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Measuring Urbanization in ASEAN from Space

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Chapter 3

Monocentric Growth and Productivity Spillover in Thailand

Nattapong Puttanapong

Abstract

During the past fifty years, Thailand has maintained its economic growth path to achieve the status of upper-middle income level. However, the growth in geographical dimension has indeed been disproportionate. The growth and productivity have been mostly concentrated within the Bangkok metropolitan and surrounding provinces. With this evidence, this study has aimed at quantitatively examining the clustering pattern and the spillover effect. In addition, this study has applied both spatial statistics and spatial econometric tests to the remote-sensing data and official surveys. The results obtained from the spatial statistical test identified that there are existing associations among the night time light density, industrial density, companies' performance, and workers' skills. Moreover, the spatial econometric test indicates that there exists productivity spillover among some firms. Both results suggest that in order to attract the expansion of production in the target areas, both infrastructure and incentive schemes should guarantee positive spillover at a higher magnitude than that obtained from the spatial econometric test conducted in this study..

Keywords: Urbanization, Thailand, Trade and Investment

1. Introduction

Since 1960, the Thai economy has been expanding continuously. The consecutive implementation of National Economic Development Plans has gradually transformed the economic structure through an export-oriented strategy. Particularly, inflows of Foreign Direct Investment (FDI) attracted by tax incentive schemes have encouraged the evolution of industrialization, and subsequently decoupled and relocated resources from agricultural activities to the manufacturing sector. The outcome of this transformation has progressed

Thailand to achieve a GNI per capita in the upper-middle income category. Empirically, as illustrated in Figures 1 - 3, the development process has influenced the continuous growth path of income per capita, longer life expectancy, and reduced unemployment.

Figure 1: GNI per capita

Figure 2: Life expectancy

Figure 3: Unemployment

Figure 4: GINI index (World Bank estimate)

Although these macro indicators exhibit the good progress of the nation's development, there still exists significant concern regarding income inequality. As shown in Figure 4, the GINI index has declined slightly since 1981. In addition, the distribution in spatial dimension has been documented by Short & Pinet-Peralta (2009) as the highest disproportion in the world. As listed in Table 1, Thailand has the highest urban primacy in the global ranking.¹ This disproportion has formulated the country's largest urbanization area around Bangkok. As stated in Robinson (2011), the expansion of urbanization in Bangkok's peripheral areas leads to four classifications of urbanized areas as follows.

- (1) The Bangkok Metropolitan Administration (BMA), an area of 1,565.2 km² (604 sq. mi). This area is legally defined as a municipality and a single province. It is also administratively recognized as Bangkok Metropolis.
- (2) The Greater Bangkok Area (GBA), an area of 4,717 km² (1,821 sq. mi). This area includes the BMA and three adjoining provinces, Nonthaburi, Pathum Thani, and Samut Prakan.
- (3) The Bangkok Metropolitan Region (BMR), an area of 7,758 km² (2,995 sq. mi). The BMR includes the BMA and five adjoining provinces, Nonthaburi, Pathum

¹ The urban primacy index is the ratio of the population of the country's largest city to the combined population of the second and the third largest cities.

Thani, Samut Prakan, Nakhon Pathom, and Samut Sakhon.

- (4) The Extended Bangkok Metropolitan Region (EBMR), an area of approximately 59,000 km² (23,000 sq. mi). The EMBR includes the BMA and twelve other provinces, Nonthaburi, Pathum Thani, Samut Prakan, Nakhon Pathom, Samut Sakhon, Ayuthaya, Saraburi, Chonburi, Chachoensao, Rayong, Ratchaburi, and Phetchaburi.

Table 1: Ranking of the urban primacy index

Table 2: The distribution of population, 1970-2010.

Table 3, exhibits the population in these four classifications of urbanized areas during 1970-2010. The statistics indicate an interesting aspect of the population during 1990-2010 within the Metropolitan ring and Outer fringe, which has experienced a very high growth rate. On the other hand, the BMA, which is the core urbanized area, experienced the lowest population growth. This evidence indicates the growth pattern has mutually corresponded to the evolution of the country's socio-economic structure. However, to constantly monitor and quantitatively examine the factors influencing this transformation, there has been a problem in the availability of timely data sources limited by both cost and accessibility. Therefore, this study introduces the analysis integrating remote-sensing data, ground surveys, and spatial econometrical methodologies. Specifically, the main objective of this study is twofold as follows;

- (1) To identify the geographical pattern of monocentric growth by jointly using night time light data, ground surveys, and spatial statistical techniques
- (2) To quantitative examine the association of monocentric growth and productivity spillover by using spatial econometric methodology

The structure of the content in this study is organized as follows. The second section introduces the review of related literature in the fields of theoretical and empirical studies. The third section identifies the sources and characteristics of the data. The fourth section outlines the methodologies applied to this study. The fifth section discusses the results and implications. The last section concludes the main findings and suggests issues for the extension of future research.

2. Literature Review

2.1 City agglomeration and economic growth

The association among growth, efficiency, and agglomeration was initially examined and documented by Marshall (1890). His work indicated that the increasing returns to the scale of intermediate sourcing, concentration of labor, and the spillover of knowledge were the main combination of forces leading to growth and agglomeration. Jacobs (1969) extended the findings of Marshall (1890), showing that the variety of industry and its proximity can generate productivity and growth. Duranton and Puga (2004) aggregated the main findings from previous literature and formulated a model which integrated the influenced economies of scale, labor pooling and knowledge spillover. This theoretical model enabled the quantitative examination of agglomeration and economic growth. McCann (2008) integrated the fundamentals of Marshall and Jacobs, together with the network of industry and transaction-cost concept, and concluded that the association of agglomeration and growth was based on the integration of these factors.

2.2 Spatial spillover and firms' productivity

There have been a large number of empirical studies investigating the spatial characteristics of productivity spillover. Particularly, many studies have indicated that the geographical proximity of firms can mutually increase productivity through spillovers of technology and knowledge. Jaffe et al. (1993) showed that these spillovers were localized and gradually declined over time. Also, the proximity of local firms to Multi-National Corporations (MNCs) can induce absorbing technology and knowledge through the network of intermediate supplies and the turnover of workers, as documented by Moreno & Trehan (1997), Halpern & Muraközy (2007), Crespo et al. (2009) and Lychagin et al. (2016). With the development of Geographic Information Systems (GIS) and spatial econometrical methods, recent studies, e.g. Tanaka & Hashigushi (2015), Thang et al., (2016) and Mariotti et al. (2015) have applied such data and techniques to quantify the magnitude of spatial spillover of productivity. Specifically, these studies confirmed the existence of spatial externality initiated by FDI and the operations of Multi-National Corporations (MNCs), which has ultimately influenced the improvement of local firms' productivity.

3. Theoretical background and research methodology

3.1 Theoretical background of productivity spillover

The specification of the empirical test follows the conventional approach applied in most literature examining the productivity of firms. As introduced by Javorcik (2004), Kohpaiboon (2006), and Blalock & Gertler (2008), the trans-log form of the modified Cobb-Douglas production function is the specification. Equation (1) is the mathematical form which represents the relationship between a firm's output and input.

$$\ln VA = \beta_0 + \beta_1 \ln L + \beta_2 \ln K + \beta_3 \ln X + e \quad (1)$$

where

$\ln VA$ = the vector of the natural logarithm of value added

$\ln L$ = the vector of the natural logarithm of total labor

$\ln K$ = the vector of the natural logarithm of capital

$\ln X$ = the vector of the natural logarithm of the controlling variables

e = residual

Specifically, the controlling variables include the value of export, imports, FDI, the quality of labor (which is based on the average schooling years), the age of firms, provincial minimum wage level, and the provincial government expenditure.

3.2 Spatial Statistics (Moran I)

As stated in the first objective of this study, the localized association between night time light and the main indicators obtained from surveys has been quantitatively examined. Specifically, the spatial autocorrelation statistic (Moran's I) has been applied for validating localized correlation. Equation (2) represents the mathematical representation of the Moran I test.

$$\text{Moran's } I = \frac{N \sum_i \sum_j W_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_i \sum_j W_{ij} \sum_i (X_i - \bar{X})^2} \quad (2)$$

where

X_i = variable of interest

\bar{X} = the mean of X_i

N = number of spatial units indexed by i and j

W_{ij} = spatial weight matrix

$(X_i - \bar{X})$ = deviation of X_i from its mean

$(X_j - \bar{X})$ = deviation of X_j from its mean

The obtained value by *Moran I* quantitatively identifies the correlation between the pair of X located within the area specified by the spatial weight matrix (W_{ij}). Fundamentally, the computation of *Moran I* is based on the concept of correlation. Hence, the value obtained by *Moran I* has a range between -1 and 1. A value close to 1 indicates that there exists a clustering value of X in most areas. On the other hand, a value of *Moran I* close to -1 specifies a dispersion pattern in which neighboring areas have the opposite characteristics.

It is noted that *Moran I* identifies any similarity in the whole data set. However, there is still a limitation to identifying the specific location of correlation. Therefore, *Local Moran I* or local indicators of spatial association (*LISA*), have been developed as an alternative methodology enabling identification of the specific location of correlation. The mathematical representation of *Local Moran I* (i.e. *LISA*) is shown in equation (3).

$$Local\ Moran\ I_i = \frac{(x_i - \bar{x}) \sum_j w_{ij} (x_j - \bar{x})}{s_i^2} \quad (3)$$

where

$$s_i^2 = \frac{\sum_j (x_j - \bar{x})^2}{(n-1)}$$

W_{ij} = spatial weight matrix

n = number of spatial units

The value of *Local Moran I_i* obtained from computation based on equation (3), indicates the correlation of X in area i and those in the neighboring areas. Similar to the methodology for the conventional correlation test, the test of statistical significance of *Local Moran I_i* can be obtained. The outcome of the test, conventionally identified as *p value*, empowers the application of *Local Moran I_i* in the analysis of spatial data, allowing identification of the localized correlation.

3.3 Spatial Econometrics

Anselin (2007), and Anselin & Rey (2014) have introduced the techniques of spatial

econometrics with two specifications, namely, the Spatial Lag Model (SLM) and the Spatial Error Model (SEM). Specifically, the spatial econometric method extends the conventional regression by incorporating the influence of spatial dependence. Under the assumption of normality distribution and i.i.d. (independent and identically distribution) of disturbances, both the SLM and SEM can be estimated using Maximum Likelihood estimation (ML). However, if the assumption of disturbances is violated, Lee (2003), and Anselin & Rey (2014) have suggested that the coefficients of both SLM and SEM can alternatively be obtained using the generalized method of moments (GMM).

3.3.1 Spatial Lag Model

In the case of the Spatial Lag Model (SLM), the spatial dependence is incorporated into the conventional linear regression as an additional independent variable. Equation (4) represents the mathematical form of SLM.

$$y = \rho W y + X \beta + u \quad (4)$$

The above equation follows the standard specification, in which the independent variable X explains the variation of the dependent variable Y . Also disturbance, u , randomly and marginally effects Y . The key modification is the incorporation of influence from the dependent variables in neighboring areas. ($W y$). Hence, the variation of Y is a combination of the effect by independent variables located in the host area and spillover from the neighbors. An example of the matrix representation of this specification is shown by equation (5).

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \rho \begin{bmatrix} (w_{11}y_1 + w_{12}y_2 + w_{13}y_3) \\ (w_{21}y_1 + w_{22}y_2 + w_{23}y_3) \\ (w_{31}y_1 + w_{32}y_2 + w_{33}y_3) \end{bmatrix} + \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} \quad (5)$$

The above matrix representation of SLM clearly shows the significant role of spatial weight W . Particularly, the specification of all the elements of the spatial weight matrix governs spillover across locations, and in general, the attribute of matrix W is based on either the adjacency or the radius of distance.

$$\ln VA = \rho W \ln y + \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln X + u \quad (6)$$

In this study, equation (6) is the SLM estimated using the provincial data obtained from the official industrial survey conducted in 2012. The magnitude and statistical significance of coefficient ρ is an indicator identifying the cross-province spillover of productivity.

3.4 Spatial Error Model

The second specification of the spatial econometric method is the Spatial Error Model. Fundamentally this approach is based on the assumption that spatial influence is the omitted variable, and the error term across location is correlated. Equation (7) indicates the mathematical form of SEM;

$$y = X\beta + u \quad ; \quad u = \lambda Wu + \varepsilon \quad (7)$$

Also this relationship is represented in matrix form as shown in equation (8).

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}; \quad \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \lambda \begin{bmatrix} (w_{11}u_1 + w_{12}u_2 + w_{13}u_3) \\ (w_{21}u_1 + w_{22}u_2 + w_{23}u_3) \\ (w_{31}u_1 + w_{32}u_2 + w_{33}u_3) \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \quad (8)$$

The above representation exhibits the role of the spatial weight matrix connecting the cross-location effect via error terms. Specifically, the magnitude and statistical significance of λ are the key determinants identifying the existence of the mechanism influencing propagation through spatially linked error terms.

$$\ln y = \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln X + u; \quad u = \lambda Wu + \varepsilon \quad (9)$$

In this study, the estimation based on SEM has the function form as shown in equation (9). The standard production function has been extended to incorporate the

spatial error relationship.

4. Data

4.1 Ground data

The Official Industrial Survey of 2012, is the main source of data for this study. This nationwide survey was conducted in 2012 by Thailand's National Statistical Office (NSO), collecting all the information related to production in 2011 by 98,842 firms. The raw data included some problems of duplication and missing values. A cleaning process was conducted in order to remove these discrepancies. Then, the cleaned data was arranged in GIS format using STATA and Quantum GIS, generating the spatial data set indicating the provincial sum of value added, employed labor, fixed assets, export value, import value, quality of labor, and FDI. Also, the average age of the firms was included in this data set.

In this study, the governmental budget allocated to each province was included in the regression analysis, representing the resources provided for servicing public goods. This data was obtained from the Ministry of Finance. Also, the provincial rate of the minimum wage, obtained from the Ministry of Labor, was included in the regression analysis. In 2011, the provincial minimum wage was determined by the Tripartite National Wage Committee. Inclusion of this provincial data captured the spatial variation of labor cost in the regression analysis.

4.2 Night Time Light (NTL) data

The Night Time Light (NTL) data for 2011 was originally produced by the Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS), administrated by the United States Air Force. This global data collected the night time light of the Earth's surface during 8.30-10.00pm. In order to eliminate noise and irrelevant information, the raw data was cleaned and processed by the National Geophysical Data Center (NGDC), under the administration of the National Oceanic and Atmospheric Administration (NOAA). The processed data has been publicly available since 1992. Each pixel of this global data represents an area of 0.86 km² with the value of light intensity having the scale of 0-64. As introduced by Henderson et al. (2012) and Pinkovski et al. (2016), the magnitude of illumination of NTL can represent the urban density and economic activity. Both studies have documented the statistically significant

relationship between NTL index and GDP. In this study, the NTL data has been transformed into a provincial index as shown in Figure 5.

Figure 5: Data transformation (from DMSP/OLS data to the NTL index)

5. Analysis of results

5.1 The geographical pattern of the monocentric growth pole

As previously stated in the introduction section, the economic growth of Thailand has been disproportionately distributed in the spatial dimension. The growth has been mostly concentrated in the Bangkok and its surrounding provinces, and this characteristic leads to various classifications of Bangkok Metropolitan. Hence, this study aims at examining the boundaries of this monocentric growth pole by integrating the spatial statistical method with the NTL density and ground data. Moreover, this computation also quantitatively identified the association between the physical indicators (i.e. the magnitude of NTL indicating urban density) and the socio-economic properties obtained from the official industrial survey.

In addition to the NTL density, there are three spatial data used in this analysis, the industrial density, firms' productivity, and labor quality. All were obtained from the official industrial survey, and transformed into the GIS format. The Local Moran I was conducted for each pair of NTL and spatial data, leading to three sets of results as shown in Table 3-5. Particularly, each set of computational outcome is composed of the result of the Moran I test, the cluster map, and the result of the statistical significance test. Based on the mathematical representation discussed in sections 3.2 and 3.3, the outcome of the Moran I test indicates the spatial autocorrelation of data. Therefore, it broadly represents the co-movement of the attributes. To further detail the spatial dimension, the localized association can be statistically validated using the local indicators of spatial association (*LISA*), which concurrently generate the cluster map and the result of the statistical significance test. Both outcomes of *LISA* jointly identify the locations having a statistically significant association between the variables.

Table 3, exhibits the result of examining the spatial relationship between NTL and industrial density. Figure (a) shows the scatter plot of Moran I and the statistic of 0.45,

implying that there exists a clustering pattern. Figures (b) and (c) identify that there are statistically significant correlations between NTL and industrial density in many provinces. Specifically, provinces with the red color in Figure (b) are areas in which both NTL and industrial density are statistically higher than in other provinces. On the other hand, provinces with the dark blue color are those having NTL and industrial density statistically lower than other provinces. Figure (c) correspondingly illustrates the p value, where the green disk indicates the p value at 1 percent, and light green identifies the p value at 5 percent. This outcome clearly specifies the statistically significant concentration of both NTL and industrial density in the area of the Extended BMR.

Table 4, shows the spatial association between NTL and firms' productivity. Figure (a) exhibits the result of the Moran I analysis, confirming the clustering pattern of positive correlation. The specific details of localized associations are illustrated in Figure (b), identifying that high productivity companies are located in the Extended BMR. Figure (c), verifies this spatial correlation with the statistical significance in the corresponding provinces.

Table 5, exhibits the last set of the spatial correlation analysis. The result indicates the localized association between NTL and the quality of labor, which is classified based on the average schooling years. Similar to the previous cases, as shown in Figure (a), the computed Moran I statistic verifies the geographical concentration of this relationship. In a similar vein, Figures (b) and (c) demonstrate the outcome of the LISA test, by identifying the statistically significant correlation between NTL and the quality of labor in the many provinces. Especially, there exists an association between high urban density and high quality of labor in the area of the Extended BMR. On the contrary, there also exists a statistically significant association between low urban density and low quality of labor in some areas.

All the main findings obtained by the three spatial correlation tests are listed in Table 6, and these analytical outcomes obviously indicate the geographical pattern of monocentric growth. Compared to the four classifications of boundaries of the Bangkok metropolitan area stated in the introduction section, the outcome of the spatial analysis is closely matched to the last classification, which is the Extended BMR, and this confirms that the physical evidence obtained from coverage of NTL density is consistent with the high magnitude of the socio-economic indicators. This characteristic affirms the agglomeration in the Extended BMR, significantly attracting economic activities and generating a substantial proportion of Thailand's GDP.

Table 4: Result of local indicators of spatial association (*LISA*) between NTL and firms' productivity

Table 5: Result of the local indicators of spatial association (*LISA*) between NTL and labor quality

Table 6: Summary of results obtained from the Local Indicators of Spatial Association (*LISA*)

5.2 The productivity spillover and agglomeration of the Extended Bangkok Metropolitan area

As shown in section 5.1, the results obtained from the spatial statistic test clearly verify the monocentric growth pole. The Extended BMR hosts the highest economic performance with the cluster of highly skilled labor. Although this outcome obviously indicates statistically significant geographical evidence, there is still the further question regarding the mechanism of spillover and its magnitude of influence. Hence, this section applies the spatial econometric technique to the nationwide industrial survey. Specifically, this empirical test is based on the theoretical background discussed in sections 3.1 and 3.3.

Table 7 lists the results obtained from three estimation techniques, the Ordinary Least Square (OLS) regression, the spatial lag model (SLM), and the spatial error model (SEM). Following the conventional form of the modified Cobb-Douglas production function as the main specification, the first column of Table 7 lists the result obtained from OLS regression. Most results are consistent to those demonstrated in literature covering this field. The labor ($\ln L$) and capital ($\ln K$) have the positive and statistically significant contribution to the creation of value added. The export activity has the positive influence on firms' productivity. However, the involvement to import does not have a statistically significant impact.

The quality of labor also yields a positive effect on firms' productivity. Nevertheless, the age of firms ($\ln AGE$) does not influence firms' performance. The FDI ($\ln FDI$), considered as the source of technological and managerial spillover, has a positive influence on firm's productivity. The minimum wage and governance expenditure in each province have been included in this regression as controlling variables. However, neither are statistically significant.

In addition to conventional estimation, this regression also includes the statistical test of the spatial specification. The statistical test of Moran I on the residuals indicates that there exists spatial autocorrelation. Therefore, the spatial econometric approach is more appropriate than the conventional OLS regression. Furthermore, the results of the Lagrange multiplier test of SLM (LM_{lag}), and the robust Lagrange multiplier test ($RobustLM_{lag}$) statistically identify that the SLM is the most appropriate specification.

The second and third columns in Table 7 list the results obtained from the estimation based on the SLM and SEM specifications. It is noted that although the results of the Lagrange multiplier test and the robust Lagrange multiplier test indicate that the SLM model is more appropriate than SEM, the results of estimations based on both models are reported in this study, in order to examine the similarities and differences. For both the SLM and SEM, the results obtained still affirm the positive contribution of labor, capital, export involvement, age of firms,

FDI, and education of labor on firms' productivity. However, the applicable provincial minimum wage and provincial governmental expenditure do not yield a statistically significant impact. Following the theoretical concept of the key features of the spatial econometric approach discussed in section 3.3, the coefficient of the spatial lag of value-added (W_{ln_VA}) identifies the magnitude of productivity spillover from the neighboring provinces. In this study, the result of SLM affirms that there exists a positive spatial externality of productivity with a magnitude of 0.16, and this outcome reveals that the productivity spillover is one of key factors generating agglomeration in the Extended BMR. In other words, the proximity to other high productivity firms can increase the value-added. Hence, the industrial sector and highly skilled labor are induced to cluster within the area of the Extended BMR.

6. Conclusions and policy recommendations

This study has empirically examined the monocentric growth pattern in Thailand. The spatial statistical test was applied to the night time light data combined with the ground survey. This test indicated that the urban density, represented by night time light, has a spatial correlation with the clustering pattern of industrial density, firms' productivity and high labor skill. The most statistically significant relationship was only found in the area of the Extended BMR. This spatial empirical test confirms the existence of a monocentric growth pole, whereby the physical evidence observed by satellite is consistent with the socio- economic characteristics.

The second part of this study applied the spatial econometric technique to the nationwide industrial survey. The outcome of this spatial empirical test verifies the existence of positive spillover of productivity. This result reveals that this positive externality is one of main factors generating agglomeration, leading to the formulation of a monocentric growth pole in Thailand.

Thailand has mostly main maintained its growth path during the past fifty years, enabling the country to achieve the development status of the upper middle income level, but the economic expansion has been concentrating within a limited location, particularly in the area of the Extended BMR. This historical characteristic of growth has led to two significant concerns regarding the future development of Thailand. Firstly, there is a conventional consensus among economists in the public, private, and academic sectors that the country has to progress with the development path in order to achieve the status of high-income level. However, there is still a question regarding the appropriate development strategy, which is, will the existing industrialization policies for export-led growth sustain the economic expansion over the

long-term? Also, this question is related to the second concern, which is the geographical dimension of economic growth. Specifically, the second crucial question for the policy makers is, will the monocentric pattern allow the country to sustain future growth? If the government would like to sustain long-term growth by establishing a second growth pole, this study suggests that the infrastructure and other support schemes (e.g. tax incentives) should generate spillover effect of at least the same magnitude as that revealed by this study. Otherwise, the expansion of production and other economic activities will continue be concentrated within the Extended BMR area.

Table 7: Regression results

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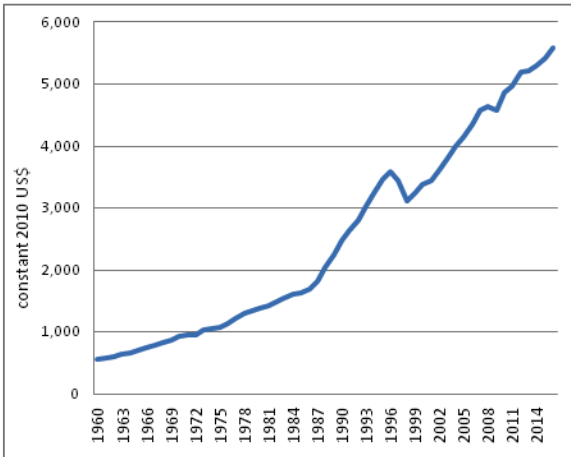
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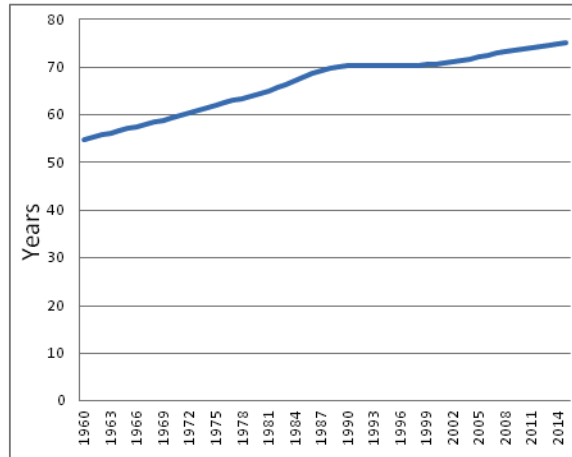
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Figure 1: GNI per capita



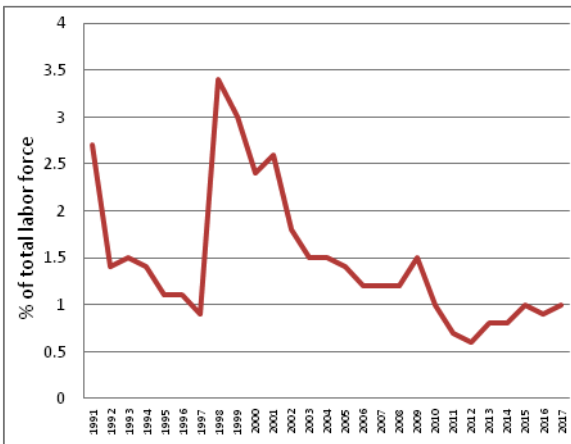
Source: World Bank's World Development Indicators

Figure 2: Life expectancy



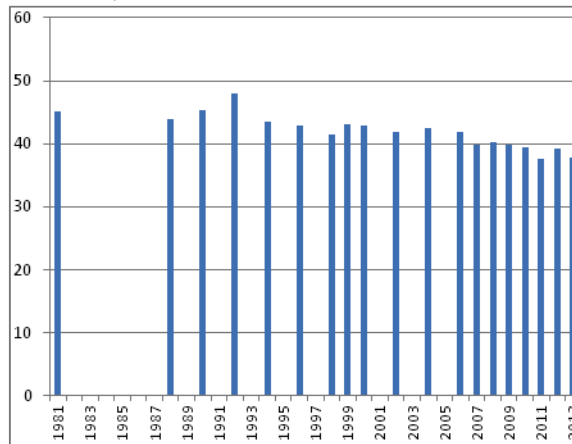
Source: World Bank's World Development Indicators

Figure 3: Unemployment



Source: World Bank's World Development Indicators

Figure 4: GINI index (World Bank estimate)



Source: World Bank's World Development Indicators

2

Table 1: Ranking of the urban primacy index

Highest urban primacy		Lowest urban primacy	
Thailand	9.48	Benin	0.58
Suriname	8.24	South Africa	0.59
Togo	7.92	Venezuela	0.65
Uruguay	7.37	Netherlands	0.70
Chile	5.98	Egypt	0.72
Uganda	5.94	Australia	0.76
Ethiopia	5.82	China	0.78
Mongolia	5.67	United States	0.84
Peru	5.43	Bolivia	0.84
Guinea	5.27	India	0.86

Source: Short & Pinet-Peralta (2009)

Table 2: The distribution of population, 1970-2010.

	1970	1980	1990	2010	% change between 1990 and 2010
City ^a	3.185	4.815	5.882	7.827	33.1%
Metropolitan ring ^b	0.619	0.886	1.345	2.393	77.9%
Metropolitan area ^c	3.804	5.701	7.227	10.220	41.4%
Outer fringe	0.884	1.133	1.363	2.164	58.8%
Metropolitan region ^e	4.688	6.834	8.590	12.384	44.2%
Extended region ^f	2.774	3.503	4.199	5.909	40.7%
Mega-urban region ^g	7.462	10.417	12.789	18.293	43.0%

Source: Robinson (2011)

Notes: ^a Bangkok Metropolitan Administration

^b Nonthaburi and Samut Prakan provinces

^c *Greater Bangkok (a) + (b)*

^d Pathum Thani, Samut Sakhon, and Nakhon Pathom provinces

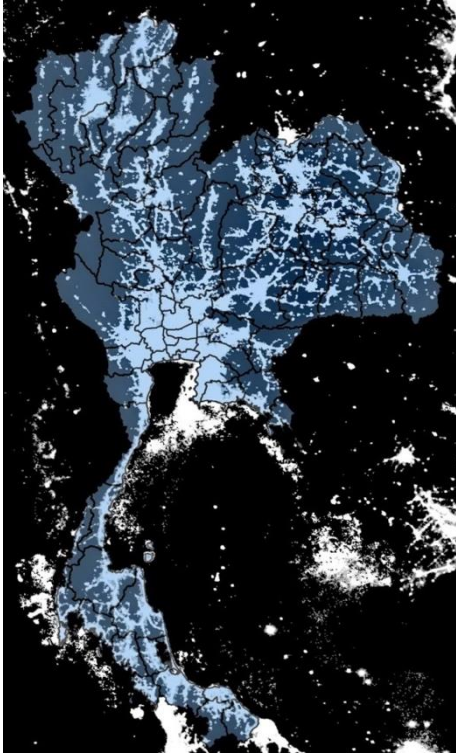
^e Bangkok Metropolitan Region (c) + (d)

^f As defined by the Thailand Development Research Institute for the Seventh Development Plan; this area includes the provinces of *Phetchaburi, Ratchaburi, Ayuthaya, Saraburi, Chachoengsao, Chonburi, and Rayong*

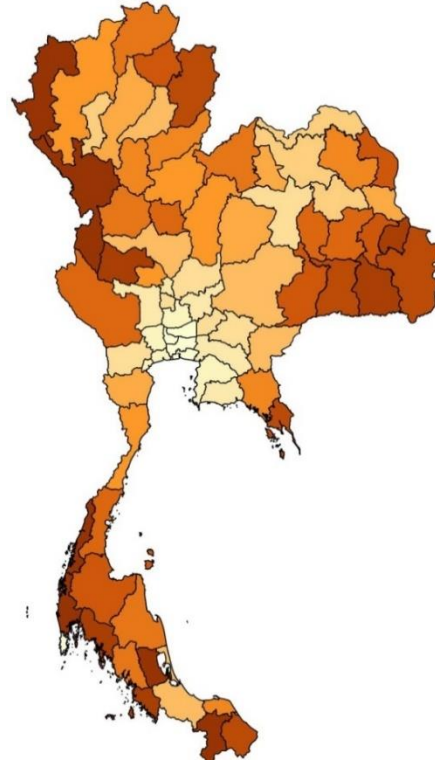
^g Extended Bangkok Metropolitan Region (e) + (f)

Figure 5: Data transformation (from DMSP/OLS data to the NTL index)

DMSP/OLS data for 2011

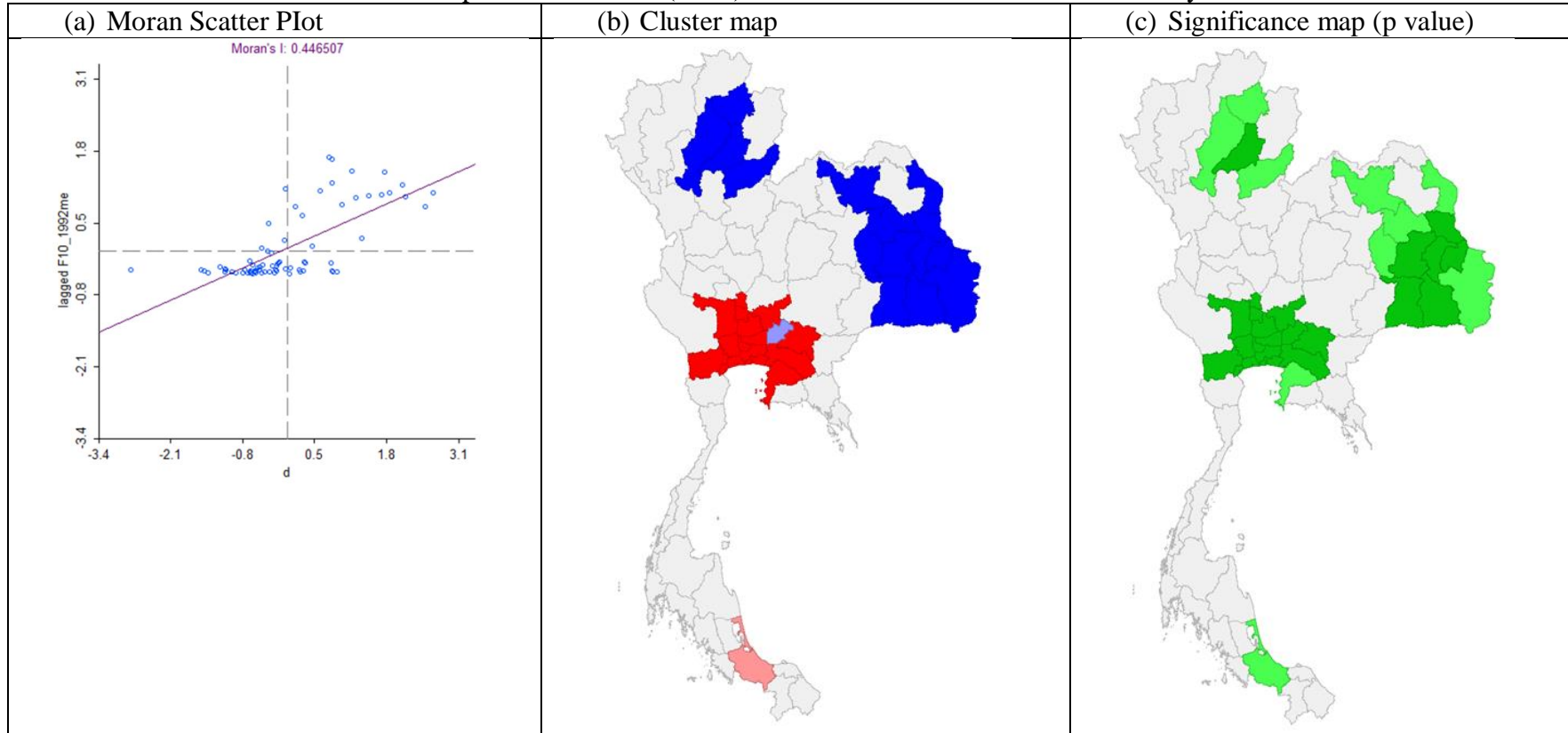


Provincial NTL index for 2011 based on DMSP/OLS data



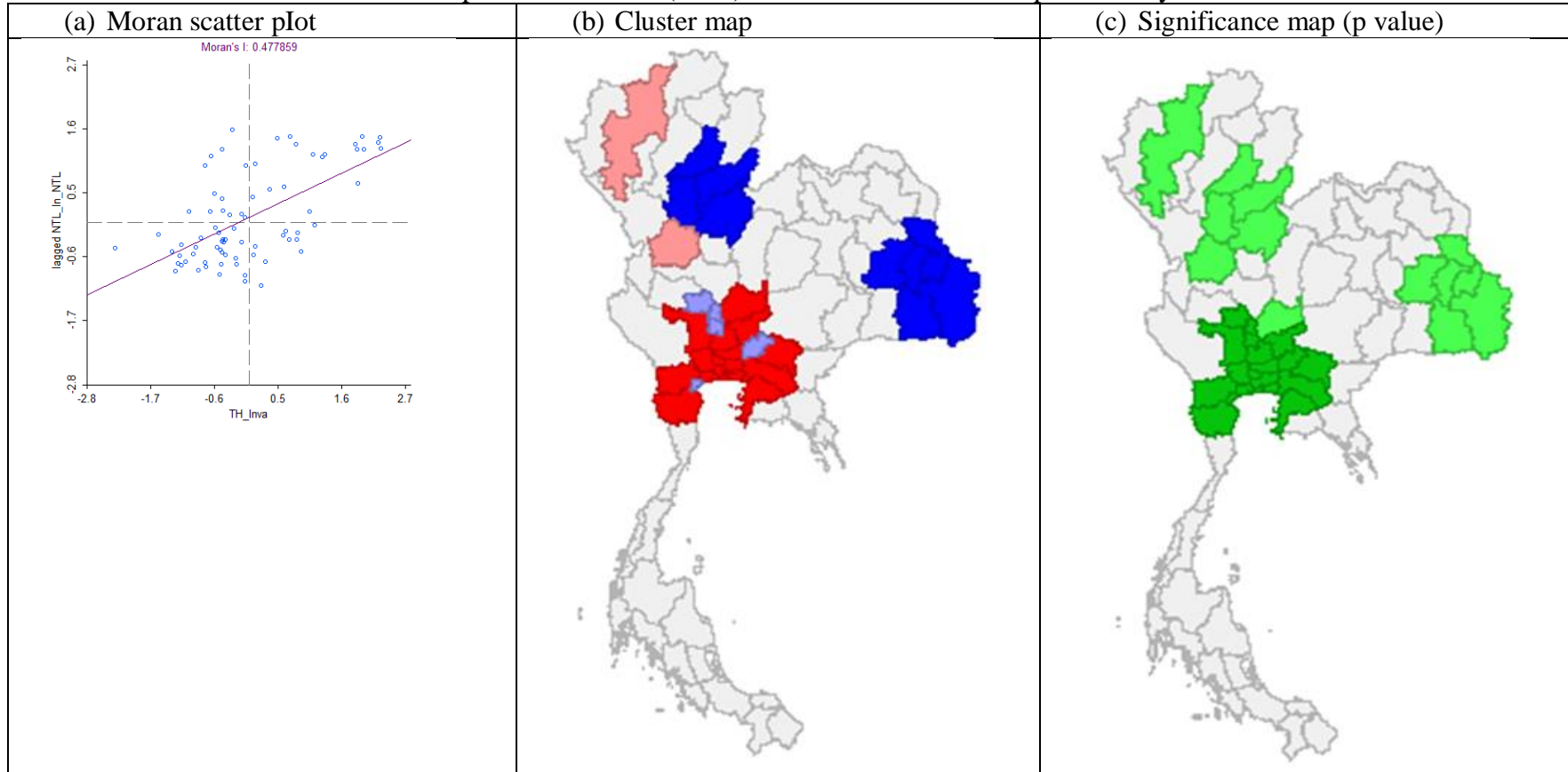
Source: Author's calculation based on DMSP/OLS data

Table 3: Result of local indicators of spatial association (*LISA*) between NTL and the industrial density



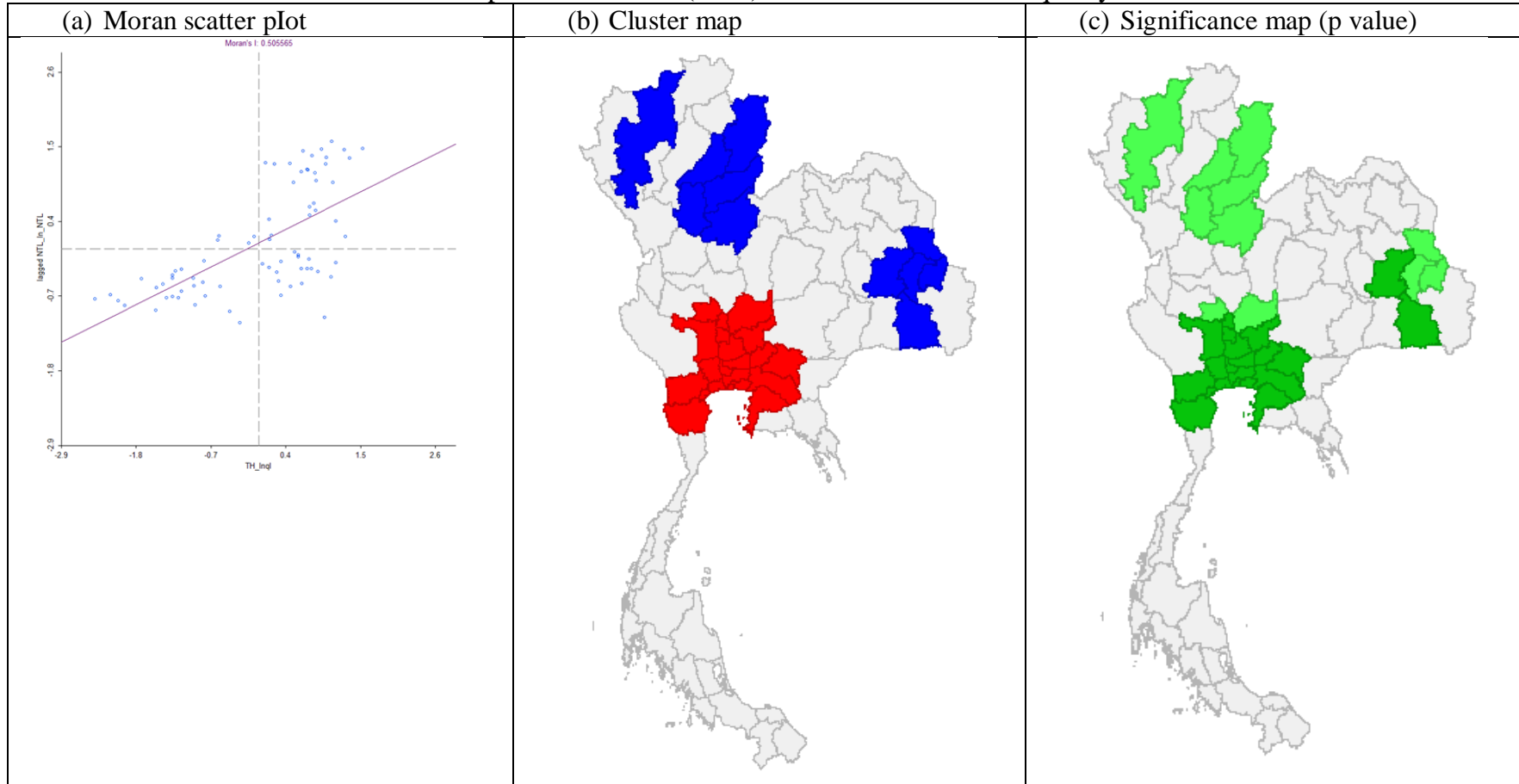
Source: Author's calculation

Table 4: Result of local indicators of spatial association (*LISA*) between NTL and firms' productivity



Source: Author's calculation

Table 5: Result of the local indicators of spatial association (*LISA*) between NTL and labor quality



Source: Author's calculation

Table 6: Summary of results obtained from the Local Indicators of Spatial Association (*LISA*)

LISA tests	Provinces with statistically significant associations	
	High values for both NTL and the surveyed indicator*	Low values for both NTL and the surveyed indicator**
Test #1: NTL and industrial density	Bangkok, Nonthaburi, Pathum Thani, Samut Prakan, Nakhon Pathom, Samut Sakhon, Samut Songkhram, Ayuthaya, Saraburi, Suphanburi, Angthong, Singburi, Chonburi, Chachoensao, Prachinburi, Ratchaburi	Phayao, Lampang, Phrae, Uttaradit, Kalasin, Nakhon Phanom, Mukdahan, Mahasarakham, Roi Et, Yasothon, Amnatchareon, Surin, Sisaket, Ubon Ratchathani
Test #2: NTL and firms' productivity	Bangkok, Nonthaburi, Pathum Thani, Samut Prakan, Nakhon Pathom, Samut Sakhon, Ayuthaya, Saraburi, Suphanburi, Singburi, Chonburi, Chachoensao, Prachinburi, Ratchaburi, Pethchaburi	Phrae, Uttaradit, Sukhothai, Phitsanulok, Mukdahan, Roi Et, Yasothon, Amnatchareon, Sisaket, Ubon Ratchathani
Test #3: NTL and workers' quality	Bangkok, Nonthaburi, Pathum Thani, Samut Prakan, Nakhon Pathom, Samut Sakhon, Samut Songkhram, Ayuthaya, Saraburi, Suphanburi, Angthong, Singburi, Chainat, Lopburi, Chonburi, Chachoensao, Prachinburi, Nakhonnayok, Ratchaburi, Pethchaburi	Chiang Mai, Nan, Phrae, Uttaradit, Sukhothai, Phitsanulok, Roi Et, Yasothon, Amnatchareon, Ubon Ratchathani, Mukdahan

Notes: * painted with dark red color in the cluster map

** painted with dark blue color in the cluster map

Table 7: Regression resultsDependent variable is \ln_VA .

	OLS	Spatial Econometric Model	
		SLM	SEM
$\ln L$	0.39 (0.13)**	0.38 (0.11)***	0.42 (0.12)***
$\ln K$	0.29 (0.09)***	0.25 (0.08)***	0.31 (0.08)***
$\ln EX$	0.12 (0.03)***	0.13 (0.03)***	0.11 (0.03)***
$\ln IM$	-0.01 (0.02)	-0.01 (0.01)	-0.01 (0.01)
$\ln AGE$	-0.66 (0.47)	-0.83 (0.43)*	-0.66 (0.42)
$\ln QL$	0.49 (0.15)***	0.39 (0.14)**	0.45 (0.13)***
$\ln FDI$	0.27 (0.07)***	0.24 (0.07)***	0.22 (0.06)***
$\ln MinWage$	0.18 (1.20)	-0.46 (1.11)	0.17 (1.14)
$\ln GovtBudget$	-0.16 (0.26)	0.04 (0.24)	-0.09 (0.23)
Constant	12.79 (7.69)	11.70 (6.87)*	11.82 (6.93)*
$W_{\ln??_VA}$		0.16 (0.05)***	
λ			0.34 (0.13)**
Statistical detail			
F-stat	97.35		
R-squared	0.93		
Pseudo-R-squared		0.94	0.93
Log likelihood	-50.67	-47.68	-49.49
AIC	121.38	117.36	118.99
Moran' s I	1.71*		
LM_{lag}	5.18**		
LM_{err}	1.32		
$RobustLM_{lag}$	3.94**		
$RobustLM_{err}$	0.08		
# of observation	76	76	76

Notes: The numbers in parenthesis are the standard error. ***, **, and * indicate the level of statistical significance at 1, 5, and 10 percent, respectively. OLS = ordinary least square, SLM = spatial lag model, SEM = spatial error model, LM = Lagrange multiplier test, AIC = Akaike information criterion, RobustLM_{lag} = robust Lagrange multiplier test for spatial lag model, and RobustLM_{err} = robust Lagrange multiplier test for spatial error.

Source: Author's calculation