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Changing age structure and input substitutability in the Thai agricultural sector

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ABSTRACT

The rapidly aging society and agricultural abandonment by young people in Thailand have changed the age structure of Thai agricultural labor, and influenced the potential for agricultural production. Thus, it is important to study the feasibility of other inputs as a substitute for labor. This paper estimated the degree of elasticity substitution of inputs, particularly young labor, older labor, and physical capital. The elasticity of input substitution was estimated using a nested constant elasticity of substitution (CES) production function and nonlinear regression analysis. Research data were obtained from the annual secondary data of government sources from 1990 to 2013. The findings indicated that the input substitutability of young and older labor was low. However, capital and labor could substitute for each other. Moreover, capital better substituted for young labor than older labor. The results suggested that both the public and private sectors should encourage young people to engage in the agricultural sector, and support investment in farm machinery as a labor substitute.

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Introduction

Agriculture plays a vital role in the Thai economy as the country is a major exporter of agricultural and food products which generate income for farming households and the labor force. However, the Thai agricultural sector is experiencing a change in its workforce age structure. Workers aged over 60 years increased from 4.79 percent in 1989 to 13.50 percent of the total agricultural labor force in 2013 (Table 1). The massive movement of young labor out of the agricultural sector has had a negative impact on agricultural production. However, the impact will depend on the degree of substitution between young and older labor, or on that between agricultural, physical capital and older labor. The impact will be less if young labor or physical capital can be easily substituted for older labor.

The different abilities or production skills between the young and older labor help to explain the degree of substitution. Stloukal (2004) examined previous studies regarding the relationship between aging and agricultural abilities in developing countries. He found that most of the older people had physical deficiencies and poor health. However, they continued working until they were very old, which might be a considerable obstacle to the expansion of agricultural yield or retaining existing production levels.

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Table 1
Age structure of the Thai agricultural labor force, 1989–2013 (%)

Age (years)	1989	1995	2001	2007	2013	Average
15–19	16.90	9.35	5.73	4.36	2.95	7.86
20–29	30.65	25.60	22.27	16.10	16.69	22.26
30–39	22.02	24.45	24.58	22.70	19.18	22.59
40–49	14.73	19.46	22.90	25.89	25.18	21.64
50–59	10.91	14.03	15.65	19.52	22.50	16.52
60 and over	4.79	7.11	8.87	11.42	13.50	9.14
Total	100	100	100	100	100	

Source: Calculated from the labor force survey (National Statistical Office, 2014)

Bryant and Gray (2005) assessed the differences in Thai farming operations between older and younger labor. They also identified the differences in utilization of land, type of production, orientation to the market, use of technology, use of credit market, and income from agriculture. Their results determined that older farmers differed from their younger counterparts in terms of farm mechanization, technological diffusion, crop choice, commercialization, and aggregate output. However, the differences were relatively low.

Previous empirical literature in Thailand focused on comparisons between capacity and the types of farming operation between the young and older labor. However, the estimated degree of input substitutability, particularly between young and older labor, and between physical capital and older labor has rarely been considered. Therefore, this paper attempted to develop an empirical model to estimate the elasticity of substitution of inputs.

Literature Review

Generally, the degree of substitutability between inputs can be measured by utilizing the elasticity of substitution, first presented by Hicks (1932). The elasticity of substitution is an economic tool commonly used to evaluate the substitutability between inputs. It is useful for decision-making on how the producer should increase or decrease the use of each input with existing production technology, when shortages of an input occur or the price changes.

The elasticity of substitution is applied to assess the input substitutability in the case where there are two inputs along an isoquant curve in the production process. An isoquant curve represents the relationship between two inputs of production at the same level of output. The degree of elasticity of substitution can be directly estimated from the production function. Alternatively, it can be measured indirectly from the cost function or the profit function based on duality theory. Nevertheless, this paper studied the aggregation or macro-level of Thai agricultural production, which has a limitation of input price regarding the price of aggregate capital which cannot be defined as a unit cost. Therefore, the estimation of elasticity of substitution from the production function was chosen because it did not require the availability of price data to estimate the function.

Four types of production functions can calculate the Hicks' elasticity of substitution: linear (additive), Leontief (fixed proportion), Cobb-Douglas, and CES (Griffin, Montgomery, & Rister, 1987, pp. 218–219). The degree of elasticity of substitution from estimating the linear function approaching infinity ($\sigma_{ij} \rightarrow +\infty$) implies perfect substitutability. For the fixed proportion (Leontief) function, the substitutability between input pairs is zero or impossible ($\sigma_{ij} \rightarrow 0$). The Cobb-Douglas function imposes that the elasticity of substitution between two inputs always equals one ($\sigma_{ij} = 1$). The CES function has less restrictive substitutability because it is used to allow more flexibility in estimating the elasticity of substitution which can be any value between zero and infinity ($0 \leq \sigma_{ij} \leq \infty$).

In addition to these functions, the translog production function developed by Christensen, Jorgenson, and Lau (1973) is also used to calculate Allen's partial elasticity of substitution (Allen, 1938). The translog production function allows flexibility in estimating the elasticity of substitution similarly to the CES function; moreover, it can include any inputs for which the estimation results for each pair of inputs may have a different elasticity of substitution. However, the estimation of Allen's elasticity is much more complex (Humphrey & Moroney, 1975, p. 70). Therefore, most empirical researchers have transformed this function into a translog cost function (Uzawa, 1962, p. 292), in which price data are needed as an estimating function.

According to the above advantages, the CES function has been extensively applied to examine the issue of substitutability of labor at different ages in macroeconomic modeling such as Guest (2007), Prskawetz and Fent (2007), and Prskawetz, Fent, and Guest (2008). In the case of Thai agriculture, Pisanwanich (2001) used the CES function to estimate the elasticity of substitutability of agricultural products in a computable general equilibrium (CGE) model. Nevertheless, the CES function was not applied to inspect the substitutability of labor at different ages in Thai agriculture.

The idea of the CES function originated with Solow (1956). Later, the general form of CES was extended by Arrow, Chenery, Minhas, and Solow (1961) as a popular instrument for research in the economics field; however it is limited as a constant return to scale. A parameter which allows the function to exist as an increasing or decreasing return to scale was added by Kmenta (1967).

The CES function of Arrow et al. (1961) has a restriction regarding the number of inputs allowing only two inputs or a pair. Thus, the n-input CES production functions with many inputs was proposed by Uzawa (1962) and McFadden (1963). However, the elasticity of substitution of all inputs in this function was equal, which is less useful for empirical research (Sato, 1967, p. 202). Hence, Sato (1967) suggested the two-level nested CES functions for three and four inputs, with different elasticity of substitution of each pair of inputs.

The nested CES function became a popular production function, found in studies by Kemfert (1998), Khan (1989), Koesler and Schymura (2012), Prywes (1986), Shen and Whalley (2013), Su, Zhou, Nakagami, Ren, and Mu (2012), and Wittmann and Yildiz (2013). Due to the reasons mentioned above, the nested CES production function was selected for use in this paper to assess the elasticity of substitution in the Thai agricultural sector.

Methods

Data Collection

To estimate the aggregate agricultural production in Thailand, the annual time-series of output and input data for 24 years from 1990 to 2013 was used. Definitions and sources of data are explained in Table 2.

Data Analysis

A two-level, nested CES production function with three inputs was adopted for quantitative analysis. The model was modified from Sato (1967) by dividing the labor input into two to analyze the problems of a changing age structure and agricultural yield. At the first level, the model specification was derived from the CES function with two inputs—young labor (L_1) and older labor (L_2):

$$L = \delta\left(\delta_1 L_1^{-\alpha_1} + (1-\delta_1)L_2^{-\alpha_1}\right)^{\frac{\beta_1}{\alpha_1}} \quad (1)$$

For the second level, the labor aggregate CES function or the composite L was further combined with the capital (K). Then, the nesting structures of the CES production function with three inputs were defined as $(L_1, L_2)K$.

$$Y = \gamma\left[\delta\left(\delta_1 L_1^{-\alpha_1} + (1-\delta_1)L_2^{-\alpha_1}\right)^{\frac{\beta_1}{\alpha_1}} + (1-\delta)K^{-\beta_1}\right]^{-\frac{\nu}{\beta_1}} \quad (2)$$

Usually estimating a function with time series data requires variables to account for the influence of technological progress. Thus, the Hicks-neutral technological change was added in the model as:

$$Y = \gamma e^{\lambda t}\left[\delta\left(\delta_1 L_1^{-\alpha_1} + (1-\delta_1)L_2^{-\alpha_1}\right)^{\frac{\beta_1}{\alpha_1}} + (1-\delta)K^{-\beta_1}\right]^{-\frac{\nu}{\beta_1}} \quad (3)$$

According to the research objective, the estimation for the degree of elasticity substitution envelops all different input pairs. Theoretically, the elasticity of substitution of a pair of (L_1, K) and a pair of (L_2, K) in Equation (3) is not allowed to differ, that is both L_1 and L_2 substitute equally for K. Then, the other two nesting structures defined as $(L_1, K)L_2$ and $(L_2, K)L_1$ were considered in this empirical estimation as follows:

$$Y = \gamma e^{\lambda t}\left[\delta\left(\delta_1 L_1^{-\alpha_2} + (1-\delta_1)K^{-\alpha_2}\right)^{\frac{\beta_2}{\alpha_2}} + (1-\delta)L_2^{-\beta_2}\right]^{-\frac{\nu}{\beta_2}} \quad (4)$$

$$Y = \gamma e^{\lambda t}\left[\delta\left(\delta_1 L_2^{-\alpha_3} + (1-\delta_1)K^{-\alpha_3}\right)^{\frac{\beta_3}{\alpha_3}} + (1-\delta)L_1^{-\beta_3}\right]^{-\frac{\nu}{\beta_3}} \quad (5)$$

where Y is the agricultural output (GDP value at reference year = 2002, THB million) L_1, L_2 and K are the input variables. L_1 is the number of the young laborers (15–59 years), L_2 is the number of older laborers (60 years and over). K is net capital stock (value at constant 2005 prices, THB million), $\gamma, \lambda, \delta_i, \alpha_i, \beta_i$, and ν are parameters which will be estimated, and γ is an efficiency parameter which reflects the technological change and efficiency level, λ is the rate of technological change, δ and δ_1 are distribution parameter $(0 \le \delta_i \le 1)$, α_i and β_i are substitution parameters $(-1 < \alpha_i, \beta_i < \infty)$ which directly determine the elasticity of substitution (σ_i), and ν is degree of homogeneity parameter which determines returns to scale.

The elasticity of substitution of the nested two-level CES production function with three inputs can be calculated by applying the formula as:

$$\text{First level}: \ \sigma_{\alpha_i} = \frac{1}{1+\alpha_i} \quad (6)$$

$$\text{Second level}: \ \sigma_{\beta_i} = \frac{1}{1+\beta_i} \quad (7)$$

In Equations (6) and (7), σ_α and σ_β are the degree of elasticity of substitution of a pair of inputs on the first and second levels, respectively. If the estimation of σ is negative, a pair of inputs can be implied as complements. Contrarily, if σ is positive, the two inputs are substitutes. The estimated results of σ can be possibly interpreted in five cases (Debertin, 2012, pp. 207–210). If $\sigma = \infty$, then both inputs can be substituted in the fixed proportion. If $\sigma > 1$, then the output can be produced if and only if one of the inputs will be utilized. If $\sigma = 1$, then the CES reduces to be the Cobb-Douglas production function. If $0 < \sigma < 1$, then the inputs can be substituted but not very easily, and if $\sigma = 0$, then there is no substitution between inputs.

The nested CES production functions were estimated using a non-linear estimation method, which relied on the

Table 2
Definitions and sources of variable data variables used in estimating aggregate agricultural production

Variable	Definition	Source
Agricultural GDP	Annual GDP at constant price values (using annual chained volume measures with reference year as 2002) Agricultural GDP composed of 3 sectors (agriculture, hunting, and forestry)	National Income of Thailand, Office of the National Economic and Social Development Board (2015b)
Agricultural labor	Number of employed persons aged 15 and above	Labor Force Survey, National Statistical Office (2014)
Agricultural capital	Net capital stock at 1988 prices	National Income of Thailand, Office of the National Economic and Social Development Board (2015a)

nonlinear optimization algorithm of the PORT routines (Gay, 1990). The R statistical software (package micEconCES) was used as modified to estimate the CES function directly by Henningsen and Henningsen (2011).

Results and Discussion

The empirically estimated results of all three different nested structures of two-level CES production functions for the Thai agricultural sector (Equations (3)–(5)) are shown in Table 3.

In Table 3, all results attained the elasticity of substitution at a satisfactory "goodness of fit" with high R-squared (R^2) values of .9577, .9568, and .9563 for the specifications 1 to 3, respectively. From the overview, the elasticities of every pair of inputs had positive elasticity that was lower than 1. Theoretically, this means that both inputs can substitute for each other. Nevertheless, the elasticity of each pair of inputs was different and could be applied for a comparative interpretation of the substitutability degree for each pair of inputs.

The estimated results highlighted two interesting findings. Firstly, in the first level of nesting function (σ_α), the degree of elasticity of substitution (σ_α) between young and older labor (L_1, L_2) was 0.50. This meant that it could be substituted but the substitution between these two inputs might not be easy. Furthermore, when comparing the ability to substitute between the young labor and the capital (L_1, K), and the substitutability between the older labor with the capital (L_2, K), the results revealed that the elasticity of substitution between the young labor and the capital was 0.64 whereas the substitutability of the older labor and the capital was 0.47. This indicated that young labor could be easily substituted by capital while older labor was hardly substituted by capital compared with younger labor and with labor itself. This may have been the result of certain specific characteristics of the young labor (higher strength and higher productivity) which were more similar to the capital (regarding the definition of capital, this research implied that the capital was agricultural machinery) than the older labor.

The second interesting finding was the substitutability in the second level of nesting function (σ_β). The elasticities of substitution for the specifications 1 to 3 were 0.65, 0.23, and 0.54 respectively. This implied that young and older labor could be easily substituted with capital $[(L_1, L_2)K = 0.65]$ compared with the substitutability between the young labor-capital composite and older labor $[(L_1, K), L_2 = 0.23]$ and the substitutability between the older labor-capital composite and young labor $[(L_2, K)L_1 = 0.54]$. However, the substitutability between the older labor-capital composite and young labor $[(L_2, K)L_1]$ was higher than the young labor-capital composite and older labor $[(L_1, K), L_2]$. This meant that older labor who could adopt and work with capital (machinery) could be easily substituted with young labor.

Table 3
Estimated results of elasticity of substitution (σ) for the Thai agricultural sector

Specification		Input pair	σ	SE	R^2
1	σ_α	L_1, L_2	0.50	0.93	.9577
	σ_β	$(L_1, L_2)K$	0.65	1.71	
2	σ_α	L_1, K	0.64	1.26	.9568
	σ_β	$(L_1, K), L_2$	0.23	0.62	
3	σ_α	L_2, K	0.47	1.45	.9563
	σ_β	$(L_2, K), L_1$	0.54	0.72	

Conclusions and Recommendations

The results determined that the substitutability of young and older labor was low. They indicated that the increasing rate of older labor cannot be replaced by the declining rate of young labor at the same level of output because the potential of the rising proportion of older labor to replace the proportion of young labor was poor. This condition will decrease the production potential of Thai agriculture in the long-term. Thus, both the public sector (such as the Vocational Education Commission and the Office of the Higher Education Commission), and the private sector (agro- and food-industry companies) should provide encouragement and motivation to engage youth into the agricultural sector through support and training courses for youth who wish to start farming.

Regarding the elasticity estimation of substitution between labor and capital, the results demonstrated that capital can better replace young labor than older labor. Moreover, older laborers who could adopt and work with machinery could be easily substituted with young laborers. Hence, to reduce the problem of a young labor shortage, the government should encourage the use of agricultural machinery to substitute for the continuously declining number of young labor by providing some policy options; for example, procurement of funds or interest-free loans to purchase agricultural machinery (under the control of the Bank for Agriculture and Agricultural Cooperatives) and knowledge dissemination on machinery and maintenance (under the control of the Vocational Education Commission).

Conflict of Interest

No conflict of interest.

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