SPATIAL INEQUALITY IN MYANMAR DURING 1992- 2016: AN APPLICATION OF SPATIAL STATISTICS AND SATELLITE DATA

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1) Introduction

- According to the World Bank's data, the nation's GNI per capita was at $1,270 in 2014. With this improvement, Myanmar was moved out of the World Bank's low-income economy bracket and has been **placed into the category of lower-middle-income economy**.
- It is necessary for Myanmar government to **reduce the income gap** among regions/states and between urban and rural areas.
- It is important to learn how the **geographical concentration of economic activity** in these countries has changed during this rapid economic growth period.

Main objectives

(1) To verify the possibility of using the **NTL data** as the proxy representing the **socioeconomic condition**.

(2) To examine the **pattern** of **spatial inequality** using the NTL data and methods of geographical **cluster detection**.

2) Related literature

2.1) Principle Component Analysis (PCA) and poverty index

- Lelli (2001), Sallu et al.(2010), Roche (2008), Islam (2013) and Berman et al. (2014) have applied **PCA** in their formulations of indices identifying **the socioeconomic status**.
- Montgomery et al. (2000), Filmer and Pritchett (2001), McKenzie (2005) and Vyas and Kumaranayake (2006) used **PCA** an estimation of **asset-based poverty index**.

2) Related literature

2.2) Nighttime Light (NTL) data and economic development research

- Henderson et al. (2012) and Pinkovskiy and Sala-i-Martin (2016) examined the relationship between **NTL and income per capita**, both published in the **top journals** in the field of economics.
- Papaioannou (2013), Alesina et al. (2012) Ebener et al. (2005) used NTL as a **proxy for income per capita**.
- Kudo and Kumagai (2012) applied NTL as an alternative way to estimate the **distribution of GDP in Myanmar**.

3) Data

3.1) Satellite data

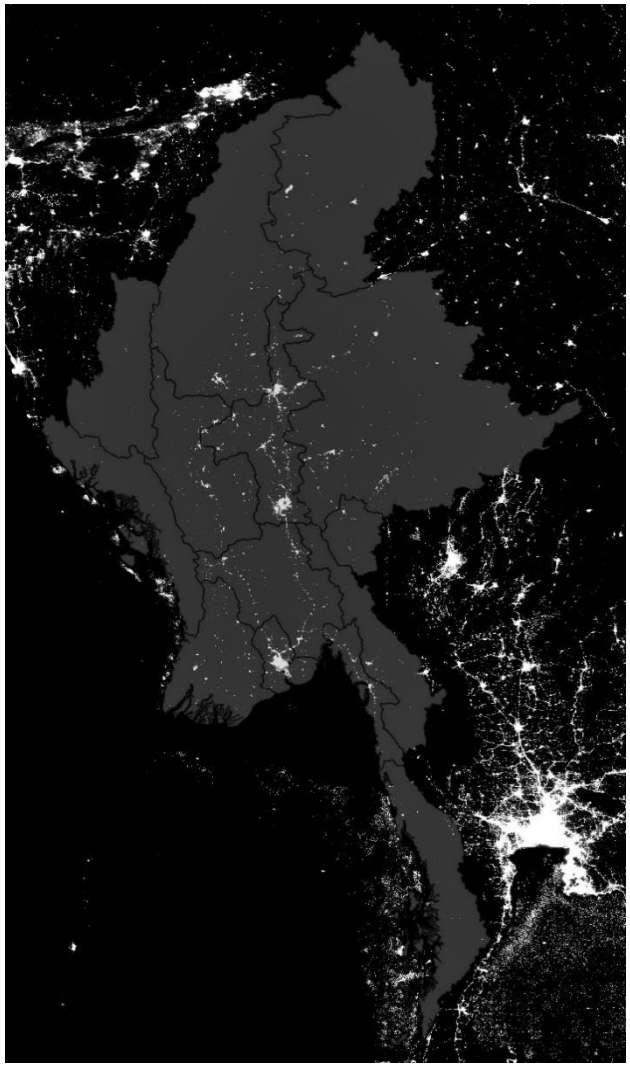
- NTL data obtained from DMSP/OLS (1992-2013)
- NTL data obtained from VIIRS-DNB (2014-2016)

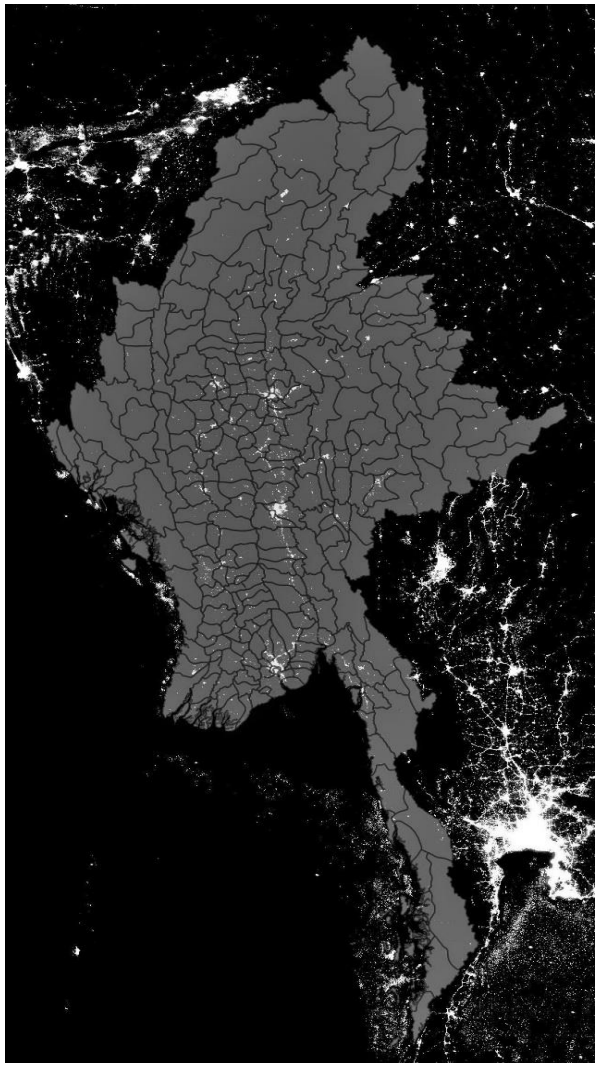
3.2) Survey data

- Integrated Household Living Conditions Assessment (IHLCA)
- Subnational Governance in Myanmar Discussion Paper Series (2013-2014)

	DMSP/OLS						VIIRS-DNB
Year / Satellite no.	F10	F12	F14	F15	F16	F18	
1992	F101992						
1993	F101993						
1994	F101994	F121994					
1995		F121995					
1996		F121996					
1997		F121997	F141997				
1998		F121998	F141998				
1999		F121999	F141999				
2000			F142000	F152000			
2001			F142001	F152001			
2002			F142002	F152002			
2003			F142003	F152003			
2004				F152004	F162004		
2005				F152005	F162005		
2006				F152006	F162006		
2007				F152007	F162007		
2008					F162008		
2009					F162009		
2010						F182010	
2011						F182011	
2012						F182012	
2013						F182013	
2014							VIIRS-DNB
2015							VIIRS-DNB
2016							VIIRS-DNB

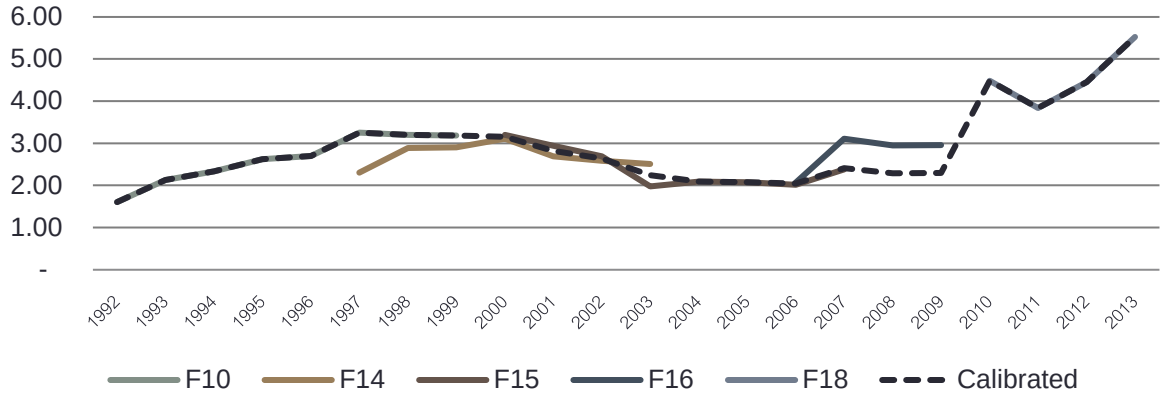
3.1) Satellite data



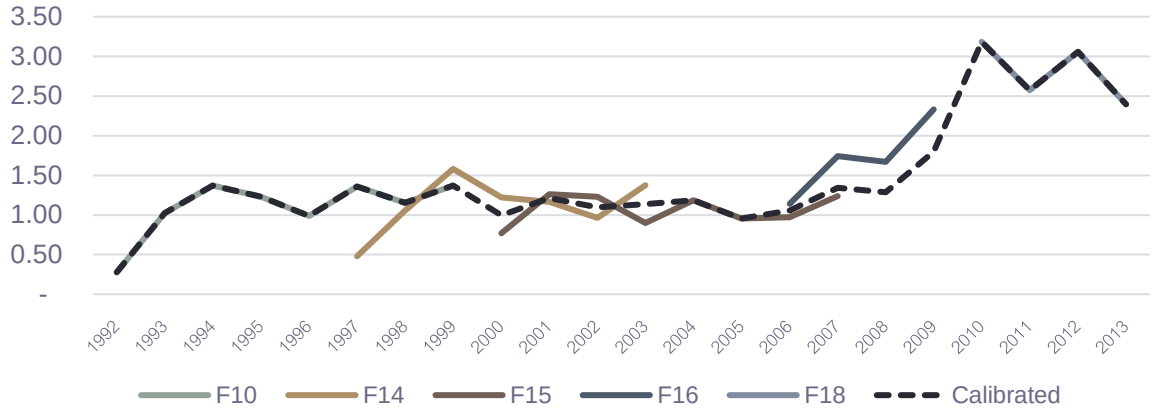


Source: Authors' calculation

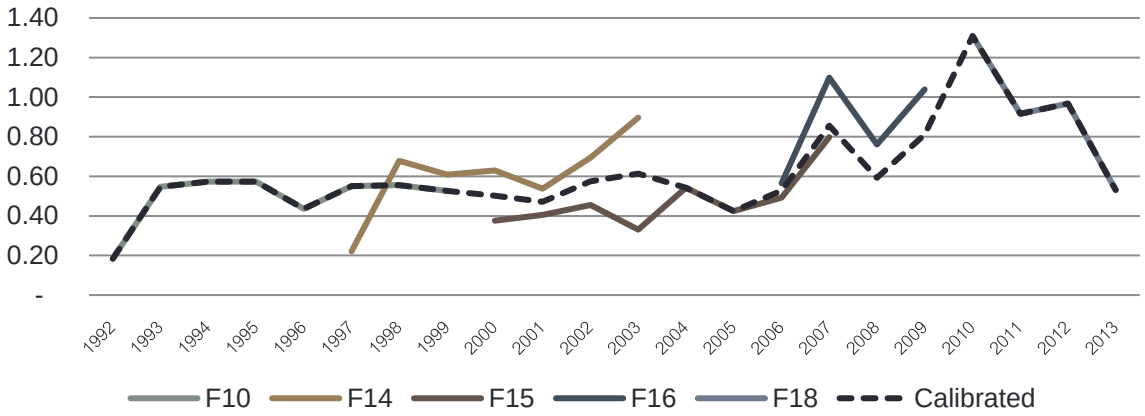
Calibrated NTL index of **Yangon**



Calibrated NTL index of **Madalay**



Calibrated NTL index of **Ayeyarwady**



Source: Authors' calculation

3.2) Survey data

	Variable	Description	Source
1	Consumption_20_pct	Consumption of 20-percent lowest income household	IHLCA Survey 2009-2010
2	Avg_HH_Size	Average household size	IHLCA Survey 2009-2010
3	Demgrph_Depend_Ratio	Demographic dependency ratio	IHLCA Survey 2009-2010
4	Avg_Land_Agri_HH	Average land owned by agricultural household	IHLCA Survey 2009-2010
5	Landless_Rate_Agri	Ratio of households not owning the land	IHLCA Survey 2009-2010
6	Access_to_Credit_Agri	Ratio of agri household accessible to credit	IHLCA Survey 2009-2010
7	Access_to_Credit_Non_Agri	Ratio of non-agri household accessible to credit	IHLCA Survey 2009-2010
8	LF_Participation_Rate	Labor force participation rate	IHLCA Survey 2009-2010
9	Unemploy_Rate	Unemployment rate	IHLCA Survey 2009-2010
10	Underemploy_Rate	Underemployment rate	IHLCA Survey 2009-2010
11	Literacy_Rate	Literacy rate	IHLCA Survey 2009-2010
12	Net_Enroll_Primary	Net enrollment in primary school	IHLCA Survey 2009-2010
13	Net_Enroll_Secondary	Net enrollment in secondary school	IHLCA Survey 2009-2010
14	Access_to_Primary	Accessibility to secondary education	IHLCA Survey 2009-2010
15	Access_to_Secondary	Accessibility to primary education	IHLCA Survey 2009-2010
16	Total_Gov_Expediture	Total government expenditure	Subnational Governance in Myanmar Discussion Paper Series (2013-2014)

4) Research methodology

4.1) Principle Component Analysis (PCA)

4.2) Spatial Cluster Analysis

- Getis-Ord Gi* statistics
- Local Indicators of Spatial Association (LISA)

4.1) Principle Component Analysis (PCA)

- In this study, the main objective of applying PCA was to **construct the new indictor** which is an **aggregate index** representing the **main socio-economic condition** of each region/state in Myanmar.
- Mathematically, PCA is the **transformation of data** generating the **new set of uncorrelated components**. Each is the linear weighted combination of original variables.
- As shown in equation (1), for the original data containing the set of variables X_1, X_2, ...,X_p.

$$
\begin{aligned}
PC_1 &= a_{11} X_1 + a_{12} X_2 + \dots + a_{1p} X_p \\
PC_2 &= a_{21} X_1 + a_{22} X_2 + \dots + a_{2p} X_p \\
&\vdots \\
PC_p &= a_{p1} X_1 + a_{p2} X_2 + \dots + a_{pp} X_p \ ,
\end{aligned}
\qquad (1)
$$

where a_{pp} identifies the weight for the p-th principal component and the p-th variable. The coefficient of the first principle component a_{11}, a_{12}, ..., a_{1p} are the outcome of optimizing the variance of PC_1 subject to the constraint of $a_{11}^2 + a_{12}^2 + \dots + a_{1p}^2 = 1$.

4.2 Spatial Cluster Analysis

The Getis-Ord Gi* statistics

- Developed by Getis and Ord (1995), the Getis-Ord G* statistics is the quantitative method for identifying the **degree of spatial concentration**.
- The outcome can indicate both cases of spatial clustering of **high-value** (i.e. the "**hot spot**") and that of low-value (i.e. the "**cold spot**"). The mathematical representation is shown in equation (2).

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij} X_j}{\sum_{j=1}^{n} X_j} \quad , \quad (2)$$

where G_i^* = the Getis-Ord G_i^* statistics
w_{ij} = the spatial weight matrix
n = number of spatial units

- Getis and Ord (1995) also included the standardized G_i^* statistics that are asymptotically normally distributed. Therefore, this enables the computation of ***p* value**, indicating the **statistically significant level** of the obtained G_i^* statistics.

4.2 Spatial Cluster Analysis

Local Indicators of Spatial Association (LISA)analysis

- Introduced by Anselin (1995), Local Indicators of Spatial Association (LISA) is the alternative method for examining the **degree of spatial dependencies**.
- The obtained statistics identify the statistical significance of the **similarity around the specific location**.
- LISA also identifies the case of statistically significant **negative correlation,** indicating the **statistically significant dissimilarity** between the core area and its neighbor.

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

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

w_{ij} = the spatial weight matrix

n = number of spatial units

$\bar{x}$ = an average of x_{ij}

5) Result discussion

5.1 Socio-economic index obtained from Principle Component Analysis (PCA)

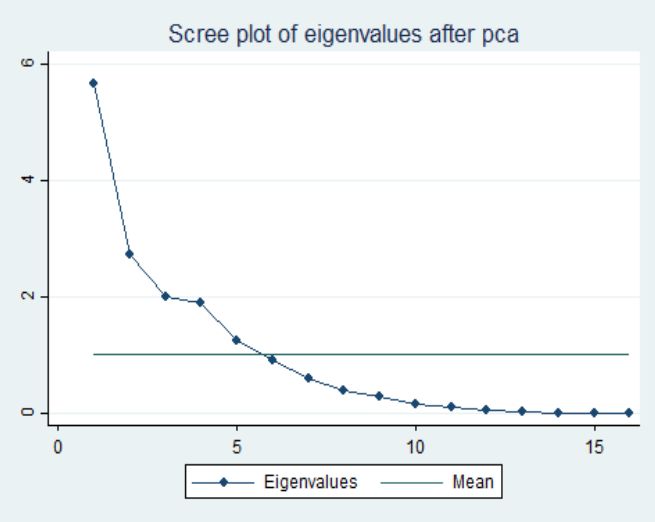
- The outcomes of PCA are principle components.
- Each principle component is the weighted combination of all variables, while the eigenvalue of each principle component represents its degree of contribution to the total variance.

Table 3: Principal components/correlation obtained from PCA

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	5.6425	2.92294	0.3527	0.3527
Comp2	2.71956	0.719056	0.17	0.5226
Comp3	2.0005	0.095196	0.125	0.6477
Comp4	1.90531	0.653587	0.1191	0.7667
Comp5	1.25172	0.344706	0.0782	0.845
Comp6	0.907013	0.315278	0.0567	0.9017
Comp7	0.591735	0.215095	0.037	0.9386
Comp8	0.37664	0.103483	0.0235	0.9622
Comp9	0.273157	0.130431	0.0171	0.9793
Comp10	0.142725	0.0297035	0.0089	0.9882
Comp11	0.113022	0.0647011	0.0071	0.9952
Comp12	0.0483209	0.0205166	0.003	0.9983
Comp13	0.0278043	0.0278043	0.0017	1
Comp14	0	0	0	1
Comp15	0	0	0	1
Comp16	0	.	0	1

Source: Authors' calculation

Figure 9: The Scree plot of eigenvalues obtained from PCA



Source: Authors' calculation

5) Result discussion

Table 4: Principal components (eigenvectors) obtained from PCA

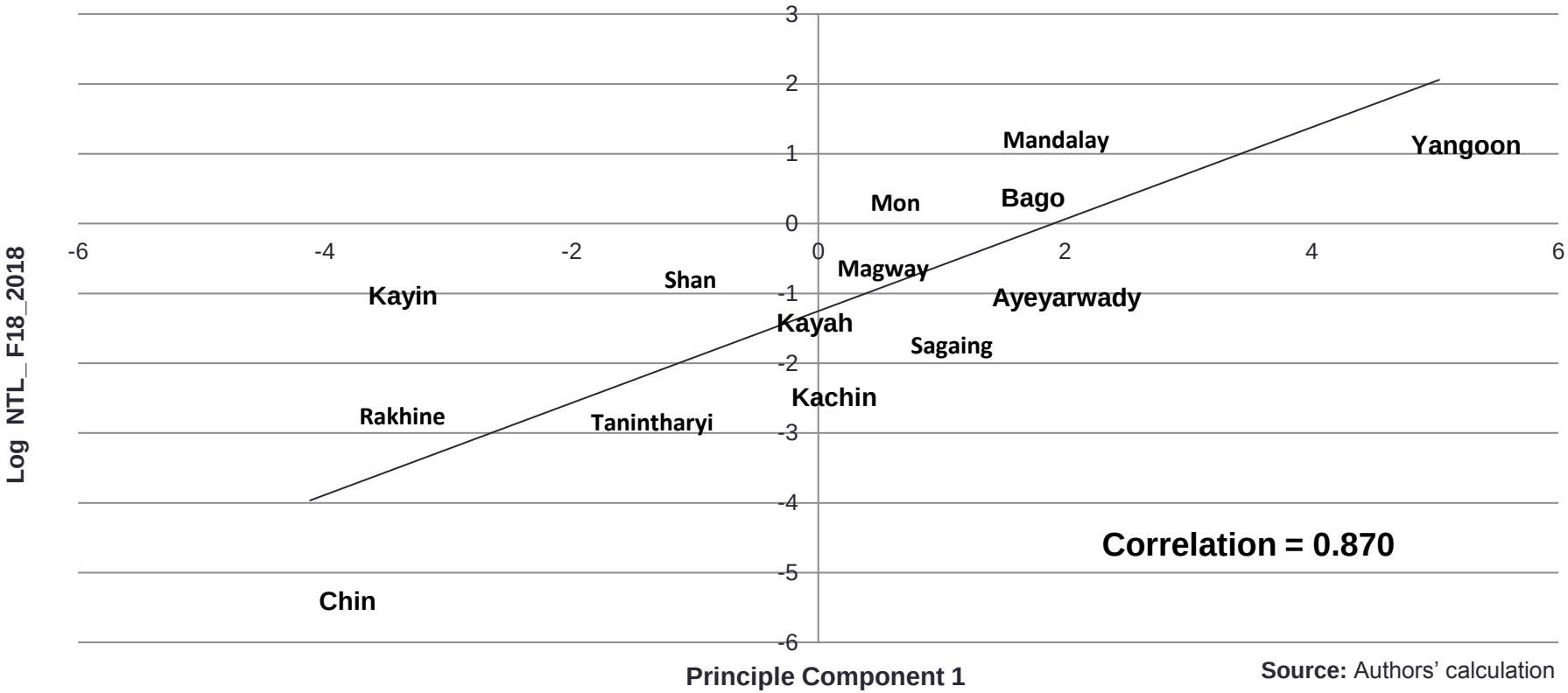
Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9	Comp10	Comp11	Comp12	Comp13
Consumptio~t	-0.192	0.1647	0.1256	-0.4392	0.3734	0.1949	-0.0656	0.4375	-0.183	0.3439	0.2849	0.0262	-0.0832
Avg_HH_Size	-0.3529	0.0455	-0.0369	0.321	-0.089	0.0604	0.1347	0.3122	0.2948	0.2408	-0.0231	-0.0353	0.0202
Demgrph_De~o	-0.378	0.0956	-0.0222	0.0409	-0.0449	0.0846	0.3736	-0.3099	-0.141	0.3173	0.202	0.4247	0.3664
Avg_Land_A~H	0.3375	-0.1133	0.2575	0.066	0.015	0.0147	-0.1624	-0.1665	0.6634	0.329	0.3997	0.1589	-0.048
Landless_R~i	0.2965	-0.3381	0.2415	0.0013	0.1682	0.0921	0.0957	0.0504	-0.2369	-0.1145	-0.0555	0.3943	0.2376
Acces~t_Agri	0.3362	-0.087	-0.0435	-0.0477	0.272	-0.1647	0.5669	-0.2014	-0.1082	0.1682	-0.085	0.0616	-0.3143
Acces~n_Agri	-0.2191	-0.2944	0.4112	-0.097	0.081	0.1749	0.2863	-0.229	0.0011	-0.1875	0.288	-0.6168	0.0675
LF_Partici~e	0.1168	-0.0003	-0.3795	-0.1121	-0.0559	0.791	0.1541	0.0063	0.1848	-0.3125	0.0988	0.1352	-0.1012
Unemploy_R~e	-0.0246	-0.2721	-0.0734	0.5439	0.2907	-0.0503	0.2227	0.4496	0.086	-0.163	0.0687	-0.0017	0.1721
Underemplo~e	-0.2236	0.2686	-0.0116	-0.1872	0.4835	-0.313	0.0688	-0.0373	0.3323	-0.4994	0.1025	0.2263	-0.1189
Literacy_R~e	0.2522	0.0745	0.4336	-0.2173	-0.2233	0.0297	0.1319	0.4716	0.0137	-0.0849	-0.0896	0.0904	0.0924
Net_Enr~mary	0.2153	0.4681	-0.0033	-0.1272	-0.1633	-0.1008	0.28	0.0018	0.1916	-0.1247	-0.0238	-0.1622	0.5739
Net_Enr~dary	0.1698	0.455	0.0684	0.2939	-0.1274	0.0377	0.3201	0.0942	-0.1323	0.0793	0.1582	-0.1216	-0.4442
Access_~mary	0.2727	0.1525	-0.2151	0.0568	0.534	0.1671	-0.1233	-0.0545	0.0188	0.2979	-0.218	-0.3388	0.2941
Access_~dary	0.1089	0.3345	0.2561	0.4156	0.1405	0.1455	-0.328	-0.1614	-0.3364	-0.2145	0.3399	0.0862	0.0769
Total_Gov~re	0.2088	-0.1649	-0.4823	-0.131	-0.1502	-0.3115	-0.0044	0.167	-0.1788	-0.0285	0.6347	-0.1087	0.1212

Following Hoque (2014), this study used **the first principle component** as the main single index representing the socioeconomic condition.

Source: Authors' calculation

5) Result discussion

There exists the significant positive relationship between the computed **first principle component** and the **NTL index** with **the correlation coefficient of 0.870**.



Source: Authors' calculation

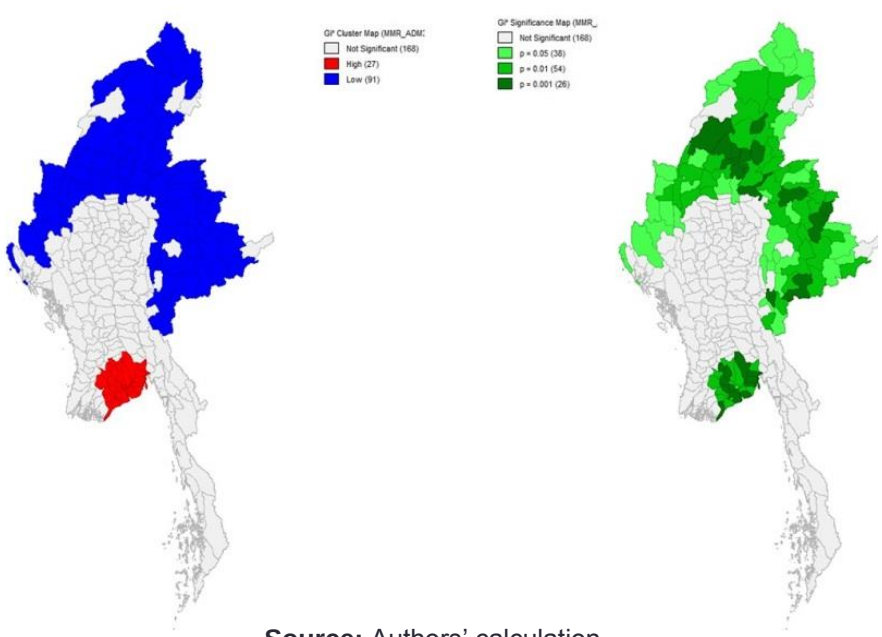
This finding quantitatively supports the use of **NTL index** as **the proxy of the stage of socioeconomic development**, yielding the subsequent outcomes of spatial inequality and clustering analysis as discussed in the next section

5) Result discussion

5.2 Spatial Cluster Analysis of Development using NTL index

1992

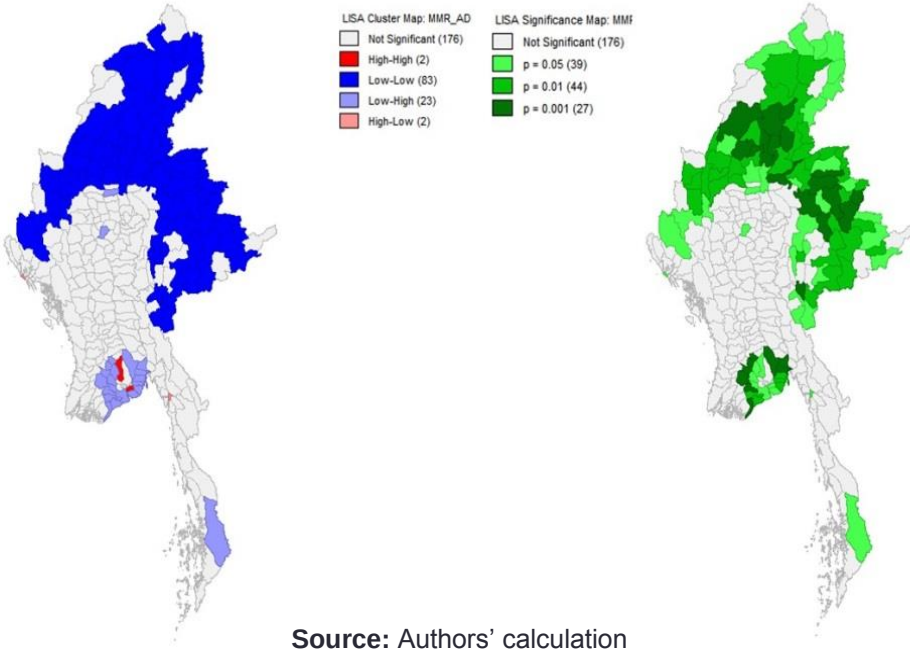
Getis-Ord Gi* statistics



Source: Authors' calculation

1992

LISA



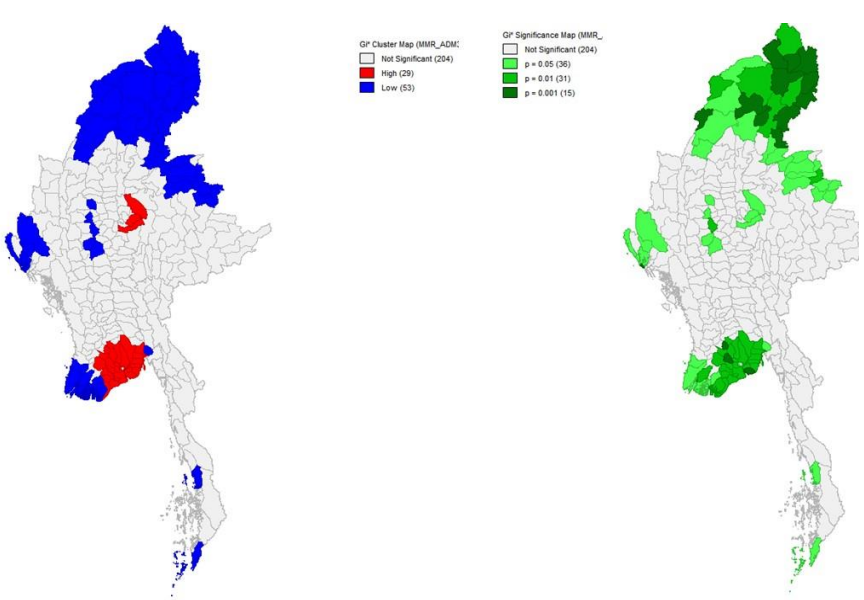
Source: Authors' calculation

5) Result discussion

5.2 Spatial Cluster Analysis of Development using NTL index

2004

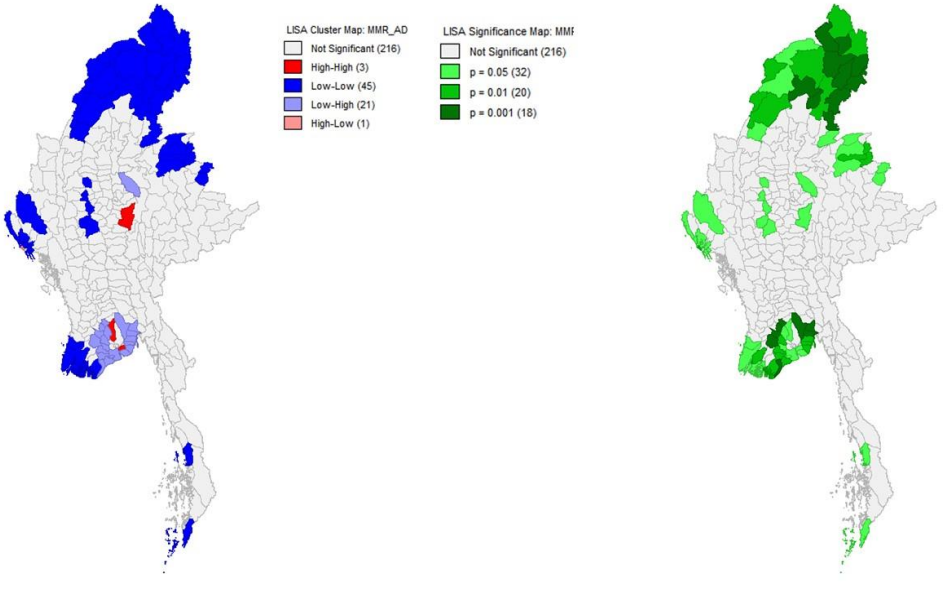
Getis-Ord Gi* statistics



Source: Authors' calculation

2004

LISA



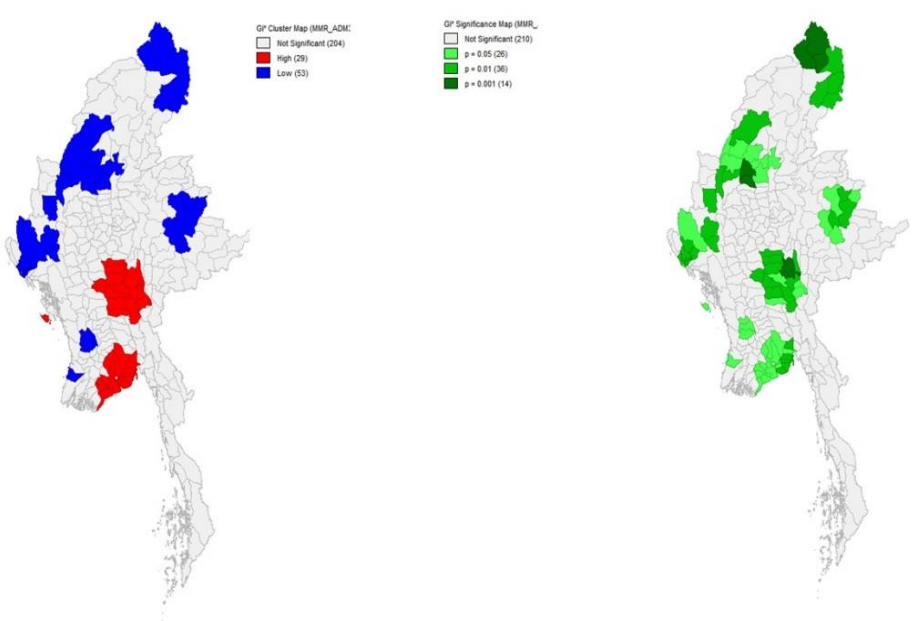
Source: Authors' calculation

5) Result discussion

5.2 Spatial Cluster Analysis of Development using NTL index

2016

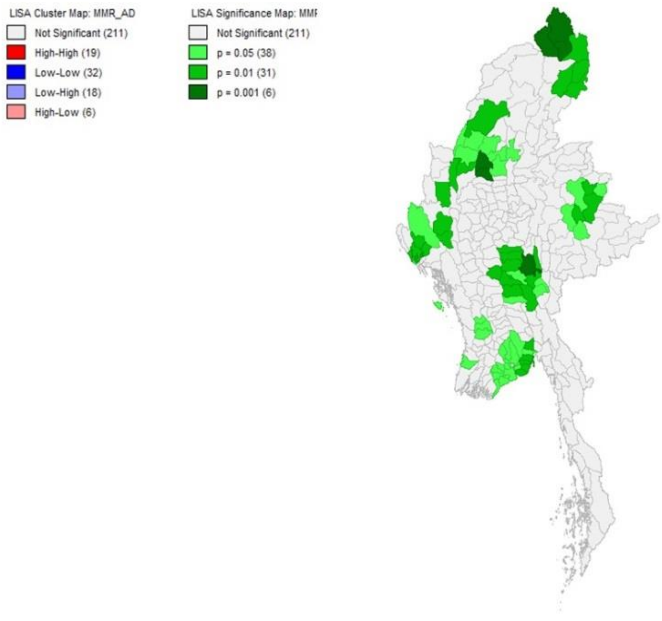
Getis-Ord Gi* statistics



Source: Authors' calculation

2016

LISA



Source: Authors' calculation

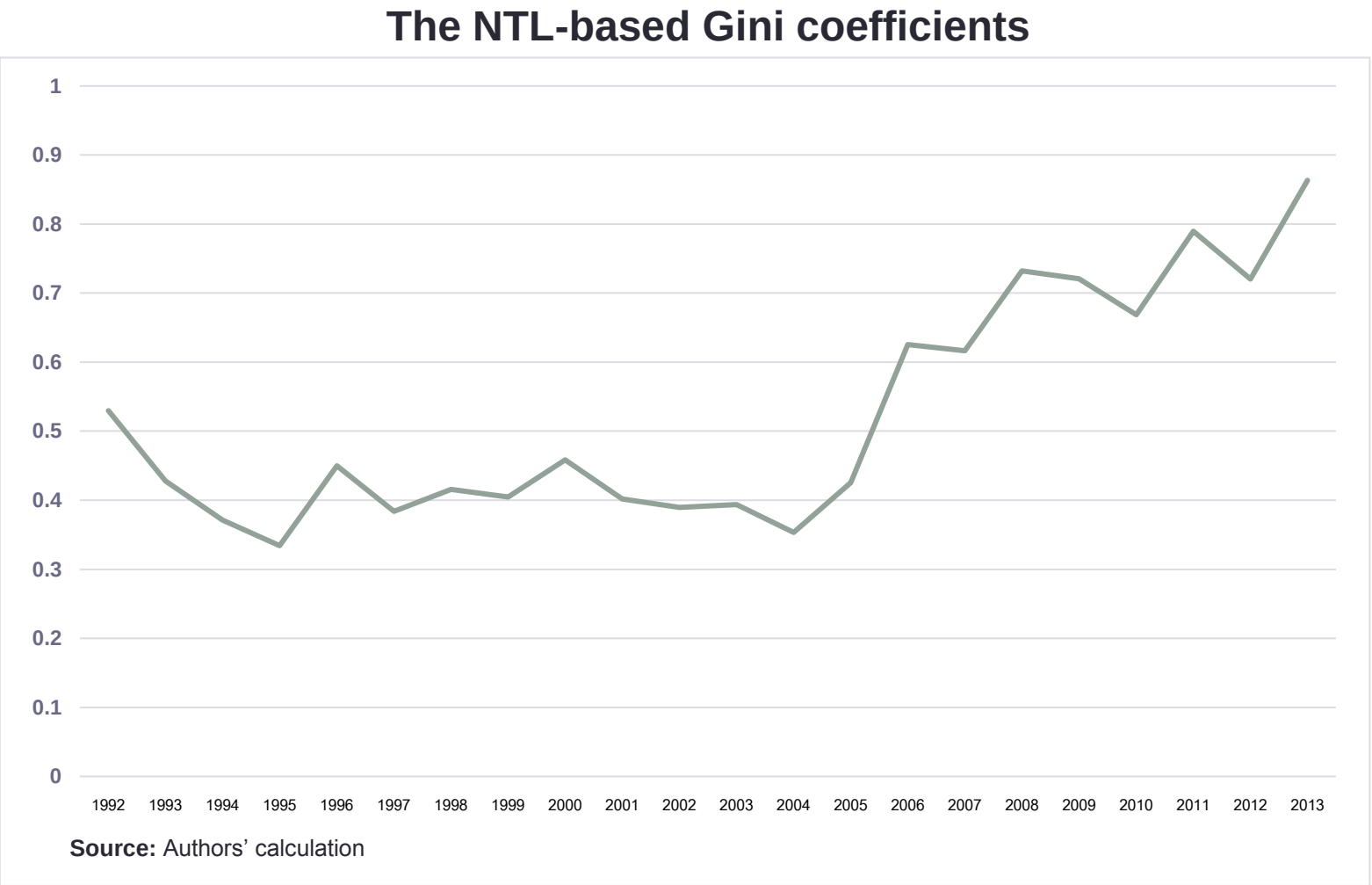
5) Result discussion

- In the case of 1992, the result clearly indicates the cluster of **high density** of high NTL index in the **area of Yangon**, i.e. technically the area of “hot spot”.
- This indicates the only urbanization in that area.
- Results obtained from both spatial detection methods also identify that there was the cluster of “**cold spot**” in the **northern region** of Myanmar, indicating the **low density of urbanization** in that area.

5) Result discussion

- In 2004, the spatial distribution had slightly changed.
- There was still the **main urbanization** in the area of **Yangon**.
- However, the coverage of **cold spot** area, i.e. the statistically low density of urbanization, **had declined**.
- After 2004, the spatial distribution of urbanization has been continuously evolving.
- In the case of 2016, the **raising significant density** of **urbanization in Naypyitaw**.
- Specifically, both results obtained from Getis-Ord Gi* statistics and LISA confirm the detected "**hot spot**" in the area of **Naypyitaw**.

5) Result discussion



5) Result discussion

- In addition to applying the spatial statistical methods for detecting the geographical distribution of socioeconomic inequality, this paper also **quantified the degree of inequality** by using the conventional Gini coefficient.
- The computed series of **NTL-based Gini coefficients** indicates that the spatial inequality was **improved during 1993-2004**.
- However, the geographical distribution of urbanization development has been **widened as identified by the rapidly increasing Gini coefficients**.
- This rising inequality is mainly caused by the **rising density in Naypyitaw.**

5) Result discussion

- The continuous urbanization and **expansion of Naypyitaw** is **twofold.**
- First, it would transform the country to the **new development path** functioning based on the **multiple growth poles**. This would allow **more opportunities for labors and businesses** to locate both their economic activities and accommodation.
- Second, however, the intended emphasis on expanding Naypyitaw might **widen the nationwide gap of development**. In addition, the increasing spatial inequality might **worsen the problems of poverty and income inequality**.

6) Conclusion

- This study has **two research objectives**.
- First, it is shown that the **single index** representing the socioeconomic condition can be formulated by applying **PCA** on survey data. Further, this **formulated index** is **highly correlated with the NTL index**.
- Second, the spatial inequality was analyzed by using two methods of **spatial cluster detection**. The obtained results show that Myanmar has been **gradually transforming** from the centralized growth pattern to the case of **multiple growth poles**.

6) Conclusion

Policy recommendation

- Additional development programs should be implemented such as the **special economic zones located at the border**.
- The development of such projects would **concurrently induce** the **economic expansion** and **bridge the gap of spatial inequity**.

6) Conclusion

Limitations and future improvement

- The constraints of **data unavailability** have been the major problem in conducting this research.
- The **alternative techniques of calibrating NTL data** should be applied in order to verify the **robustness of results** obtained from methods of spatial cluster detection.
- More details of related **private and public development projects** should be discussed to identify the **relationship between** their **outcomes and the analytical evidences** obtained from spatial cluster detection methods.

Thank you

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