and “labor force aged 60+ with capital” indicated that the public sector should support the use of agricultural mechanization that is easily used by older farmers along with providing financing support so that they can increase production efficiency. Furthermore, investment in irrigation schemes may indirectly moderate the impact of aging on production efficiency.

Conflict of Interest

There is no conflict of interest.

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