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Substitutability of Skill and Unskilled Labor in Production Structure of Thailand 2001-2014

Kitti Limskul
Thongchart Bowonthumrongchai

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Abstract

The economic sector published by the NESDB **under the** National Account System (UNSNA) in Thailand 2001-2015 is expressed in GDP at market price and GDP at factor cost. The latter is produced from their factor inputs used and substitutability between capital and labor. In a computable general equilibrium or CGE economic modeling, the researcher would like to have reliable parameters in the model construction and simulation exercises. Especially, the 'elasticity of substitution' is such crucial parameters.

In this study, we would like to apply an econometric method to estimate the 'elasticity of substitution' of the economic sector under the national account. We have further refined the possibility of substitution between labor inputs. Dimensions of substitution in our study comprise 'capital-labor factor input'. The labor input is further nested with the dimension of 'Thai national or domestic labor with foreign labor'. The nested labor inputs are further decomposed by the 'skills and unskilled' labor inputs between Thai nationals and foreign labors respectively.

We have applied the functional form of Constant Elasticity of Substitution. The direct estimation has been tried. However, we have followed the 'translog' linearization of our estimation procedure. The estimation results are quite robust and suitable for the CGE model construction.

The result has shown that the overall elasticity of substitution between capital and labor are very normal and closed to the value of 1.00 for most of the sectors. Exceptions are the agriculture sector which has its EOS of 1.153. This implies that capital is flexibly substituted for labor by mechanization process during the period of study (2001-2014) occurred in the agriculture sector. Internal labor movement has flowed out from the sector while more machines were in place to substitute for labor shortage. It might be the case that labor intensive still prevailed and there was not yet need to replace the capital for cheap labor of both unskilled Thai nationals and foreign workers.

It is also clear that substitution between skills and unskilled Thai workers was quite inflexible as we have expected. The elasticity of substitution is much lower than the norm of 1.00. It was still hard to substitute the skills by the unskilled ones when wage of the skills increased during the period.

Finally, the substitutability of Thai workers and foreign workers both the skills and unskilled labor had upper bound of substitutability with the EOS of 0.7 level. This implies a likelihood of a barrier on labor movement across Thai borders. Perhaps, it was owing to the language barrier between the CLMV countries and Thailand.

Keyword: Elasticity of Substitution, Nested Skills and Unskilled labor, National and Foreign Labor

1. The situation of Thai and Foreign Labor Employment in Thailand 2010

The National Statistical Office has launched a special survey on national and foreign labor on top of the Population Census in 2010. It is noted that 39.49 million persons who resided in Thailand are employed in 2010. Among these employed persons, 1.898 million persons are non-Thai nationals (4.8% of total employment). The sectors which have majorly employed foreign labors (both skills and unskilled labor) are manufacturing [1], agriculture [2], wholesale and retail trade, repair of motor vehicles motorcycles [3], construction [4], Accommodation and food service activities [5], and activities of households as employers [6] respectively. The manufacturing industry employed foreign guest labor of 573,764 persons as compared with the Thai employees of 4.565 million persons respectively.

We have reclassified foreign guest labor of 1.898 million persons under the Census 2010 into the national account sector. There are skilled[1] labor altogether 3.5 million persons or 9% of total employment comprising highly skilled workers of 100,714 persons and semi and low skilled workers of 1.79 million persons respectively. The *Mining and Quarrying* sector employed foreign skilled labor (4.46% of total labor employed in this sector). In terms of wage bills, the *Mining and Quarrying* sector has paid 25.73% of total wage bills in this sector. *The Service* sector absorbed foreign skilled labor of 60,533 persons. The *Manufacturing* sector has employed a large number of 'unskilled foreign Labors'. They amount to 553,892 persons or 10.78% of total employed labor in this sector respectively.

Table 1: Employment of Thai National-foreigner Labor in the 2010 Population Census (Unit: Thousand persons)

Industry/activities	Nationals		Total
	Thai	Non-Thai	
(1) Agriculture, forestry and fishing	16,517,021	***354,739[2]***	16,871,760
(2) Mining and Quarrying	32,251	3,231	35,482
(3) Manufacturing	4,565,967	***573,764[1]***	5,139,731
(4) Electricity, gas, steam and air conditioning supply	93,743	1,409	95,152
(5) Water supply; sewerage, waste management, and remediation activities	42,963	1,042	44,005

[1] It is skill labor by 'Occupation'. In our study, we have further filtered them with education level as additional criteria. Detail of classification in Occupation-Education as skills-unskilled labor is shown in section 3 below.

(6) Construction	1,269,562	***123,693[4]***	1,393,255
(7) Wholesale and retail trade, repair of motor vehicles motorcycles	4,456,744	***214,040[3]***	4,670,784
(8) Transportation and storage	744,709	13,958	758,667
(9) Accommodation and food service activities	1,832,314	***109,692[5]***	1,942,006
(10) Information and communication	124,747	1,921	126,668
(11) Financial and insurance activities	355,813	4,097	359,910
(12) Real estate activities	75,223	6,006	81,229
(12) Professional, scientific and technical activities	180,753	5,275	186,028
(13) Administrative and support service activities	233,437	13,980	247,417
(14) Public administration and defense, compulsory social security	1,589,285	7,029	1,596,314
(15) Education	1,086,792	34,794	1,121,586
(16) Human health and social work activities	528,596	6,121	534,717
(17) Arts, entertainment and recreation	119,473	4,364	123,837
(18) Other services activities	1,050,392	35,058	1,085,450
(19) Activities of households as employers; undifferentiated goods and services-producing activities of households for own use	452,061	***89,872[6]***	541,933
(20) Activities of extraterritorial organizations and bodies	1,396	1,887	3,283
(21) Unknown	2,246,055	292,423	2,538,478
Total	37,599,297	**1,898,395**	39,497,692

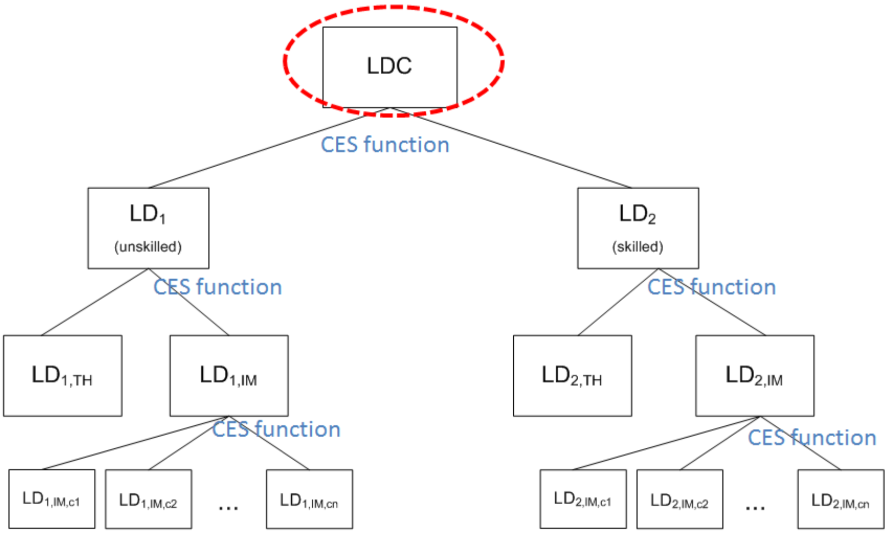
Note: Occupational code classification under ILO, see Table 2 below.
Source: Thailand's National Statistical Office, Population Census, 2010

2. Conceptual Framework of Substitutability between Skill and Unskilled Labor

In the production block, the production of value-added at factor cost (and grosses output) is defined as the nested structure. In the first tier, value-added is produced by utilizing labor and capital inputs. In the second and third tiers, labor utilization is complementary between the skilled and unskilled labor inputs. The substitution is deepened into the labor input requirement who is both Thais and non-Thais as well.

A composite labor demand function (LDC) comprises demand for unskilled labor (LD_1) and skilled labor (LD_2) which would be supplied from the domestic labor pool and foreign labor pool accordingly. At equilibrium, given the profit maximization behavior, an employer would choose to employ between capital and labor at certain substitutability, the degree of which is represented by 'elasticity of substitution'. In the sub-nested level, the employer would choose to hire between two types of labor supply namely skilled labor and unskilled labor at the equilibrium wage ratio to maximize his profit criterion. The relative wage ratio works to allocate between skilled-unskilled labor demand and supply of labor market. It is assumed that at the equilibrium wage employers would rather choose Thai nationals from the pool of Thai labor market first if a necessary condition is met. However, as skilled-unskilled national labor is not fully sufficiently met with his profit criterion he would be forced to acquire the supply of foreign skilled and unskilled labor.

Chart 1: Nested Labor Demand and Employment



The first-tier demand for labor skilled and unskilled labor in any j-th sector is determined by the employer's profit maximization behavior. The 'Constant Elasticity of Substitution (CES), ρ_j^{LD} represents the production flexibility in the structure of labor employed by skill-unskilled types. At any time t-th, composite demand for labor is simultaneously determined as

$$LDC_{j,t} = B_j^{LDC}[\beta_j^{LDC} SLD_{j,t}^{-\rho_j^{LDC}} + (1-\beta_j^{VA}) ULD_{j,t}^{-\rho_j^{LDC}}]^{-\frac{1}{-\rho_j^{LDC}}}$$

Where $SLD_{j,t}$ is skilled labor demand of industry j-th ; $ULD\ j,t$ is unskilled labor demand of industry j-th ; B_j^{LDC} is efficiency parameter of composite demand for labor and β_j^{LDC} is distribution parameter of demand for labor and ρ_j^{LDC} elasticity of substitution between skilled and unskilled labor respectively. The necessary condition for profit maximization criterion of employer simultaneously determined by

$$SLD_{j,t} = \left[\frac{\beta_j^{LDC}}{(1-\beta_j^{LDC})}\frac{WULD_{j,t}}{WSLD_{j,t}}\right]^{\sigma_j^{LDC}} ULD_{j,t}$$

Where $WULD_{j,t}$ is the wage rate of unskilled labor in industry j-th ; $WSLD_{j,t}$ is the wage rate of skilled labor in industry j-th and σ_j^{LDC} is the 'Elasticity of substitution' between skilled-unskilled labor inputs ; $0 < \sigma_j^{LDC} < \infty$ in the composite labor demand function.

Second-tier labor demand and employment between Thai nationals and foreign labor is determined in the same fashion as above but now skilled labor employment is chosen between Thai national vis-à-vis foreign guest laborers. Likewise, the employer will choose unskilled Thai national vis-à-vis foreign guest labor upon the wage ratio between the pair. At equilibrium, the employment of skilled (l=2) and unskilled (l=1) laborers who are labor Thai (TH) as well as foreign guest labor (IM) is determined after each respective wage rate adjustment until the demand balance with supply (excess demand=0).

$$LD1_{j,t} = \alpha_j^{LD1}\,[\textstyle\sum_l B_{country,j}^{LD1}\, LD1_{country,j,t}^{-\rho_j^{LD1}}]^{-\frac{1}{\rho_j^{LD1}}}$$

$$LD1_{country,j,t} = [\frac{B_{country,j}^{LD1} WC_{j,t}}{WTI_{country,j,t}}]^{\sigma_j^{LD1}} (B_j^{LD1})^{\sigma_j^{LD1}-1} LD1_{j,t}$$

Country set comprises TH= Thai national and IM= migrant or guest labor

$$LD2_{j,t} = \alpha_j^{LD2}\,[\sum_l B_{country,j}^{LD2}\, LD2_{country,j,t}^{-\rho_j^{LD2}}]^{-\frac{1}{\rho_j^{LD2}}}$$

$$LD2_{country,j,t} = [\frac{B_{country,j}^{LD2} WC_{j,t}}{WTI_{country,j,t}}]^{\sigma_j^{LD2}} (B_j^{LD2})^{\sigma_j^{LD2}-1} LD2_{j,t}$$

Country set comprises TH= Thai national and IM= migrant or guest labor

3. Mathematical Model

3.1 Production Function with Factor Inputs' Substitution

In this section, we would like to estimate the elasticity of substitution parameters applying the studies by Kmenta (1964) and related studies[2]**.** Kmenta has suggested an

[2] (1) Kamenta, J., (1964), "On Estimation of the CES Production Function," Social System Research Institute, University of Wisconsin, Paper No.6410, See also https://cran.r-project.org/web/packages/micEconCES/vignettes/CES.pdf
(2) Henningsen A. and Henningsen G, (2011), "Econometric Estimation of the "Constant Elasticity of Substitution" Function in R: Package micEconCES," IFRO Working Paper 2011/9, University of Copenhagen, Department of Food and Resource Economics.

application of first-order Taylor series approximation of the traditional two-input CES function:

$$y = \gamma e^{\lambda t}(\delta x_1^{-\rho} + (1-\delta)x_2^{-\rho})^{-\frac{\upsilon}{\rho}} \quad (1)$$

where : Output Quantity; x_1: Input Quantities type 1; x_2: Input Quantities type 2; $\gamma, \delta, \upsilon, \rho$: Parameters which $\sigma = 1/(1+\rho)$ is the elasticity of substitution.

In the logarithmic form the CES function is:

$$\ln(y) = \ln(\gamma) + \lambda t - \frac{\upsilon}{\rho} ln(\delta x_1^{-\rho} + (1-\delta)x_2^{-\rho}) \quad (2)$$

Define a function

$$f(\rho) = -\frac{\upsilon}{\rho} ln(\delta x_1^{-\rho} + (1-\delta)x_2^{-\rho}) \quad (3)$$

So that

$$\ln(y) = \ln(\gamma) + \lambda t + f(\rho) \quad (4)$$

Now we can approximate the logarithm of the CES function by a first-order Taylor series approximation around ρ = 0:

$$\ln(y) \approx \ln(\gamma) + \lambda t + f(0) + \rho f'(0) \quad (5)$$

We define a function

$$g(\rho) \equiv \delta x_1^{-\rho} + (1-\delta)x_2^{-\rho} \quad (6)$$

So that

$$f(\rho) = -\frac{\upsilon}{\rho}\ln(g(\rho)) \quad (7)$$

Now we can calculate the first partial derivative of $f(\rho)$

$$f'(\rho) = \frac{\upsilon}{\rho^2}\ln\big(g(\rho)\big) - \frac{\upsilon}{\rho}\frac{g'(\rho)}{g(\rho)} \quad (8)$$

And the derivatives of $g(\rho)$ in higher-order

$$g'(\rho) \equiv -\delta x_1^{-\rho}\ln(x_1) - (1-\delta)x_2^{-\rho}\ln(x_2) \quad (9)$$

$$g''(\rho) \equiv \delta x_1^{-\rho}\ln(x_1)^2 + (1-\delta)x_2^{-\rho}\ln(x_2)^2 \quad (10)$$

$$g'''(\rho) \equiv -\delta x_1^{-\rho}\ln(x_1)^3 - (1-\delta)x_2^{-\rho}\ln(x_2)^3 \quad (11)$$

At the point of approximation ρ = 0, we have

$$g(0) = 1 \quad (12)$$

Now we calculate the limit of $f(\rho)$ as ρ → 0:

$$f(0) = \lim_{\rho\to 0} f(\rho) \quad (13)$$

$$= \lim_{\rho\to 0}\frac{-\upsilon\ln(g(\rho))}{\rho} \quad (14)$$

$$= \lim_{\rho\to 0}\frac{-\upsilon\frac{g'(\rho)}{g(\rho)}}{1} \quad (15)$$

$$= \upsilon(\delta\ln(x_1) + (1-\delta)\ln(x_2)) \quad (16)$$

And the limit of $f'(\rho)$ as $\rho \to 0$:

$$f'(0) = \lim_{\rho \to 0} f'(\rho) \quad (17)$$

$$= \lim_{\rho \to 0} \left(\frac{v}{\rho^2} \ln\big(g(\rho)\big) - \frac{v}{\rho} \frac{g'(\rho)}{g(\rho)}\right) \quad (18)$$

$$= \lim_{\rho \to 0} \frac{v \ln\big(g(\rho)\big) - v\rho \frac{g'(\rho)}{g(\rho)})}{\rho^2} \quad (19)$$

$$= \lim_{\rho \to 0} \frac{v\frac{g'(\rho)}{g(\rho)} - v\frac{g'(\rho)}{g(\rho)}) - v\rho \frac{g''(\rho)g(\rho) - (g'(\rho))^2}{g(\rho)^2}}{2\rho} \quad (20)$$

$$= \lim_{\rho \to 0} -\frac{v}{2} \frac{g''(\rho)g(\rho) - (g'(\rho))^2}{g(\rho)^2} \quad (21)$$

$$= -\frac{v}{2} \frac{g''(0)g(0) - (g'(0))^2}{g(0)^2} \quad (22)$$

$$= -\frac{v}{2}(\delta(\ln(x_1))^2 + (1-\delta)(\ln(x_2))^2 - (-\delta \ln(x_1) - (1-\delta)\ln(x_2))^2 \quad (23)$$

$$= -\frac{v}{2}(\delta(\ln(x_1))^2 + (1-\delta)(\ln(x_2))^2 - \delta^2 \ln(x_1)^2 - 2\delta(1-\delta)\ln(x_1)\ln(x_2) - (1-\delta)^2 \ln(x_2)^2) \quad (24)$$

$$= -\frac{v}{2}\begin{bmatrix} (\delta - \delta^2)\ln(x_1)^2 + \big((1-\delta) - (1-\delta)^2\big)\ln(x_2)^2 \\ -2\delta(1-\delta)\ln(x_1)\ln(x_2) \end{bmatrix} \quad (25)$$

$$= -\frac{v}{2}\begin{bmatrix} \delta(1-\delta)\ln(x_1)^2 + (1-\delta)\big(1-(1-\delta)\big)\ln(x_2)^2 \\ -2\delta(1-\delta)\ln(x_1)\ln(x_2) \end{bmatrix} \quad (26)$$

$$= -\frac{v\delta(1-\delta)}{2}[\ln(x_1)^2 - 2\ln(x_1)\ln(x_2) + + \ln(x_2)^2] \quad (27)$$

$$= -\frac{v\delta(1-\delta)}{2}[(\ln(x_1) - \ln(x_2)]^2 \quad (28)$$

We obtain the first-order Taylor series approximation around ρ = 0:
Following (6)

$$\ln(y) \approx \ln(\gamma) + \lambda t + v\delta \ln(x_1) + v(1-\delta)\ln(x_2) - \frac{v\rho}{2}\delta(1-\delta)(\ln(x_1) - \ln(x_2))^2$$

The Kmenta's approximation can also be written as a restricted 'translog' function[3], following (7) and where the two restrictions, following (8) are

$$\ln(y) = \alpha_0 + \alpha_1 \ln(x_1) + \alpha_2 \ln(x_2) + \frac{1}{2}\beta_{11}(\ln(x_1))^2 + \frac{1}{2}\beta_{22}(\ln(x_2))^2 + \beta_{12}\ln(x_1)\ln(x_2)$$

$$\beta_{12} = -\beta_{11} = -\beta_{22}$$

[3] Hoff. A (2004), "The Linear Approximation of the CES Function with n Input Variables," Marine Resource Economics, 19, 295-306.

If constant returns to scale are to be imposed, a third restriction $\alpha_1 + \alpha_2 = 1$, following (9). The parameters of the CES function can be calculated from the parameters of the restricted 'translog' function by:

$\gamma = \exp(\alpha_0$, following (10); $\upsilon = \alpha_1 + \alpha_2$ following (11)
$\delta = \frac{\alpha_1}{\alpha_1+\alpha_2}$, following (12);
and $\rho = \frac{\beta_{12}(\alpha_1+\alpha_2)}{\alpha_1\alpha_2}$ following (13) respectively.

The parameters above may be estimated by 'Restricted Least Square' techniques. In our study, we have relied on various econometric model estimations.

3.2 Data on Employment of Skill and Unskilled Labor in Thailand

3.2.1 Classification of Employed Labor by Occupations

The ILO defined skilled and unskilled labor by occupation as follows[4]: Managers and professionals occupation would be defined as skilled labor while technicians, clerical support workers, services and sales workers, skilled agricultural, forestry and fishery workers, craft and related trades workers, and plant and machine operators and assemblers would be defined as semi-skilled labor respectively. The rest of the occupation would be defined as unskilled labor.

Table 2: International Labor Organization's Definition of Skill and Unskilled labor.

Occupation	ILO's Definition	This study
1. Managers	skilled	skilled
2. Professionals	skilled	skilled
3. Technicians and associate professionals	skilled	skilled
4. Clerical support workers	Semi-skilled	unskilled
5. Service and sales workers	Semi-skilled	unskilled
6. Skilled agricultural, forestry and fishery workers	Semi-skilled	unskilled
7. Craft and related trades workers	Semi-skilled	unskilled
8. Plant and machine operators and assemblers	Semi-skilled	unskilled
9. Elementary occupations	unskilled	unskilled
10. Workers not classifiable by occupation	-	unskilled

Source: International Labor Organization

In our study, we have compiled data from the Labor Force Survey (LFS) conducted by the National Statistical Office, the government of Thailand, 2001-2515 in our estimation.

[4] http://www.ilo.org/wcmsp5/groups/public/documents/publication/wcms_172572.pdf

We have tabulated employment data by sector according to ‘occupation-*education’* relationships below. We intentionally shrink the dimension of skills to be only '*Skill vs. Unskilled*’ following the OECD. We have carefully aggregate employment by sector according to their sector codes. It has changed over time according to NSO's working definition in their field survey.

Table 3: Sector Classification and Aggregation Coding in Current Study.

Sector Classification		Aggregation coding	
	Notation	**Previous**	**Current**
1. Agriculture, forestry, and fishing	AGR	01-03	01-05
2. Mining and Quarrying	MIN	05-09	10-14
3. Manufacturing	MANU	10-33	15-37
4. Public Utilities	PUB	35-39	40-41
5. Construction	CONS	41-43	45
6. Wholesale and retail trade, repair of motor vehicles motorcycles	TRADE	45-47	50-52
7. Transportation and storage	TRANS	49-53	60-64
8. Service	SER	55-96	55,65-93
Unknown	OTH	97-99	95-99

Source: NSO, LFS 2001-2015

Table 4: Nomination of Skill and Unskilled Labor by Occupational Classification

No.	**Occupation Classification**	**Nomination**
1	Managers	Skilled
2	Professionals	Skilled
3	Technicians and associate professionals	Skilled
4	Clerical support workers	unskilled
5	Service and sales workers	unskilled
6	Skilled agricultural, forestry and fishery workers	unskilled
7	Craft and related trades workers	unskilled
8	Plant and machine operators and assemblers	unskilled
9	Elementary occupations	unskilled
10	Workers not classifiable by occupation	unskilled

Note: This study adapted from ILO concerning the objective of the model

Table 5: Nomination of Human Capital Intensity by Education Investment Level

No.	Education Classification	Human Capital Investment intensity
1	None	Low intensity
2	Less than elementary	Low intensity
3	Primary education	Low intensity
4	Lower secondary education	Low intensity
5	Upper Secondary level education -General/Academic	Moderate
6	Upper Secondary level education -Vocational	Moderate
7	Upper Secondary level education - Teacher Training	Moderate
8	Post-secondary education -General/Academic	Moderate
9	Post-secondary education -Vocational	Moderate
10	Post-secondary education- Teacher Training	Moderate
11	Bachelor degree education-Academic	Highly intensive
12	Bachelor degree in education-Higher Technical Education	Highly intensive
13	Bachelor degree in education-Teacher Training	Highly intensive
14	Master degree level	Highly intensive
15	Doctoral degree level	Highly intensive
16	Other education	Not classified
17	Unknown education	Not classified

Table 6: Skill – Unskilled Labor Matching Criteria in This study

Occupation	Human capital Investment intensity	Skill Classification
1. Managers	Occupational dominant.	Skilled
2. Professionals Technicians and associate professionals	Occupation dominant	Skilled
3.1 Clerical support workers	Moderate	Skilled
3.2 Clerical support workers	Low intensity	unskilled
4.1 Service and sales workers	Moderate	Skilled
4.2 Service and sales workers	Low – intensity	unskilled
5.1 Skilled agricultural, forestry and fishery workers	Moderate	Skilled
5.2 Skilled agricultural, forestry and fishery workers	Low – intensity	unskilled
6.1 Craft and related trades workers	Moderate	Skilled
6.2 Craft and related trades workers	Low – intensity	unskilled
7.1 Plant and machine operators and assemblers	Moderate	Skilled

7.2 Plant and machine operators and assemblers	Low – intensity	unskilled
8.1 Elementary occupations Workers	Moderate	Skilled
8.2 Elementary occupations	Low - intensity	unskilled
9. Workers not classifiable by occupation	(assumed)	unskilled
10. Unknown	(assumed)	unskilled

Note: Skilled Matching Criterion by Occupation by Human capital Investment

In our study, we would like to match the skilled-unskilled Thai and foreign labor with the average wage of Thai national from the LFS 2010. Besides, we obtain wage of foreign labor from the publication of international human resource consultant Adecco (2015)[5] to arrive at the foreign labor wage rate.

Table 7: Average wage by the occupation of the Thai National

	The average wage (Baht/month/person)
Managers	30,513.51
Professionals	27,829.38
Technicians and associate professional	21,092.06
Clerical support workers	16,171.75
Service and sales workers	10,164.60
Skilled agricultural, forestry and fishery workers	9,262.37
Craft and related trades workers	9,191.38
Plant and machine operators and assemblers	11,078.49
Elementary occupations	8,646.32

Note: Labor categories which are not classified by occupation or 'Unknown' occupations are assumed to have equal average wage rate as those of the elementary occupations
Source: LFS, 2010.

Table 8: Foreign Skilled Labor Employed in Japanese Enterprise in Thailand 2015

	The average wage (Baht/month/person)
Managers	150,000
Professionals	100,000
Technicians and associate professional	90,000

Source: Adecco (2015), report on Japanese expatriate salary in Thailand

[5] Adecco (2015), Thailand Salary Guide 2015

We have relied on Adecco's report in 2015 on a salary of Japanese expatriate in Thailand to represent the foreign skilled labor. Also, we have relied on the TDRI's survey for foreign unskilled labor who is working in Thailand. Here, TDRI has reported a wage differential between Thai and foreign unskilled workers.

Table 9: Daily Wage differential between Thai-Foreign Unskilled Labor

	Daily Wage rate of Foreign Workers	**% Wage Differential**	**Daily Wage rate of Thai Workers**
fishery	230	14	262
related to fishery	216	15.74	250
Agriculture (crop)	162	19.96	194
Livestock (animal farming)	195	15.74	226
Rice mill	161	19.96	193
Brick factories	156	19.96	187
Ice Factory	168	19.96	202
Water Transportation	174	19.96	209
Construction	200	19.96	240
Mining/quarrying	163	19.96	196
In the house service	174	19.96	209

Source: TDRI

The wage differential by sector (approximation) will be used as a reference in the calibration of the average wage of the unskilled foreign worker by occupation. We have calibrated this wage rate simultaneously with wage bill as control total of aggregation according to the SAM (or IO) production sectoral value-added that corresponded with occupational wage. That is the Wage bill $=\sum_{l=1}^{n} W_l L_l$. Finally, we have calibrated the employed labor by skill type in each economic sector.

Table 10: Percentage Composition of Thai-Foreign Labor Employed by Economic Sector

	National Skill Labor	**Foreign skill Labor**	**National Unskilled Labor**	**Foreign Unskilled Labor**	**Total**
Agriculture, forestry, and fishing	0.53%	0.02%	97.32%	2.13%	**100.00%**
Mining and Quarrying	22.98%	25.73%	48.92%	2.37%	**100.00%**
Manufacturing	17.49%	4.14%	70.68%	7.68%	**100.00%**
Public Utilities	47.85%	3.52%	47.99%	0.64%	**100.00%**
Construction	26.43%	4.35%	63.67%	5.55%	**100.00%**
Wholesale and retail trade, repair of motor vehicles motorcycles	9.95%	1.97%	85.06%	3.02%	**100.00%**
Transportation and storage	14.25%	2.58%	82.00%	1.17%	**100.00%**
Service	44.59%	4.52%	48.95%	1.94%	**100.00%**
Unknown	7.21%	1.05%	82.95%	8.79%	**100.00%**

Source: Calculated in this study

Table 11: Sector Wage bill of Thai-Foreign Labor Employed (Billion Baht)

	National Skill Labor	Foreign Skill Labor	National Unskilled Labor	Foreign Unskilled Labor
Agriculture, forestry, and fishing	1.66	0.06	302.03	6.61
Mining and Quarrying	17.25	19.32	36.72	1.78
Manufacturing	145.23	34.39	586.81	63.79
Public Utilities	64.84	4.77	65.04	0.86
Construction	17.86	2.94	43.03	3.75
Wholesale and retail trade, repair of motor vehicles motorcycles	49.36	9.76	422.19	15.01
Transportation and storage	32.20	5.84	185.32	2.65
Service	605.14	61.41	664.31	26.30
Unknown	0.35	0.05	4.04	0.43

Table12: Thai-Foreign Employed Labor by Skills (Persons)

	National Skill Labor	Foreign Skill Labor	National Unskilled Labor	Foreign Unskilled Labor	Total
Agriculture, forestry and fishing	31,611	261	16,485,412	354,477	**16,871,761**
Mining and Quarrying	5,246	1,584	27,004	1,645	**35,479**
Manufacturing	400,474	19,873	4,165,493	553,892	**5,139,732**
Public Utilities	42,158	784	94,549	1,668	**139,159**
Construction	165,037	6,468	1,104,525	117,225	**1,393,255**
Wholesale and retail trade, repair of motor vehicles motorcycles	269,200	11,107	4,187,545	202,933	**4,670,785**
Transportation and storage	48,688	2,105	696,021	11,852	**758,666**
Service	2,426,102	60,533	5,204,183	259,562	**7,950,380**
Unknown	65,137	1,999	2,180,919	290,425	**2,538,480**
Total					**39,497,697**

Table13: Thai-Foreign Employed Labor by Skills (in percentage)

	National Skill Labor	Foreign Skill Labor	National Unskilled Labor	Foreign Unskilled Labor	Total
Agriculture, forestry and fishing	0.19%	0.00%	97.71%	2.10%	**100.00%**
Mining and Quarrying	14.79%	4.46%	76.11%	4.64%	**100.00%**
Manufacturing	7.79%	0.39%	81.04%	10.78%	**100.00%**
Public Utilities	30.29%	0.56%	67.94%	1.20%	**100.00%**
Construction	11.85%	0.46%	79.28%	8.41%	**100.00%**
Wholesale and retail trade, repair of motor vehicles motorcycles	5.76%	0.24%	89.65%	4.34%	**100.00%**
Transportation and	6.42%	0.28%	91.74%	1.56%	**100.00%**

	National Skill Labor	Foreign Skill Labor	National Unskilled Labor	Foreign Unskilled Labor	Total
storage					
Service	30.52%	0.76%	65.46%	3.26%	**100.00%**
Unknown	2.57%	0.08%	85.91%	11.44%	**100.00%**

Source: NSO's Population Census 2010 with adjustment.

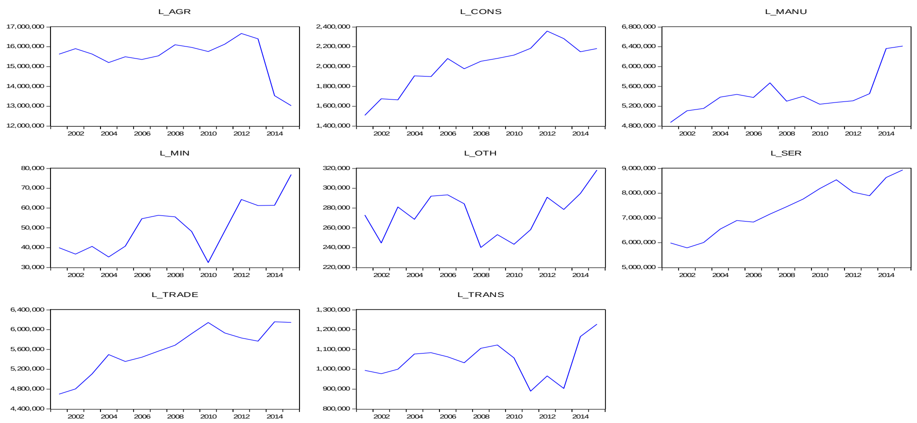
We have tabulated the skill-unskilled labor by 'occupation-education' data from the LFS according to our definition above to apply in our estimation. The 'Labor Force Survey' in Thailand has classified 'wage earner' and 'non-wage earner' in the database. The total employed labor (see graph below) in the agricultural sector has declined drastically as a result of declining numbers of wage earners since 2006. This may be a result of the rising average wage of unskilled wage-earners overtime since 2006 has induced a capital-labor substitution away from labor usage in the sector, if not introduce the usage of foreign migrants in the sector.

Perhaps, labor who are non-wage earners, mostly self-employed laborers later has responded and induce a decline in total employment in agriculture after 2013-2014.

We have observed overall increases in the average wage of both skilled and unskilled wage earners in all sectors. Despite, wage growth in Thailand recently, employment has increased satisfactorily until 2014. The growth of demand for labor has been owing to the economic growth of both domestic demand and export demand respectively. During, the last decades, Thailand has enjoyed steady growth from a stable government and balanced growth policy between domestic demand and export-led growth.

The rapid growth of aggregate demand has not been proportionately balanced from the aggregate supply. Especially, the insufficient infrastructure development and delay in investment in new technology have callused a delay in capital intensive away labor-intensive technology in the manufacturing sector during the last decades.

Chart 2: Total Number of Employed Persons by National Account Sector Retrieved from the LFS 2001-2014 (in persons)



Total Employed Labor by National Account Sector 2001 2015
(in persons of skilled and unskilled, both wage and non-wage earners)

Chart 3: Number of Skill Wage Earners by National Account Sector Retrieved from the LFS 2001-2014 (in persons)

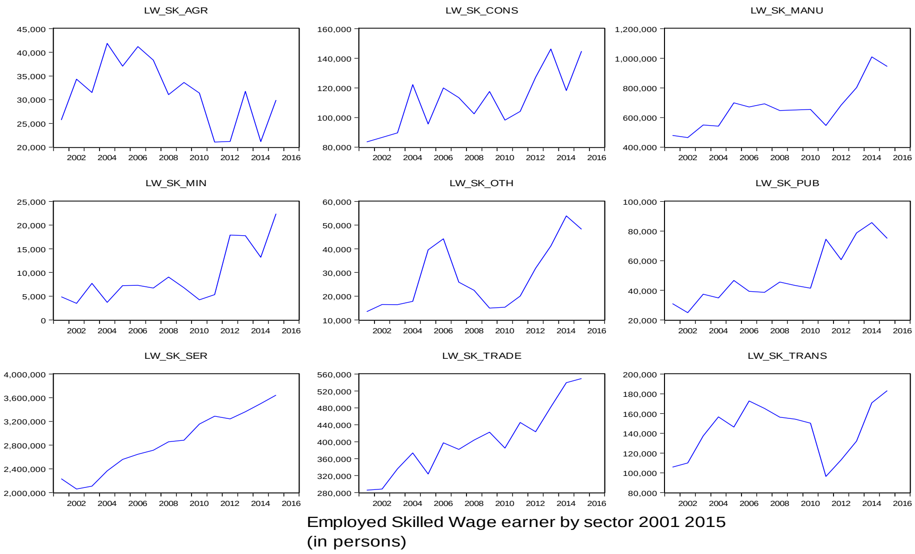


Chart 4: Number of Unskilled Wage Earner by National Account Sector Retrieved from the LFS 2001-2014 (in persons)

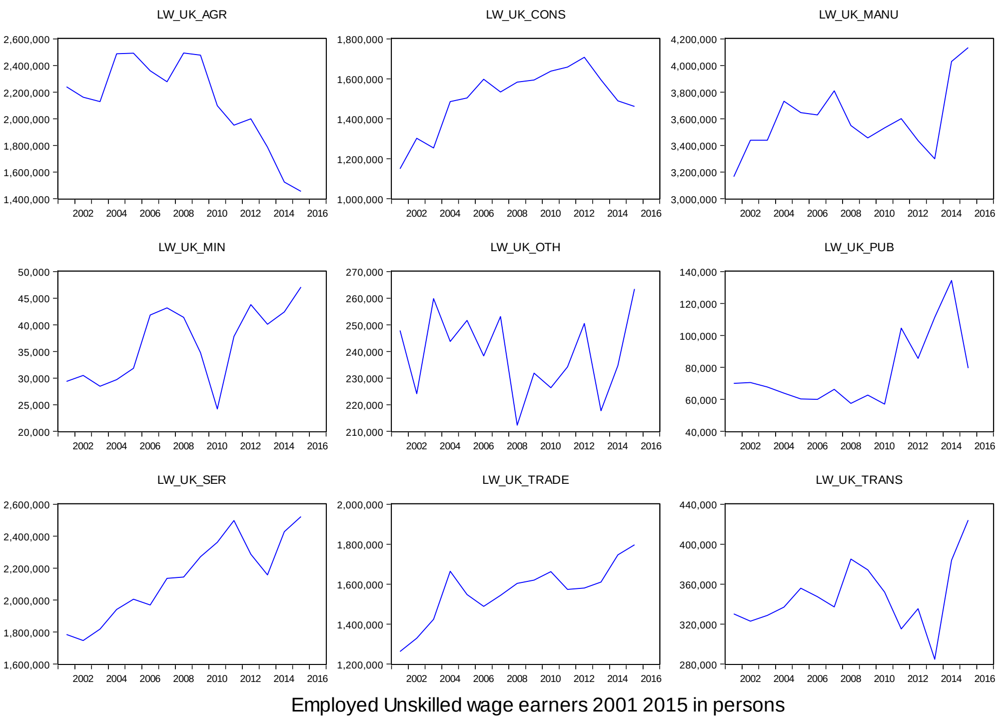
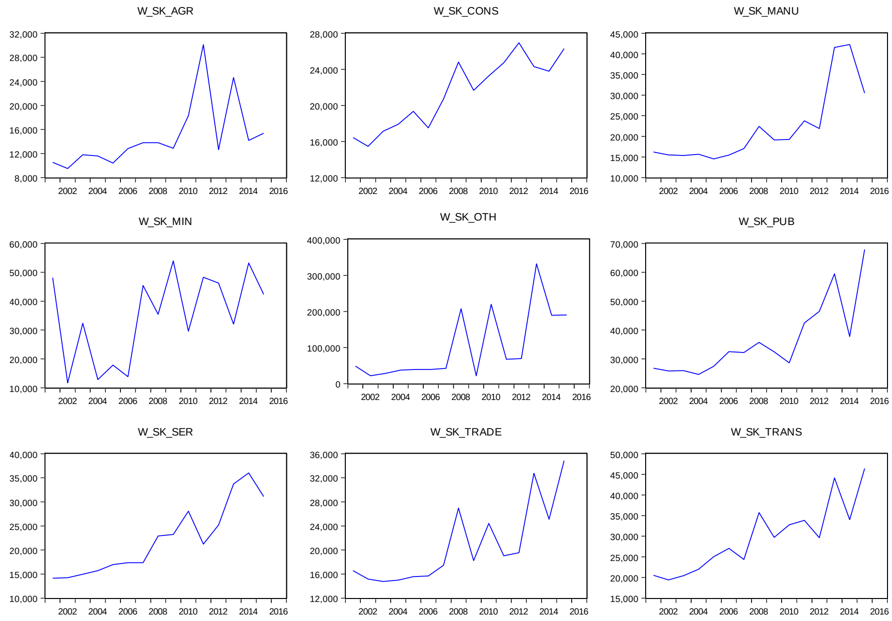


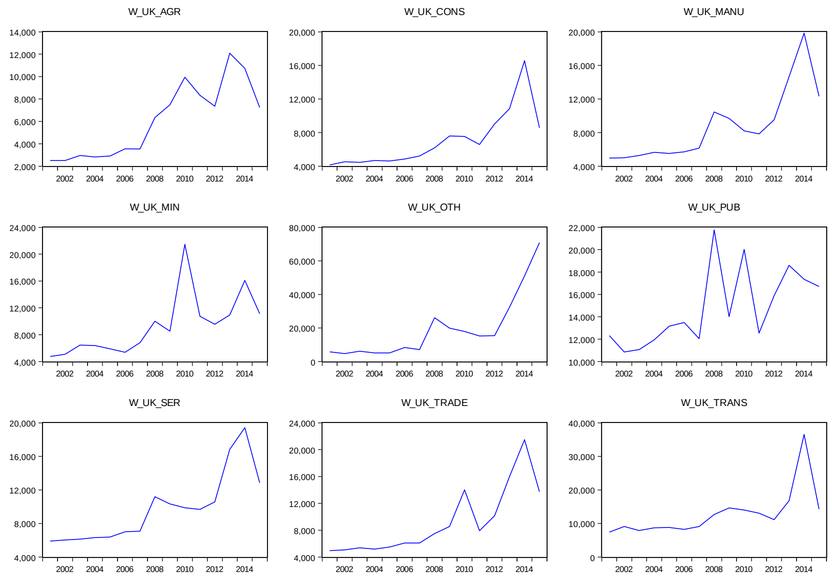
Chart 5: Average Wage of Skill Wage Earner by National Account Sector Retrieved from the LFS 2001-2014 (baht per month)



Average Wage of Skilled Labor 2001 2015
(in baht per month)

Note: imputed from skilled w age earnersl

Chart 6: Average Wage of Unskilled Wage Earner by National Account Sector Retrieved from the LFS 2001-2014 (baht per month)



Average Wage of Unskilled Labor (imputed from wage earners)
2001 2015 (in baht per month)

4. Estimation Results

The demand for skilled-unskilled Thai nationals and foreign labor is induced demand. Firms would maximize profit by choosing between inputs in certain combinations. In other words, if any input price increases, the firm would try to substitute for the cheaper inputs to sustain the attainable highest profit level. In our study, we assume that firms combine two primary inputs namely 'capital services and labor inputs' under given production technology to produce 'value added at factor cost'. In our analysis, we have compiled the capital stock data from the 'National Accounts Statistics' published by the National Economic and Social Development Board, the Thai government. The complied time series data of capital stock is corresponding with employment data (the equilibrium between demand and supply for labor) by the economic sector 2001- 2015. Three variables on value added at factor cost, net capital stock at a constant price, and employed labor would be used in our econometric model estimation.

The estimated form of production in our study is assumed to follow the CES (Constant Elasticity of Substitution between Capital and Labor) technology, assuming a 'Tanslog' functional form proposed by Kamenta (1964) and Henningsen A. and Henningsen G, (2011), mentioned earlier. The estimation results are as follows:

Table 14: Estimation Result of Production Structure and EOS by Sector, Thailand

	α_0	α_1	α_2	β_{12}	ρ	σ	R^2	D.W.
Agriculture	-524.65	29.50	82.95	-2.90	-0.13	**1.153**	0.957	2.43
Mining and Quarrying	-225.95	34.91	4.69	-0.37	-0.09	**1.098**	0.991	2.49
Manufacturing	-427.53	14.26	77.56	-0.94	-0.08	**1.085**	0.962	2.89
Public Utilities	611.25	61.79	8.15	1.89	0.26	**0.792**	0.990	2.79
Construction	-1.17	-13.44	26.39	-0.13	0.00	**0.995**	0.978	2.60
Wholesale and retail trade	-984.46	152.20	-25.02	-4.58	0.15	**0.867**	0.986	2.70
Transportation and Communication	242.96	-43.71	28.56	-2.57	-0.03	**1.032**	0.987	1.72
Services	-1,898.91	359.82	-221.82	21.74	-0.04	**1.039**	0.995	1.36

Note: 1) $\ln(VA_i) = \alpha_0 + \alpha_1 \ln(K_i) + \alpha_2 \ln(L_i) + \frac{1}{2}\beta_{11}(\ln(K_i))^2 + \frac{1}{2}\beta_{22}(\ln(L_i))^2 + \beta_{12}\ln(K_i)\ln(L_i)$. Where restriction is $\beta_{12} = -\beta_{11} = -\beta_{22}$ $\rho = \frac{\beta_{12}(\alpha_1+\alpha_2)}{\alpha_1\alpha_2}$; Finally $\sigma = \frac{1}{1+\rho}$ is the elasticity of substitution (EOS).

Source of data: Applying the capital stock series from the National account's statistics, published by the NESDB, (various issues), the Thai government. Labor and employment by the National account sector are compiled from the Labor Force Survey (various issues) of the NSO.

Table 15: Estimation result of Substitutability between Skill and Unskilled Thai Labor by National Account Sector

	α_0	α_1	α_2	β_{11}	ρ	σ	R^2	D.W.
Agriculture	0.255	0.100	0.900	0.020	0.227	**0.815**	0.99	1.95
Mining and Quarrying	0.659	0.431	0.570	0.164	0.667	**0.600**	0.99	2.32
Manufacturing	0.620	0.379	0.621	0.132	0.560	**0.641**	0.99	2.11
Public Utilities	0.692	0.492	0.508	0.227	0.909	**0.524**	0.99	1.68
Construction	0.608	0.364	0.636	0.123	0.532	**0.653**	0.99	2.20
Wholesale and retail trade	0.649	0.427	0.574	0.162	0.664	**0.601**	0.99	2.25
Transportation and Communication	0.635	0.393	0.607	0.140	0.588	**0.630**	0.99	0.84
Services	0.693	0.500	0.500	0.249	0.994	**0.501**	0.99	2.34
Unclassified	0.658	0.313	0.680	0.095	0.443	**0.693**	0.99	2.44

Note: We apply the 'Translog' functional form to estimate the EOS of skill (L_SK) and unskilled (L_UK) labor with Thai Nationals by sector of production.

$\ln(L_i) = \alpha_0 + \alpha_1 \ln(L\_SK_i) + \alpha_2 \ln(L\_UK_i) + \frac{1}{2}\beta_{11}(\ln(L\_SK_i))^2 + \frac{1}{2}\beta_{22}(\ln(L\_UK_i))^2 + \beta_{12}\ln(L\_SK_i)\ln(L\_UK_i)$. Where restrictions are as follows: $\beta_{12} = -\beta_{11} = -\beta_{22}$; $\rho = \frac{\beta_{12}(\alpha_1+\alpha_2)}{\alpha_1\alpha_2}$; and $\sigma = \frac{1}{1+\rho}$.

Source: Ibid.,

Table 16: Estimation Results of Skill-Unskilled Thai National and Migrants Labor

	α_0	α_1	α_2	β_{12}	ρ	σ	R^2	D.W.
Skilled-Labor TH-immigrant	0.678	0.616	0.394	0.098	0.406	**0.711**	0.99	2.02
Unskilled-Labor TH-immigrant	0.656	0.726	0.267	0.063	0.322	**0.756**	0.99	2.39

Note: Skilled labor (notations and restriction also applied here)

$\ln(L\_SK_i) = \alpha_0 + \alpha_1 \ln(L\_TH_i) + \alpha_2 \ln(L\_IM_i) + \frac{1}{2}\beta_{11}(\ln(L\_TH_i))^2 + \frac{1}{2}\beta_{22}(\ln(L\_IM_i))^2 + \beta_{12}\ln(L\_TH_i)\ln(L\_IM_i)$

Unskilled Labor (notation and restriction also applied here)

$\ln(L\_UK_i) = \alpha_0 + \alpha_1 \ln(L\_TH_i) + \alpha_2 \ln(L\_IM_i) + \frac{1}{2}\beta_{11}(\ln(L\_TH_i))^2 + \frac{1}{2}\beta_{22}(\ln(L\_IM_i))^2 + \beta_{12}\ln(L\_TH_i)\ln(L\_IM_i)$

Source: Ibid.,

The result has shown that the overall elasticity of substitution between capital and labor are very normal and closed to the value of 1.00 for most of the sectors. Exceptions are the agriculture sector which has its EOS of 1.153. This implies that capital is flexibly substituted for labor by mechanization process during the period of study (2001-2014). This was in fact after the 'Turning Point' in 2000 (Bowonthumrongchai, 2019). It has occurred in the agriculture sector. Internal labor movement has flowed out from the sector while more machines were in place to substitute for labor shortage. In fact migrants from neighboring countries did help somewhat along the border area. But, the process of mechanization was obviously observed for the sector. The Public Utilities and Trade on the other hand had found to be inflexibility substitution between capitals for labor. It might be the case that labor intensive still prevailed and there was not yet need to replace the capital for cheap labor of both unskilled Thai nationals and foreign workers (See Table 14).

It is also clear that substitution between skills and unskilled Thai workers was quite inflexible as we have expected. The elasticity of substitution is much lower than the norm of 1.00 (See Table 15). This signified that the unskilled workers with Thai nationals seemed to have no contribution on the 'learning by doing' process. It was still hard to substitute the skills by the unskilled ones when wage of the skills increased during the period.

Finally, the substitutability of Thai workers and foreign workers both the skills and unskilled had upper bound of substitutability with the EOS of 0.7 level. This implies a likelihood of a barrier on labor movement across Thai borders. Perhaps, it was owing to the language barrier between the CLMV countries and Thailand (See Table 16).

3.2.2 Conclusions

In our study, our main objective is to calibrate parameters for the CGE model of Thailand. We would like to calculate the impact of migrant labor under meaningful scenarios. We have found that the parameters of the CGE model (including our previous study) are more or less *ad hoc* and taken from some other literature, if not a 'back of the envelope' calibration. It is sometimes unacceptable and not relevant to the economic development epoch of Thailand. We have decided to estimate our parameters.

We have estimated the coefficients of a CES (Constant Elasticity of Substitution) production form where capital and labor inputs are substitutabilities. This is to calibrate the 'Elasticity of Substitution (EOS) of Thai production structure, applying the National Accounts Statistics of the NESDB on 'Net and Gross Capital Stock by Sector'. Furthermore, we have estimated the EOS of between 'skill and unskilled' labor of Thai nationalities, applying the Labor Force Survey 2001-2015. The definition of skills derived from 'Occupation-Education' by sector. Besides, with information from 'Population Census 2010' by the National Statistical Office, we have also tried cross-sectional pooling estimates of EOS of 'Thai-Foreign' labor by skills.

In our study, we have some reflection on our estimates and 'Hypothesis Testing' of estimation results as follows: The individual 'translog' model estimation of EOS between capital and labor in our study has produced acceptable determination coefficients (R^2), however, some ***coefficients*** estimates are *insignificant statistically*, judging from their-t_statistics and 'p-value'. Thus, the *rejection of the null hypothesis* may in some case have been failed to achieve. (See Appendix for detail estimations). We have tried the 'pool estimation', for skilled-unskilled estimations and found that the result is *robust* and significant with acceptable goodness-of-fit.

Since the functional forms of EOS estimation and econometric technique are numerous. We would propose a further study by trying to estimate with other alternative forms. This is to follow Vern Caddy (1981), and Kamenta (1964) and Henningsen A. and Henningsen G, (2011) respectively. This can be done with more sophisticated econometric methods.

Appendix

A. List of Variables

A1: List of Variables used in estimation of Elasticity of Substitution between 'Skilled and Unskilled labor' by Economic Sector (National Accounts)

Variable	Description
L_SK_AGR	Agriculture, forestry, and fishing: Skilled Labor
L_UK_AGR	Agriculture, forestry, and fishing: Unskilled Labor
L_SK_MIN	Mining and Quarrying: Skilled Labor
L_UK_MIN	Mining and Quarrying: Unskilled Labor
L_SK_MANU	Manufacturing: Skilled Labor
L_UK_MANU	Manufacturing: Unskilled Labor
L_SK_PUB	Public Utilities: Skilled Labor
L_UK_PUB	Public Utilities: Unskilled Labor
L_SK_CONS	Construction: Skilled Labor
L_UK_CONS	Construction: Unskilled Labor
L_SK_TRADE	Wholesale and retail trade, repair of motor vehicles motorcycles: Skilled Labor
L_UK_TRADE	Wholesale and retail trade, repair of motor vehicles motorcycles: Unskilled Labor
L_SK_TRANS	Transportation and storage: Skilled Labor
L_UK_TRANS	Transportation and storage: Unskilled Labor
L_SK_SER	Service: Skilled Labor
L_UK_SER	Service: Unskilled Labor
L_SK_OTH	Unknown: Skilled Labor
L_UK_OTH	Unknown: Unskilled Labor
LW_SK_AGR	Agriculture, forestry, and fishing: Skilled Wage Earner
LW_UK_AGR	Agriculture, forestry, and fishing: Unskilled Wage Earner
LW_SK_MIN	Mining and Quarrying: Skilled Wage Earner
LW_UK_MIN	Mining and Quarrying: Unskilled Wage Earner
LW_SK_MANU	Manufacturing: Skilled Wage Earner
LW_UK_MANU	Manufacturing: Unskilled Wage Earner
LW_SK_PUB	Public Utilities: Skilled Wage Earner
LW_UK_PUB	Public Utilities: Unskilled Wage Earner
LW_SK_CONS	Construction: Skilled Wage Earner
LW_UK_CONS	Construction: Unskilled Wage Earner

LW_SK_TRADE	Wholesale and retail trade, repair of motor vehicles motorcycles: Skilled Wage Earner
LW_UK_TRADE	Wholesale and retail trade, repair of motor vehicles motorcycles: Unskilled Wage Earner
LW_SK_TRANS	Transportation and storage: Skilled Wage Earner
LW_UK_TRANS	Transportation and storage: Unskilled Wage Earner
LW_SK_SER	Service: Skilled Wage Earner
LW_UK_SER	Service: Unskilled Wage Earner
LW_SK_OTH	Unknown: Skilled Wage Earner
LW_UK_OTH	Unknown: Unskilled Wage Earner
W_SK_AGR	Agriculture, forestry, and fishing: Average wage of Skilled Labor
W_UK_AGR	Agriculture, forestry, and fishing: Average wage of Unskilled Labor
W_SK_MIN	Mining and Quarrying: Average wage of Skilled Labor
W_UK_MIN	Mining and Quarrying: Average wage of Unskilled Labor
W_SK_MANU	Manufacturing: Average wage of Skilled Labor
W_UK_MANU	Manufacturing: Average wage of Unskilled Labor
W_SK_PUB	Public Utilities: Average wage of Skilled Labor
W_UK_PUB	Public Utilities: Average wage of Unskilled Labor
W_SK_CONS	Construction: Average wage of Skilled Labor
W_UK_CONS	Construction: Average wage of Unskilled Labor
W_SK_TRADE	Wholesale and retail trade, repair of motor vehicles motorcycles: Average wage of Skilled Labor
W_UK_TRADE	Wholesale and retail trade, repair of motor vehicles motorcycles: Average wage of Unskilled Labor
W_SK_TRANS	Transportation and storage: Average wage of Skilled Labor
W_UK_TRANS	Transportation and storage: Average wage of Unskilled Labor
W_SK_SER	Service: Average wage of Skilled Labor
W_UK_SER	Service: Average wage of Unskilled Labor
W_SK_OTH	Unknown: Average wage of Skilled Labor
W_UK_OTH	Unknown: Average wage of Unskilled Labor

A2: List of Variables for the Estimation of Elasticity of Substitution between 'Capital and Labor'

In this econometric estimation, the notation is represented by L***_'sector'; K_'sector' and Vafc_'sector'*** respectively.

The sector is defined according to National Account Statistics. It is measured in terms of value-added namely the 'gross domestic product at factor cost'. The capital stock and value-added at factor cost is measured in constant prices.

A3. 'Translog' Estimation of EOS Capital-Labor in National Account

1. Agriculture Sector

Dependent Variable: LOG(VAFC_AGRR)				
Method: Least Squares (Gauss-Newton / Marquardt steps)				
Date: 10/26/16 Time: 15:31				
Sample (adjusted): 2001 2014				
Included observations: 14 after adjustments				
LOG(VAFC_AGRR) = C(1) +C(2)*LOG(K_AGRR_2002)+C(3)*LOG(L_AGR)				
+ (1/2)*C(4)*LOG(K_AGRR_2002)^2 + (1/2)*C(5)*LOG(L_AGR)^2+C(6)				
*LOG(K_AGRR_2002)*LOG(L_AGR)				
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-524.6489	232.4195	-2.257336	0.0539
C(2)	29.50254	15.23026	1.937101	0.0887
C(3)	82.95217	39.64067	2.092603	0.0697
C(4)	-0.441675	0.937846	-0.470946	0.6503
C(5)	-5.352444	2.861382	-1.870580	0.0983
C(6)	-2.895104	1.452252	-1.993528	0.0813
R-squared	0.957615	Mean dependent var		13.28796
Adjusted R-squared	0.931124	S.D. dependent var		0.095466
S.E. of regression	0.025054	Akaike info criterion		-4.238018
Sum squared resid	0.005022	Schwarz criterion		-3.964136
Log likelihood	35.66612	Hannan-Quinn criter.		-4.263370
F-statistic	36.14895	Durbin-Watson stat		2.437377
Prob(F-statistic)	0.000028			

2. Mining Sector

Dependent Variable: LOG(VAFC_MINR)				
Method: Least Squares (Gauss-Newton / Marquardt steps)				
Date: 10/05/16 Time: 09:57				
Sample (adjusted): 2001 2014				
Included observations: 14 after adjustments				
LOG(VAFC_MINR) = C(1) +C(2)*LOG(K_MINR_2002)+C(3)*LOG(L_MIN) +				
(1/2)*C(4)*LOG(K_MINR_2002)^2 + (1/2)*C(5)*LOG(L_MIN)^2+C(6)				
*LOG(K_MINR_2002)*LOG(L_MIN)				
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-225.9502	73.36494	-3.079811	0.0151
C(2)	34.91182	12.65917	2.757829	0.0248
C(3)	4.687496	4.660459	1.005802	0.3440
C(4)	-2.547771	1.098414	-2.319500	0.0490
C(5)	0.004847	0.440324	0.011008	0.9915
C(6)	-0.368379	0.433303	-0.850165	0.4199
R-squared	0.991233	Mean dependent var		11.97412
Adjusted R-squared	0.985754	S.D. dependent var		0.207053
S.E. of regression	0.024713	Akaike info criterion		-4.265414
Sum squared resid	0.004886	Schwarz criterion		-3.991532
Log-likelihood	35.85790	Hannan-Quinn criter.		-4.290767
F-statistic	180.9036	Durbin-Watson stat		2.490082
Prob(F-statistic)	0.000000			

2. Construction Sector

Dependent Variable: LOG(VAFC_CONR)	
Method: Least Squares (Gauss-Newton / Marquardt steps)	
Date: 10/05/16 Time: 14:08	
Sample (adjusted): 2001 2014	
Included observations: 14 after adjustments	

LOG(VAFC_CONR) = C(1) +C(2)*LOG(K_CONR_2002)+C(3)*LOG(L_CON)				
+ (1/2)*C(4)*LOG(K_CONR_2002)^2 + (1/2)*C(5)*LOG(L_CON)^2				
+C(6)*LOG(K_CONR_2002)*LOG(L_CON)				
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1.174876	136.2686	-0.008622	0.9933
C(2)	-13.44354	20.73478	-0.648357	0.5349
C(3)	26.39407	27.94920	0.944359	0.3726
C(4)	1.535352	1.791934	0.856813	0.4165
C(5)	-1.694766	6.236064	-0.271769	0.7927
C(6)	-0.943160	1.768898	-0.533191	0.6084
R-squared	0.961607	Mean dependent var		12.15302
Adjusted R-squared	0.937612	S.D. dependent var		0.118544
S.E. of regression	0.029609	Akaike info criterion		-3.903920
Sum squared resid	0.007014	Schwarz criterion		-3.630038
Log-likelihood	33.32744	Hannan-Quinn criter.		-3.929273
F-statistic	40.07451	Durbin-Watson stat		2.894404
Prob(F-statistic)	0.000019			

4. Manufacturing Sector

Dependent Variable: LOG(VAFC_MANR)			
Method: ARMA Conditional Least Squares (Gauss-Newton / Marquardt			
steps)			
Date: 10/05/16 Time: 09:48			
Sample (adjusted): 2002 2014			
Included observations: 13 after adjustments			
Convergence achieved after 8 iterations			
Coefficient covariance computed using outer product of gradients			
LOG(VAFC_MANR) = C(1) +C(2)*LOG(K_MANR_2002)+C(3)*LOG(L_MAN)			
+ (1/2)*C(4)*LOG(K_MANR_2002)^2 + (1/2)*C(5)*LOG(L_MAN)^2+C(6)			
*LOG(K_MANR_2002)*LOG(L_MAN)+[AR(1)=C(7),ESTSMPL="2002			
2014"]			

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-427.5259	64.49313	-6.629015	0.0006
C(2)	14.25657	17.29860	0.824146	0.4414
C(3)	77.55754	28.41089	2.729853	0.0342
C(4)	-1.916433	0.932052	-2.056144	0.0855
C(5)	-12.65040	6.283501	-2.013273	0.0907
C(6)	1.891498	1.882401	1.004833	0.3538
C(7)	-0.489092	0.322462	-1.516744	0.1801
R-squared	0.989519	Mean dependent var		14.46409
Adjusted R-squared	0.979039	S.D. dependent var		0.157070
S.E. of regression	0.022741	Akaike info criterion		-4.425604
Sum squared resid	0.003103	Schwarz criterion		-4.121401
Log-likelihood	35.76643	Hannan-Quinn criter.		-4.488132
F-statistic	94.41438	Durbin-Watson stat		2.793768
Prob(F-statistic)	0.000011			
Inverted AR Roots	-.49			

5. Public Administration

Dependent Variable: LOG(VAFC_PUBR)				
Method: ARMA Conditional Least Squares (Gauss-Newton / Marquardt				
steps)				
Date: 10/05/16 Time: 14:17				
Sample (adjusted): 2002 2014				
Included observations: 13 after adjustments				
Failure to improve likelihood (non-zero gradients) after 6 iterations				
Coefficient covariance computed using outer product of gradients				
LOG(VAFC_PUBR) = C(1) +C(2)*LOG(K_PUBR_2002)+C(3)*LOG(L_PUB)				
+ (1/2)*C(4)*LOG(K_PUBR_2002)^2 + (1/2)*C(5)*LOG(L_PUB)^2+C(6)				
*LOG(K_PUBR_2002)*LOG(L_PUB)+[AR(1)=C(7),ESTSMPL="2002				
2014"]				

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	611.2478	3394256.	0.000180	0.9999
C(2)	61.78516	249.9111	0.247229	0.8130
C(3)	8.146464	19.36004	0.420788	0.6886
C(4)	-4.332159	17.07968	-0.253644	0.8082
C(5)	-1.374179	1.467166	-0.936622	0.3851
C(6)	-0.134537	1.512182	-0.088969	0.9320
C(7)	0.999932	0.217601	4.595259	0.0037
R-squared	0.978262	Mean dependent var		12.26775
Adjusted R-squared	0.956524	S.D. dependent var		0.169215
S.E. of regression	0.035283	Akaike info criterion		-3.547105
Sum squared resid	0.007469	Schwarz criterion		-3.242902
Log-likelihood	30.05618	Hannan-Quinn criteria.		-3.609633
F-statistic	45.00238	Durbin-Watson stat		2.603182
Prob(F-statistic)	0.000099			
Inverted AR Roots	1.00			

6. Wholesale and Retail Trade Sector

Dependent Variable: LOG(VAFC_TRADR)				
Method: ARMA Conditional Least Squares (Gauss-Newton / Marquardt				
steps)				
Date: 10/05/16 Time: 14:30				
Sample (adjusted): 2002 2014				
Included observations: 13 after adjustments				
Convergence achieved after 17 iterations				
Coefficient covariance computed using outer product of gradients				
LOG(VAFC_TRADR) = C(1) +C(2)*LOG(K_TRADR_2002)+C(3)				
*LOG(L_TRAD) + (1/2)*C(4)*LOG(K_TRADR_2002)^2 + (1/2)*C(5)				
*LOG(L_TRAD)^2+C(6)*LOG(K_TRADR_2002)*LOG(L_TRAD)				
+[AR(1)=C(7),ESTSMPL="2002 2014"]				
	Coefficient	Std. Error	t-Statistic	Prob.

C(1)	-984.4601	450.9940	-2.182867	0.0718
C(2)	152.2039	82.62409	1.842125	0.1150
C(3)	-25.02279	60.86921	-0.411091	0.6953
C(4)	-8.133119	10.09253	-0.805855	0.4511
C(5)	11.81633	11.79919	1.001452	0.3553
C(6)	-4.579867	9.766185	-0.468952	0.6557
C(7)	0.453526	0.111465	4.068785	0.0066
R-squared	0.985889	Mean dependent var		13.73423
Adjusted R-squared	0.971777	S.D. dependent var		0.115604
S.E. of regression	0.019421	Akaike info criterion		-4.741195
Sum squared resid	0.002263	Schwarz criterion		-4.436991
Log-likelihood	37.81777	Hannan-Quinn criter.		-4.803722
F-statistic	69.86511	Durbin-Watson stat		2.699815
Prob(F-statistic)	0.000028			
Inverted AR Roots	.45			

7. Transport and Communication Sector

Dependent Variable: LOG(VAFC_TRANR)				
Method: ARMA Conditional Least Squares (Gauss-Newton / Marquardt				
steps)				
Date: 10/05/16 Time: 14:29				
Sample (adjusted): 2002 2014				
Included observations: 13 after adjustments				
Convergence achieved after 40 iterations				
Coefficient covariance computed using outer product of gradients				
LOG(VAFC_TRANR) = C(1) +C(2)*LOG(K_TRANR_2002)+C(3)				
*LOG(L_TRAN) + (1/2)*C(4)*LOG(K_TRANR_2002)^2 + (1/2)*C(5)				
*LOG(L_TRAN)^2+C(6)*LOG(K_TRANR_2002)*LOG(L_TRAN)				
+[AR(1)=C(7),ESTSMPL="2002 2014"]				

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	242.9631	527.4366	0.460649	0.6613
C(2)	-43.71361	88.61670	-0.493289	0.6393
C(3)	28.55585	56.34374	0.506815	0.6304
C(4)	4.046738	7.936002	0.509921	0.6283
C(5)	1.685862	5.206489	0.323800	0.7571
C(6)	-2.569352	5.782631	-0.444322	0.6724
C(7)	0.179561	0.567749	0.316269	0.7625
R-squared	0.986759	Mean dependent var		13.38588
Adjusted R-squared	0.973518	S.D. dependent var		0.195684
S.E. of regression	0.031844	Akaike info criterion		-3.752186
Sum squared resid	0.006084	Schwarz criterion		-3.447982
Log-likelihood	31.38921	Hannan-Quinn criter.		-3.814713
F-statistic	74.52316	Durbin-Watson stat		1.723304
Prob(F-statistic)	0.000023			
Inverted AR Roots	.18			

8. Service Sector

Dependent Variable: LOG(VAFC_SERR)			
Method: ARMA Conditional Least Squares (Gauss-Newton / Marquardt			
steps)			
Date: 10/05/16 Time: 16:10			
Sample (adjusted): 2002 2014			
Included observations: 13 after adjustments			
Convergence not achieved after 500 iterations			
Coefficient covariance computed using outer product of gradients			
LOG(VAFC_SERR) = C(1) +C(2)*LOG(K_SERR_2002)+C(3)*LOG(L_SER)			
+ (1/2)*C(4)*LOG(K_SERR_2002)^2 + (1/2)*C(5)*LOG(L_SER)^2+C(6)			
*LOG(K_SERR_2002)*LOG(L_SER)+[AR(1)=C(7),ESTSMPL="2002			
2014"]			

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1898.905	2383.849	-0.796571	0.4561
C(2)	359.8199	431.0556	0.834741	0.4358
C(3)	-221.8230	244.6897	-0.906548	0.3996
C(4)	-34.36980	40.19044	-0.855173	0.4253
C(5)	-14.28430	16.42424	-0.869708	0.4179
C(6)	21.74165	24.22028	0.897663	0.4039
C(7)	0.526025	0.426074	1.234584	0.2631
R-squared	0.995413	Mean dependent var		14.57124
Adjusted R-squared	0.990825	S.D. dependent var		0.172236
S.E. of regression	0.016498	Akaike info criterion		-5.067449
Sum squared resid	0.001633	Schwarz criterion		-4.763245
Log-likelihood	39.93842	Hannan-Quinn criter.		-5.129976
F-statistic	216.9841	Durbin-Watson stat		1.357196
Prob(F-statistic)	0.000001			
Inverted AR Roots	.53			

9. Pool Estimation

Dependent Variable: LOG(L_SK_?/L_UK_?)				
Method: Pooled Least Squares				
Date: 10/25/16 Time: 09:18				
Sample (adjusted): 2001 2014				
Included observations: 14 after adjustments				
Cross-sections included: 8				
Total pool (balanced) observations: 112				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.937119	0.334021	-2.805566	0.0065
AGR--LOG(LW_UK_AGR/LW_SK_AGR)	-0.849681	0.228005	-3.726593	0.0004
CONS--LOG(LW_UK_CONS/LW_SK_CONS)	-1.014486	0.362330	-2.799897	0.0066

MANU--LOG(LW_UK_MANU/LW_SK_MANU)	-0.913402	0.387345	-2.358109	0.0212
MIN--LOG(LW_UK_MIN/LW_SK_MIN)	-0.881328	0.105511	-8.352946	0.0000
OTH--LOG(LW_UK_OTH/LW_SK_OTH)	-1.036086	0.099662	-10.39596	0.0000
SER--LOG(LW_UK_SER/LW_SK_SER)	-2.050543	1.077831	-1.902471	0.0613
TRADE--LOG(LW_UK_TRADE/LW_SK_TRADE)	-0.293534	0.366376	-0.801182	0.4258
TRANS--LOG(LW_UK_TRANS/LW_SK_TRANS)	-0.844105	0.251948	-3.350311	0.0013
VAFC_?R--2001	1.29E-06	4.58E-07	2.825390	0.0062
VAFC_?R--2002	1.24E-06	4.25E-07	2.917972	0.0048
VAFC_?R--2003	1.14E-06	3.94E-07	2.900597	0.0050
VAFC_?R--2004	1.07E-06	3.67E-07	2.917124	0.0048
VAFC_?R--2005	9.92E-07	3.55E-07	2.795039	0.0067
VAFC_?R--2006	9.30E-07	3.44E-07	2.701197	0.0087
VAFC_?R--2007	9.04E-07	3.22E-07	2.812880	0.0064
VAFC_?R--2008	7.71E-07	3.13E-07	2.461548	0.0163
VAFC_?R--2009	8.34E-07	3.20E-07	2.606148	0.0112
VAFC_?R--2010	7.22E-07	3.01E-07	2.404078	0.0189
VAFC_?R--2011	7.51E-07	2.93E-07	2.562561	0.0126
VAFC_?R--2012	6.89E-07	2.80E-07	2.461695	0.0163
VAFC_?R--2013	6.47E-07	2.84E-07	2.273521	0.0261
VAFC_?R--2014	6.36E-07	2.67E-07	2.382515	0.0200
Fixed Effects (Cross)				
AGR--C	0.235627			
CONS--C	1.608485			
MANU--C	-0.754770			
MIN--C	0.753517			
OTH--C	1.037312			
SER--C	-1.623889			
TRADE--C	-0.793306			
TRANS--C	-0.462976			
Fixed Effects (Period)				
2001--C	0.063707			
2002--C	0.079184			
2003--C	0.100404			
2004--C	0.042471			
2005--C	0.077250			

2006--C	0.054092			
2007--C	0.037583			
2008--C	-0.072443			
2009--C	-0.129192			
2010--C	0.013828			
2011--C	-0.105814			
2012--C	-0.100115			
2013--C	-0.037636			
2014--C	-0.023320			
	Effects Specification			
Cross-section fixed (dummy variables)				
The period fixed (dummy variables)				
R-squared	0.989069	Mean dependent var		-1.751247
Adjusted R-squared	0.982416	S.D. dependent var		0.989335
S.E. of regression	0.131192	Akaike info criterion		-0.940850
Sum squared resid	1.187576	Schwarz criterion		0.102859
Log-likelihood	95.68760	Hannan-Quinn criter.		-0.517384
F-statistic	148.6532	Durbin-Watson stat		0.967203
Prob(F-statistic)	0.000000			

Dependent Variable: LOG(L_SK_?/L_UK_?)				
Method: Pooled Least Squares				
Date: 10/24/16 Time: 17:06				
Sample: 2001 2015				
Included observations: 15				
Cross-sections included: 8				
Total pool (balanced) observations: 120				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.882717	0.192904	-4.575938	0.0000
AGR--LOG(LW_UK_AGR/LW_SK_AGR)	-0.047234	0.259676	-0.181896	0.8562

CONS--LOG(LW_UK_CONS/LW_SK_CONS)	-0.880614	0.204794	-4.299999	0.0001
MANU--LOG(LW_UK_MANU/LW_SK_MANU)	-0.616932	0.159274	-3.873400	0.0002
MIN--LOG(LW_UK_MIN/LW_SK_MIN)	-0.798003	0.067006	-11.90939	0.0000
OTH--LOG(LW_UK_OTH/LW_SK_OTH)	-1.012115	0.063800	-15.86379	0.0000
SER--LOG(LW_UK_SER/LW_SK_SER)	-1.732101	0.432847	-4.001647	0.0001
TRADE--LOG(LW_UK_TRADE/LW_SK_TRADE)	0.032217	0.229594	0.140322	0.8888
TRANS--LOG(LW_UK_TRANS/LW_SK_TRANS)	-0.896681	0.186371	-4.811260	0.0000
L_?--2001	2.58E-08	2.77E-08	0.933838	0.3534
L_?--2002	3.43E-08	2.55E-08	1.344120	0.1830
L_?--2003	3.36E-08	2.62E-08	1.280720	0.2042
L_?--2004	3.99E-08	2.64E-08	1.511224	0.1349
L_?--2005	4.23E-08	2.66E-08	1.589620	0.1161
L_?--2006	3.45E-08	2.66E-08	1.296781	0.1987
L_?--2007	2.83E-08	2.59E-08	1.091728	0.2784
L_?--2008	-6.38E-09	2.64E-08	-0.241610	0.8097
L_?--2009	3.73E-09	2.59E-08	0.144231	0.8857
L_?--2010	-3.33E-09	2.57E-08	-0.129551	0.8973
L_?--2011	-1.52E-08	2.66E-08	-0.573617	0.5679
L_?--2012	-5.23E-09	2.66E-08	-0.196914	0.8444
L_?--2013	-2.48E-09	2.53E-08	-0.098044	0.9222
L_?--2014	-3.44E-09	2.96E-08	-0.116224	0.9078
L_?--2015	2.17E-09	2.91E-08	0.074334	0.9409
Fixed Effects (Cross)				
AGR--C	-2.932399			
CONS--C	1.379552			
MANU--C	0.238569			
MIN--C	0.703022			
OTH--C	0.940422			
SER--C	0.142805			
TRADE--C	-0.567658			
TRANS--C	0.095686			
Fixed Effects (Period)				
2001--C	0.038211			
2002--C	0.041320			
2003--C	0.060837			

2004--C	-0.023578			
2005--C	-0.026448			
2006--C	0.002964			
2007--C	0.025869			
2008--C	-0.041220			
2009--C	-0.094292			
2010--C	0.029708			
2011--C	-0.026016			
2012--C	-0.060245			
2013--C	0.036752			
2014--C	0.024627			
2015--C	0.011513			
	Effects Specification			
Cross-section fixed (dummy variables)				
The period fixed (dummy variables)				
R-squared	0.994502	Mean dependent var		-1.737879
Adjusted R-squared	0.991277	S.D. dependent var		0.993060
S.E. of regression	0.092751	Akaike info criterion		-1.637804
Sum squared resid	0.645203	Schwarz criterion		-0.592495
Log-likelihood	143.2683	Hannan-Quinn criter.		-1.213299
F-statistic	308.3299	Durbin-Watson stat		1.305411
Prob(F-statistic)	0.000000			

References

1. Arrow J.K., Chenery H.B., Minhas B.S., and Solow M.R. (1961), "Capital-Labor substitution and economic efficiency," Review of Economics and Statistics, 43(3): 225-250.
2. Bergstrom T. (2011), Lector Notes on Elasticity of Substitution, UCSB Economics 210 A.
3. Bowonthumrongchai, (2019), Lewis Turning Point and Agricultural Development in the Mekong: A Case of Thailand, The Social Science Review, Special Issue No. 156, March 2019, The Economic Society of Saitama University, Japan
4. Chambers Robert G., (1988), Applied Production Analysis: A Dual Approach, Cambridge University Press
5. Hoff. A (2004), "The Linear Approximation of the CES Function with n Input Variables," d, 19: 295-306.
6. Henningsen A. and Henningsen G, (2011), "Econometric Estimation of the "Constant Elasticity of Substitution" Function in R: Package micEconCES," IFRO Working Paper 2011/9, University of Copenhagen, Department of Food and Resource Economics.
7. Kmenta, J,. (1964), "On Estimation of the CES Production Function," Social Systems Research Institute, University of Wisconsin, Paper No.6410.
8. Vern Caddy (1981), Empirical Estimation of the Elasticity of Substitution: A Review, Impact Project Research Center, Preliminary Working Paper OP-09, Melbourne, Australia, 1976, reprint 1981.