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## **Growth Dispersion of Asean Countries: Evidence from Night Lights**

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### **Abstract**

The spatial dispersion of growth is as important as growth itself because it can indicate the degree of inclusiveness, urbanization, and unbalanced development. This paper used data on night lights at the sub-national level of ASEAN countries from 2005 to 2010. A dispersion of growth is defined as a standard deviation normalized by a level of night lights in each sub-national area. This paper shows that the night light measure is an efficient proxy of gross sub-national output. The estimation also indicates that democratic institutions for ASEAN6 can improve the degree of growth dispersion, whereas an effect of regional linkages can either increase or decrease the means of transportation and level of development of a country. Most of the factors for CLMV, which are countries with a beginning stage of growth, support less dispersion of growth owing to the low effectiveness of domestic developmental distribution mechanisms.

**Keywords:** Economic Growth, Night Lights, ASEAN, Spatial Inequality, Urbanization, Growth Dispersion

## 1. Introduction

Economists have long been interested in economic growth because it is an indicator of social development and individual well-being. Growth has many advantages, and encouraging economic growth has been the goal of many countries. Moreover, economic growth can be comparable among countries and time, which is another reason why most academic studies have concentrated on economic growth.

However, many empirics suggested that growth itself may not always be beneficial to society. The economy may grow with inequality. In some countries, institutions do not provide equal resources and opportunities at the beginning, resulting in the development of unequal conditions. Individuals within the same country obtain unequal advantages from their economic growth, which cannot bring sustainable development.

Economic growth refers to the level of growth of an economy. Economists view that economic growth as not only referring to the level but also to the diffusion of growth, which is defined as the dynamic distribution of economic benefits. The development can be sustained if this distribution is equalized. Sachs (2012) indicated that level and diffusion of growth are similarly important. The distribution of benefits is the key to ensuring inclusive growth, which supports long term development. Ensuring that some areas do not lag behind creates effective exchange, expanded market, and efficient division of labor. Thus, sustainable development needs to focus on both the level and diffusion of economic growth.

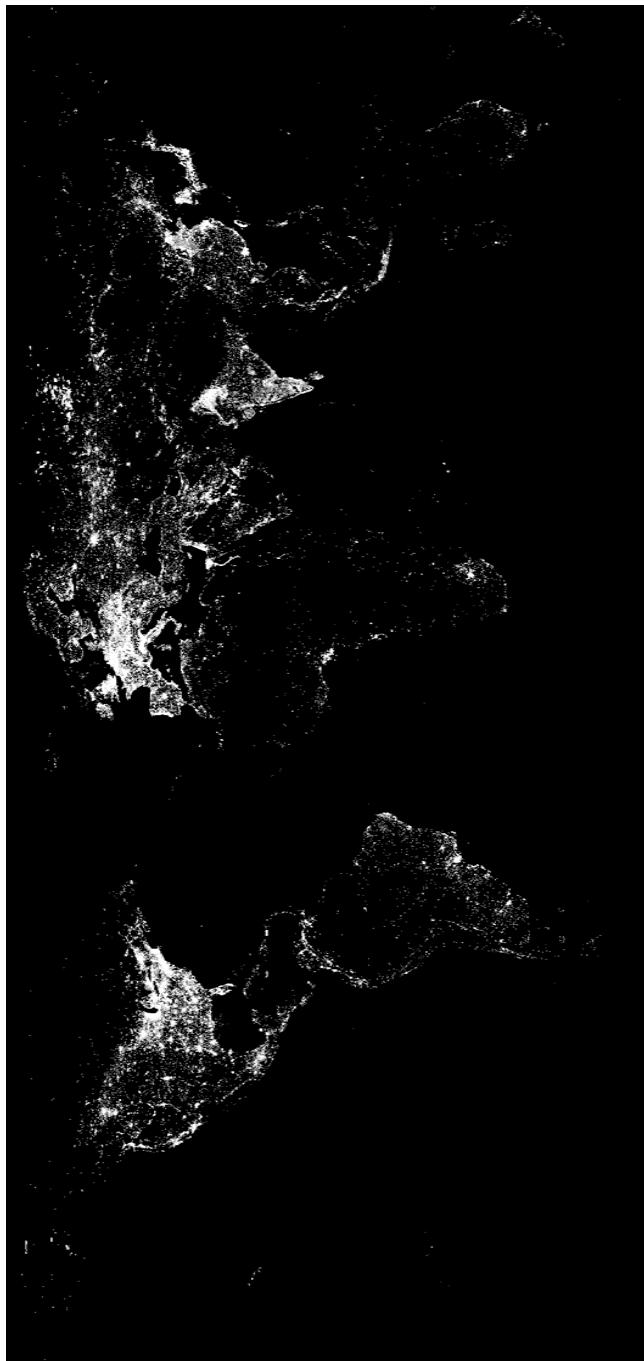
Measuring the diffusion of growth has various challenges. Henderson, Storeygard, and Weil (2012) proposed a novel and credible instrument to proxy economic activities including growth, that of night lights. Night lights can measure the level of growth for each area of interest effectively because its dispersion can show the diffusion of economic activities. Night lights have been used to estimate events on Earth. The U.S. Airforce Defense Meteorological Satellite Program (DMSP) has used censor-detecting Visible and Near Infrared (VNIR), which measures and forecasts with meteorological purposes, for various big cities since 1942.

Night light images from outer space have been applied by Croft (1973, 1978, and 1979) to estimate human economic activities because the lights were recorded in film strips format. Welch (1980) used night light images to evaluate the energy consumption rate of big cities. Sullivan (1989) converted film strips into raster images with 10x10 km resolution, which later became the starting point in the continuous collection of data in raster format.

Elvidge et al. (1997) linked night lights of 21 high density areas in 1994–1995 to economic activities, such as GDP and electricity consumption values, by log-linear equations, and found a strong relationship between night lights and economic activities. Elvidge et al. (1997) and Doll et al. (2000) used night lights at 1x1 degree to forecast cross-country GDP and determined that estimation is 80% accurate when compared with the GDP reported by the World Resource Institute.

The relationship between night lights and per capita income was investigated by Ebener et al. (2005) in both national and sub-national levels. They tested using various model specifications and determined that both summation and mean of night lights had a high correlation with income per capita. Moreover, grouping countries by agricultural output enabled higher precision. However, although estimation at the national level was good, estimation at the sub-national level was significantly low. The reason for these differences in estimations was explained by Sutton et al. (2007) in their study on India, China, Turkey, and the USA, where they found that migration within country (among sub-national level) could have a significant effect on night lights.

Henderson et al. (2012) proposed estimation of GDP growth instead of GDP level using night lights. They studied countries around the world and found that night lights could be used for efficient estimation of GDP growth of advanced countries or those with good national accounts. Less developed countries or those without good national accounts, such as African countries would have low estimation efficiency. They also showed statistically that night lights best fitted proxy income growth. Figure 1 shows the night lights around the world in 2010. Kulkarni et al. (2011) studied the relationship between night



**Figure 1.** Raster Image of night lights at 2010 (NOAA's Earth observation group)

lights and GDP growth in 2001–2007 in China, India, and USA and found that night lights can be used to estimate income and GDP growth. Because estimation with night lights is a novel technique, aiming to study growth appears to be the only objective of economic papers. Studies on the dispersion of night lights as a proxy for the diffusion of GDP growth is minimal. Hence, the present paper aims to measure night lights and use the dispersion of lights relative to light level to represent dispersion of growth.

Section 2 provides details on data and measurement. Section 3 describes the methodology. Section 4 presents the results. Section 5 concludes this paper.

## 2. Data and Measurement

This paper studies 10 ASEAN countries, including Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The dataset used for estimation comes from data on the first layer sub-national level.<sup>1</sup> The study periods are 2005 and 2010. This paper uses 2005 because Cambodia, Laos, Myanmar, and Vietnam (CLMV countries) have some numbers of sub-national data. Hence, CLMV countries can be compared with other ASEAN countries using data from the same period. Among all years in the study period, 2010 had the latest updated and complete dataset for the whole ASEAN countries.

Gross Regional Product (GRP) refers to the value of all final goods and services produced within the borders, either national (GDP) or sub-national (GPP), and serves as the definition of a country's economy in a year. GRP is collected from various local sources, mainly from the national statistical offices of each country. ASEAN6 and Vietnam have complete datasets, whereas Cambodia, Laos, and Myanmar have few datasets.

Night lights data are collected in raster image form by the Defense Meteorological Satellite Program (DMSP) and the Department of Defense program run by Airforce Space and Missile Systems (SMC). Night lights

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<sup>1</sup> The first layer sub-national level of Singapore is country level. Hence, Singapore cannot be explored in the sub-national level.

data are provided by NOAA's Earth Observation Group. DMSP's night light satellite imagery covers the whole planet between latitudes 65 degrees N and 65 degrees S at a resolution of 30 arc second, which is roughly equivalent to an area of 0.81 square kilometers near the equator. This paper has clipped an image into the ASEAN area. The data are filtered to remove light caused by forest fires and any other natural sources, such as northern and southern lights. Thus, the end result is an image at the global level of lights generated mostly by human activity. Luminosity or light intensity is a digital number between 0 and 63, where zero refers to no light and 63 stands for maximum light. However, the top coding of 63 is an artifact of the limitations of satellite sensors and appoints to a problem in measuring growth over time, especially in densely populated urban regions.

Let  $i$  index the region,  $\tilde{y}_i$  be the true real GRP, and  $\hat{y}_i$  the measured GRP. The relationship between true and measured GRP is given by

$$\tilde{y}_i = \hat{y}_i + \varepsilon_{\tilde{y},i}, \quad (1)$$

where  $\varepsilon_{\tilde{y},i}$  is a measurement error in the true GRP of region  $i$ .

Let  $NL_i$  be the level of observed lights of region  $i$ .  $NL_i$  results from the true GRP within a country with consumption and production channels. Hence

$$NL_i = \beta_i \tilde{y}_i + \varepsilon_{NL,i}, \quad (2)$$

where  $\beta_i$  is correlation between true GRP and night lights, and  $\varepsilon_{NL,i}$  is a measurement error in night lights of region  $i$

The assumption that underlies this specification is that the total observable lights in a region ( $NL$ ) and total true income ( $\tilde{y}$ ) share a simple constant relationship in their same region. However, because the night light dataset is only man-made, it increases with the number of people and true income.

The error term in Equation (2) is a noise in the way measured lights reflect GRP. This noise includes measurement error in lights, that is, the difference between true light emanating into space and what the satellite records. Measurement error in GRP is not related to an error in the equation that determines observable light,  $Cov(\varepsilon_{\tilde{y},i}, \varepsilon_{NL,i}) = 0$ . The equation for the estimation of the relationship between output and lights is

$$\hat{y}_i = \hat{\Psi}_i NL_i + \varepsilon_i. \quad (3)$$

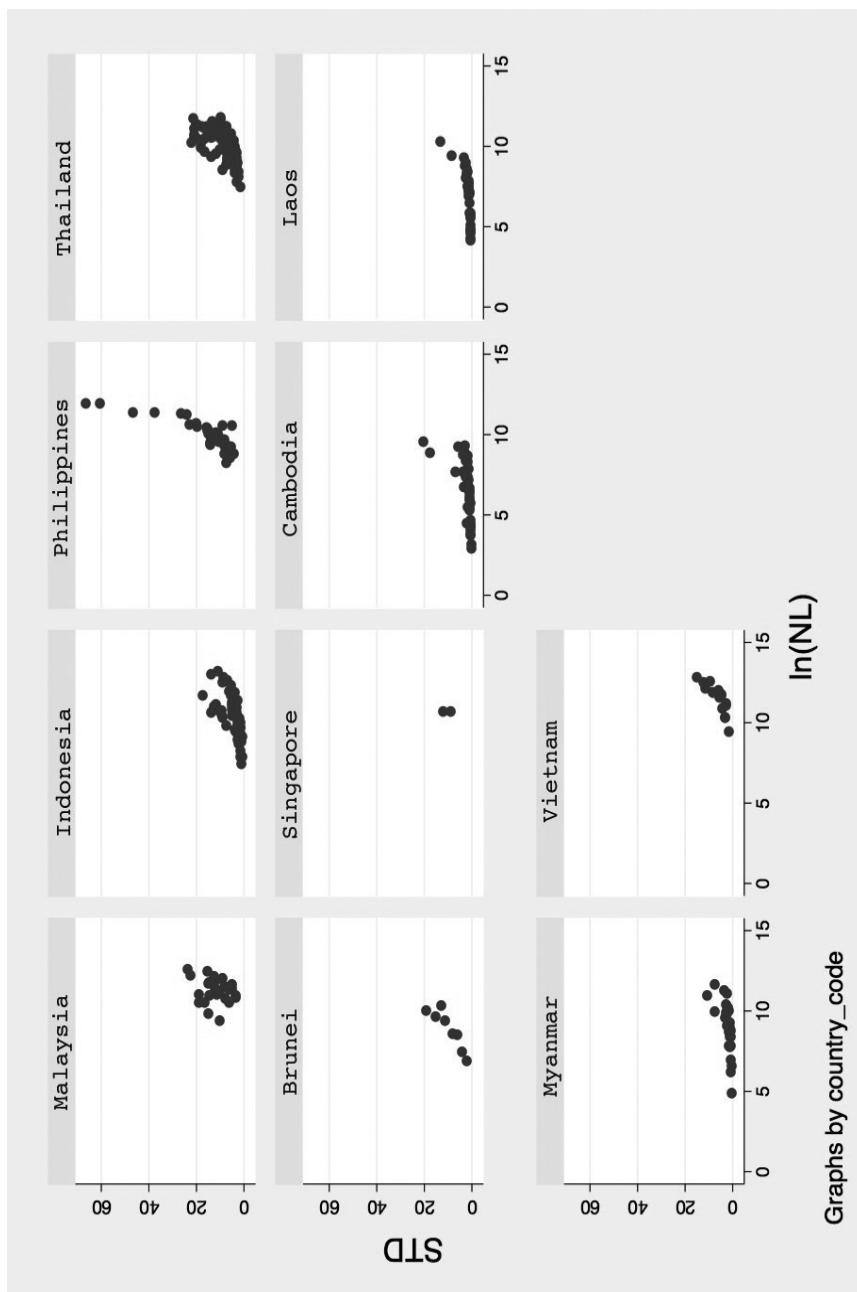
The OLS parameter  $\hat{\Psi}_i$  is  $Cov(NL, \hat{y}_i) / \text{var}(x)$ , which gives a biased estimate in  $1/\beta$ . This paper does not aim for a precise estimator. Thus, the equation considers  $\hat{\Psi}_i$  as a best fit relationship for use in producing proxies for true income growth. These proxies are  $\hat{y}_i = \hat{\Psi}_i NL_i$ .

The growth of night lights best fits GRP growth. Thus, the dispersion of night lights should reflect the distribution of economic output. This aspect is an advantage of night light measure because the dispersion of true real income is unobservable.

**Dispersion of Growth:** The spatial dispersion of growth in this paper is defined as growth with the equal dispersion of economic output, and is measured by the Coefficient of Variation (CV), which refers to dispersion relative to the level of night light growth. The CV is defined as the ratio of the standard deviation to the mean of any variable of interest. This paper applies CV as the standard deviation-to-growth of night lights. An increase in CV indicates the standard deviation of night lights relative to growth, which implies that some areas lag in development relative to few areas (i.e., the capital). This case shows low dispersion per unit of growth or high growth-concentration. High growth-dispersion or low growth-concentration exists if CV decreases. Lower CV is preferable under the concept of spatially inclusive growth.

Figure 2 shows the scatter charts of standard deviation and night lights of all ASEAN countries. For ASEAN6, the Philippines has the highest dispersion of night lights. Malaysia has higher spatial dispersion of growth than other ASEAN countries. CLMV shows growth in few big cities.

Figure 2. Relationship between standard deviation and night lights (in log form)



**Democratic Institutions:** Democratic institutions are one of the key factors that foster the diffusion of economic output. Democracy is the empowerment of people by including them in a country's development process. The benefit of growth would be more diffused if more people are included in economic activities. This paper measures the quality of democratic institutions using two variables. First, this paper uses the revised combined polity score (Polity2) of the Polity IV databases (Marshall and Jagers, 2005). This variable combines scores for constraints on the chief executive, competitiveness of political participation, and the openness and competitiveness of executive recruitment, with scores ranging from -10 to +10. Higher values indicate more democratic institutions.

Second, the quality of democratic institutions can be measured by the level of corruption. Corruption coincides with low quality because of the lack of supervision. It also results in lesser probability for people to cooperate leading to the failure of collective action, and highlights the extracting growth. The variable used to identify corruption level is Corruption Perception Index (CPI), which is collected from Transparency International. The CPI scores are based on how corrupt a country's public sector is perceived. The CPI is a composite index and a combination of surveys and assessments of corruption, which are collected by a variety of reputable institutions. The CPI ranges from 0 to 10. Higher values indicate lower levels of corruption.

**Regional Linkages:** Areas with regional (i.e., international and domestic) connections should have higher growth relative to areas without connections. Regional linkages (i.e., trade and travel) bring foreign income into areas. However, data on the values of regional linkages of each sub-country area are unavailable. This paper uses dummy variables to proxy regional linkages; these variables include the number of commercial airports (#AIRPORT), international airports (#INTERPORT), and seaports (#SEAPORT) in each area. However, the interpretation of the three variables may not be exactly the same. The number of commercial airports indicates domestic passengers, whereas the amount of international airports indicates at most, the number

of international passengers. The number of seaports is indicative mainly of exports and imports. The different results of estimation among the three variables could lead to varied interpretations.

### 3. Methodology

This paper is divided into two parts. The first part tests how night lights can measure economic activities of ASEAN countries effectively, while the second part evaluates factors that drive the spatial dispersion of growth of ASEAN countries.

This paper only uses available sub-country level dataset in 2005 and 2010 to measure economic activity with night lights because of the ability to check for efficiency. The estimation is done by the fixed-effects model and then checks whether the coefficient is statistically significant. The equation relates GRP ( $y_i$ ) to region-specific effects ( $\alpha_i$ ), a year-specific effect ( $\phi_t$ ), and growth of night lights ( $NL_i$ ).

$$NL_i = \beta y_i + \alpha_i + \phi_t + \varepsilon_{NL,i} \quad (4)$$

where  $\varepsilon_{NL,i}$  is a disturbance term, and  $\beta_i$  represents the relationship between GRP growth and growth of night lights of ASEAN countries.

This paper also uses sub-national data to examine the factors affecting dispersion of growth. Estimation is performed using the fixed-effect model under control variables. The equation relates the dispersion of growth, which is measured by CV, to region-specific effect ( $\alpha_i$ ), democratic institutions (Polity2 or CPI), and regional linkages (AIRPORT, INTERPORT, and SEAPORT).

$$CV_i = \beta_1 Polity\ 2_i \text{ (or } CPI_i \text{)} + \beta_2 \# AIRPORT_i + \beta_3 \# INTERPORT_i$$

$$+ \beta_4 \# SEAPORT_i + \delta_i CAPITAL_i + \alpha_i + \eta_{CV,i},$$

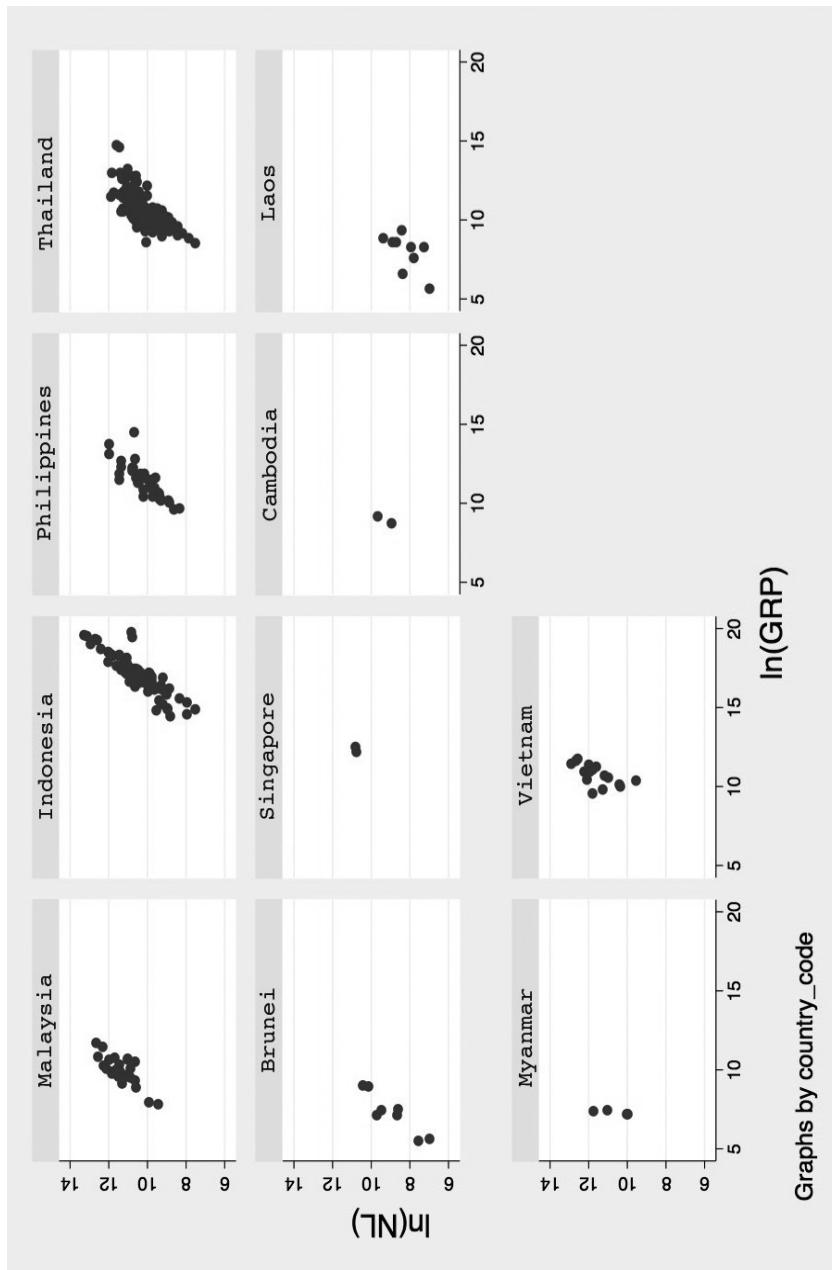
where  $\eta_{CV,i}$  is a disturbance term, and  $CAPITAL$  is a dummy variable to represent the capital city of each country.

## **4. Results**

### **4.1 Night lights as a measure of economic activity.**

This subsection shows how good night lights as proxy in the GRP in ASEAN countries and checks the efficiency of night lights to measure GRP. Figure 3 shows a scatter plot of night lights and GRP of each country. A clear positive correlation is seen through eyeballing. This paper plots complete data for ASEAN6 and Vietnam, and only available data (on GRP) of Cambodia, Laos, and Myanmar.

Figure 3. Relationship between night lights (in log form) and GRP (in log form)



**Table 1:** Fixed effect estimates of night lights and GRP

		ln(NL)							
		ASEAN6				CLMV			
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(GRP)		0.1245*	0.6883***	0.6501***	0.8507*	0.7621*	0.6025*	0.5634**	2.3974***
		(0.0218)	(0.0892)	(0.0983)	(0.1058)	(0.2744)	(0.2059)	(0.1330)	(0.4962)
Country FE	no	yes	yes	no	no	yes	yes	yes	no
Region FE	no	no	no	yes	no	no	no	no	yes
Year FE	no	no	yes	yes	no	no	yes	yes	yes
R-squared	0.1261	0.6886	0.7622	0.1261	0.5378	0.8497	0.575	0.5378	
#Obs	288	288	288	288	31	31	31	31	

Method of estimation is fixed effects OLS with robust standard error and clustered by country (shown in parentheses). \*\*\*, \*\*, and \* indicate significance at 1-, 5-, and 10-percent levels, respectively.

Table 1 shows the estimation of relationship between night lights (in log form) and GRP (in log form). Columns (1)–(4) report results of ASEAN6 countries and column (5)–(8) report results of CLMV.

Column (1) does not include fixed effects, and shows a strongly significant correlation between night lights and GRP of ASEAN6 countries. Column (2) controls country fixed effects and indicates a strongly significant relationship. The value of coefficient in Column (2) is lower than that of Column (1) because the equation in Column (2) captures variances between countries. Column (3) adds year fixed effect to capture time variant factors. Result shows strong significance in Columns (1) and (2).

The result of the relationship between night lights and GRP under regional fixed effects is shown in Column (4). The strong significance of its coefficient implies a strong relationship even in the sub-country level. The equations indicate that night lights can efficiently proxy GRP in each region of ASEAN6 countries.

Columns (5)–(8) report the repeated estimation of ASEAN6 to CLMV countries. Results in these columns are in line with the results of a previous study that found that night lights and GRP have a strongly significant correlation. The coefficient in Column (8) is significantly high because of the inefficient recording of GRP for CLMV.

#### **4.2 Dispersion of growth and its determinants**

This paper uses the coefficient of variation to measure the dispersion of growth inversely. Thus, CV is defined as the ratio of the standard deviation to the growth of night lights. The lower CV means that the more equal distribution of nightlights across area which implies better dispersion of growth. The unit of analysis is first layer regional level. Increased equal distribution of night lights or higher dispersion of economic growth is reflected by the lower value of coefficient of variation. This paper expects the negative relationship between CV and polity2 (or CPI) because bad institutions reduce probability to expand growth benefits, while the amount of infrastructure can be positive or negative.

Table 2 reports country fixed effects estimation between the dispersion of growth and its determinants, namely, democratic institutions, regional linkages, and capital city. The results of all ASEAN countries are shown in Columns (1)–(2), ASEAN5 in Columns (3)–(4), and CLMV in Columns (5)–(6). Brunei is excluded from the estimation because of its lack of data of democratic institutions.

Columns (1)–(2) report the factors of dispersion of growth of ASEAN countries. Polity2 score has a significantly negative relationship with CV, whereas the coefficient of corruption perception index has a negative but insignificant value. This correlation indicates that the quality of democratic institutions improved the dispersion of economic growth. Regional linkages can affect the dispersion of growth in different ways. The results in Columns (1) and (2) move in a similar direction. The amount of commercial airports

increases the dispersion of growth, whereas the amount of international airports decreases it. Commercial airports carry both domestic and international transportation, whereas international airports have mainly an international connection.

Thus, commercial airports distribute economic benefits, but international airports bring mainly foreign travelers to areas; however, foreigners may not help distribute benefits. Seaports are another one of the channels of regional linkages, particularly for export and import products. The effects of the number of seaports are positive and almost significant to increase CV or decrease the dispersion of growth. Seaports may grow faster than other surrounding areas, but the consequences of growth from seaports concerns the income distribution mechanisms of each country. The effect of a capital city is not different from any other cities.

**Table 2:** Estimates of the dispersion of growth

	CV					
	ASEAN		ASEAN5		CLMV	
	(1)	(2)	(3)	(4)	(5)	(6)
Polity2	-0.0341*		-0.0367*		0.0669***	
	(0.0179)		(0.0171)		(0.0000)	
CPI		-0.0955		-0.2219		-0.0693**
		(0.0583)		(0.3153)		(0.0213)
#AIRPORT	-0.1482**	-0.1474**	-0.1720*	-0.1713*	0.0123	0.0123
	(0.0589)	(0.0588)	(0.0847)	(0.0836)	(0.0348)	(0.0348)
#INTERPORT	0.3272***	0.3264***	0.3259**	0.3250**	0.1433*	0.1433*
	(0.0916)	(0.0913)	(0.1040)	(0.1032)	(0.0590)	(0.0590)
#SEAPORT	0.2300*	0.2258*	0.3580	0.3538	0.1287**	0.1287*
	(0.1305)	(0.1304)	(0.2639)	(0.2617)	(0.0408)	(0.0408)
CAPITAL	0.1948	0.1711	-0.0385	-0.0721	0.4160	0.4160
	(0.3793)	(0.3670)	(0.6780)	(0.6334)	(0.4569)	(0.4569)
Country FE	yes	yes	yes	yes	yes	yes
R-squared	0.4979	0.4939	0.4268	0.4188	0.3725	0.3847
#Obs	408	412	280	284	128	128

Method of estimation is fixed effects OLS with robust standard error and clustered by country (shown in parentheses). \*\*\*, \*\*, and \* indicate significance at 1-, 5-, and 10- percent levels, respectively.

This paper divides ASEAN countries into two groups; ASEAN5 and CLMV. Columns (3)–(4) show results on ASEAN5. Equations in this group are similar to the cases of all ASEAN countries. Democratic institutions and commercial airports increase dispersion of growth, whereas international airports decrease it, they are statistically significant or almost significant. Seaports and capital cities do not have significant effects.

The results on CLMV are different in some ways from ASEAN5 countries. The results are shown in Columns (5)–(6). Polity2 score shows that increasing democracy will increase the unequal distribution of growth, this may happen because the democracy of CLMV is better in the urban area than the rural area. When they start to develop, the urban take effect first, then disperse to the rural. While CPI shows that the more corruption, the more distribution of growth, because politicians in the low democratic country may corrupt through infrastructure projects. When they add more projects, they take more corruption together with distribute the growth to rural areas. Developing these areas within a short period will entail excessively high costs. Growth matters only in some supportive areas when democratic institutions improve. The amount of commercial airports does not have a significant effect on the dispersion of growth, which differs from those obtained by previous studies. This result is different from other cases. This may have resulted from the low additional airport in each country. In the initial stage of development, the number of international airports and seaports increases growth together with standard deviation. These infrastructures reduce the dispersion of growth and depend on income transmission mechanisms and the capacity for inclusive institutions in the future. Capital cities do not change the dispersion of growth.

## 5. Conclusion

Satellite night light data are an efficient proxy for economic activity in a region, particularly in ASEAN countries. Night lights can be used to measure growth in the forms of level and dispersion. This paper begins by proposing how night lights measure economic activity efficiently and finds

that both fit factors each other well.

This paper uses the coefficient of variation of night lights to measure dispersion of growth because high dispersion growth exists when the level increases with the decrease in standard deviation. The dispersion of growth of each country is determined by democratic institutions and regional linkages. The higher inclusive democratic institutions cause a high dispersion of growth. Domestic linkages support higher dispersion of growth than international linkages because of poor income distribution mechanisms.

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