Regional Convergence in Bangladesh using Night Lights

Syed Abul, Basher and Salim, Rashid and Mohammad Riad, Uddin

14 June 2022

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Syed Abul Basher[2] **Salim Rashid[3]** **Mohammad Riad Uddin[4]**

ABSTRACT. We analyze economic convergence across 64 districts of Bangladesh using newly harmonized satellite night light data over 1992-2018. The growth in night lights—taken as a proxy for regional economic activity—reveals overwhelming evidence of absolute convergence. Regional differences in night light (or income) growth have been shrinking at an annual convergence rate of 4.57%, corresponding to a half-life of 15 years. Net migration plays a relatively prominent role in the regional convergence process.

KEYWORDS: Night lights, convergence, Bangladesh
JEL CODES: O47, R11

[1] We would like to thank an anonymous reviewer for helpful comments and Syed Rafsan Ali for excellent research assistance.
[2] **Corresponding Author:** Department of Economics, East West University, Jahurul Islam City, Plot A-2, Aftabnagar, Dhaka 1212, Bangladesh. Phone: +8809666775577 ext. 198. Email: syed.basher@ewubd.edu
[3] Center for Urban Studies and Sustainable Development, East West University, Jahurul Islam City, Plot A-2, Aftabnagar, Dhaka 1212, Bangladesh. Email: srashid@ewubd.edu
[4] World Bank, Plot E, 32 Syed Mahbub Morshed Avenue, Dhaka 1207, Bangladesh. Email: muddin6@worldbank.org

1. Introduction

Empirical analysis of convergence between and within countries remains an active area of research among applied economists. Johnson and Papageorgiou (2020) summarize an extensive literature on cross-country convergence and document a lack of progress in closing the income gap between countries. An extensive literature on regional (or within country) convergence also exists. A comprehensive analysis by Gennaioli et al. (2014) document that regions within a country tend to converge faster than countries do, although regions of rich countries converge more rapidly than poor countries. The unavailability of regional income data over time in Bangladesh has held back a comprehensive analysis of income convergence covering all regions of Bangladesh.

Fortunately, the emergence of satellite night lights (hereafter NL) data—which is publicly available and can be collected at low cost and at a large scale—has unleashed a new research field in economics. To date, NL data have been used as a proxy for local economic activity, analyzing regional income disparity, urbanization trends across regions, real-time conflict monitoring, among other applications – see Donaldson and Storeygard (2016) for a review of studies using NL data in economics. In this paper, we use newly available integrated and consistent NL data to examine regional income convergence across 64 districts of Bangladesh from 1992-2018. Recent applications of NL data to study regional convergence include Chanda and Kabiraj (2020) and Basher et al. (2022), who respectively examine regional convergence across districts of India and subdistricts of Bangladesh. The main novelty of this paper is the consistency of the NL data and a more extended coverage of data.

The remaining analysis proceeds as follows. Sections 2 and 3 describe the data and methodology, respectively. Section 4 presents the main empirical results. Section 5 draws the conclusion.

2. Data and descriptive statistics

Our primary data come from Li et al. (2020) who developed a harmonized global NL dataset for 1992-2018, the longest and most consistent database available to date. The two primary sources of NL data are Defense Meteorological Satellite Program (DMSP)/Operational Linescan System (OLS) and the Visible Infrared Imaging Radiometer Suite (VIIRS). The harmonization of DMSP/OLS and VIIRS data proceeds in three steps. First, the DMSP-OLS data from different satellites are intercalibrated to ensure continuity and comparability. The DMSP/OLS data are available annually from 1992 to 2013. Second, the VIIRS data are available monthly (2014-2018) and therefore are aggregated annually based on a weighting approach that ensures cloud-free high quality radiance data. Third, the VIIRS data are converted into DMSP/OLS-like NL data using a sigmoid function that preserves the spatial similarity of the two datasets as close to each other. The resulting harmonized data over the 27 years (1992-2018) are temporally consistent and offer promising avenues of research. Finally, we apply the HP filter to remove short-run

fluctuations. The empirical analysis that follows is based on the trend component of the HP-filtered data. Table 1 presents the definition and data sources used in the convergence regressions.

Table. Data and sources

Variable name	Description	Unit of measures	Source
Night light intensity	Harmonized nighttime light data for 1992-2018.	Digital number (DN) values divided by area sq. km.	Li et al. (2020)
Population density	Population density, 1991	Per sq. km.	BBS (2015)
Literacy	Literacy rate for persons aged 7 years and above, 1991.	Percentage of people who can both read and write with understanding a short simple statement about their everyday life.	Ministry of Planning (2011)
Agri income p.c.	Agriculture real income per capita, 1995-96.	Taka	Ministry of Planning (2011)
Mfg. share in output	Share of manufacturing in regional GDP, 1995-96.	Percentage point	Ministry of Planning (2011)
Rural road	Length of roads in 1993, includes national and regional highways. We also tried "rural roads class 1" and "rural roads class 2" as alternative measures.	Kilometer	World Bank (1996)
Net migration	Equals to net migration divided by population, where net migration is defined as the difference between in-migration and out-migration over 1981-1990. A negative net migration implies net out-migration and vice versa. Includes both domestic and international migration.	Rate of change (%)	Iqbal and Roy (2014)

Table 2 presents some descriptive analyses of the night lights and other data. The median NL intensity has increased over eight folds from 1992 to 2018, while the volatility (measured by the coefficient of variation) exhibits a noticeable decline. Among the regressors, the volatility of manufacturing share in output is the highest, which is consistent with the industrial sector being more volatile than the other sectors. The comparably low volatility of literacy and agriculture income per capita suggests that improvements in these areas come very gradually.

Table 2. Descriptive statistics

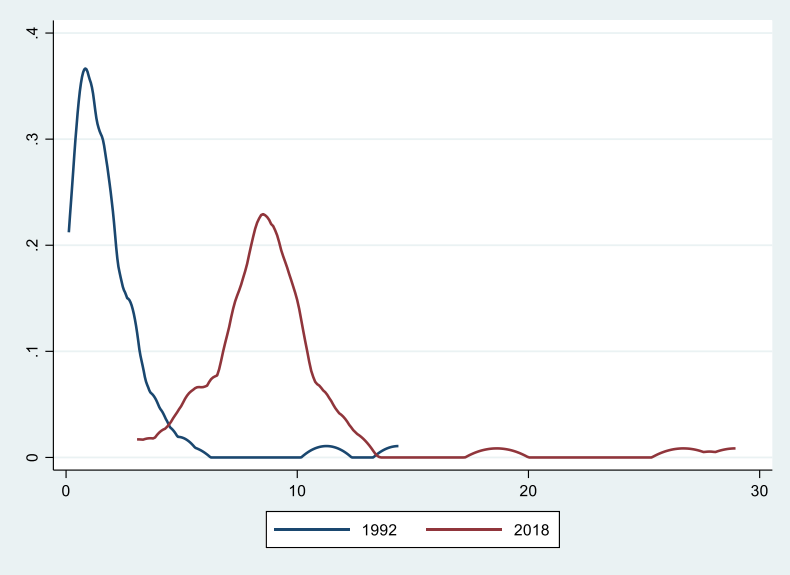
Variable	Mean	Median	Std. Dev.	Skewness	Kurtosis	C.V.	Obs.
Night lights, 1992	1.75	1.11	2.27	3.77	19.45	1.29	64
Night lights, 2018	8.99	8.39	4.16	3.32	16.08	0.46	64
Population density	819.07	776	529.77	3.80	22.60	0.64	64

Literacy	30.93	28.38	7.67	1.02	3.50	0.24	64
Man. share in output	8.35	5.50	8.41	2.32	8.01	1.00	64
Agri income p.c.	3683.19	3490.59	1092.94	-0.03	3.87	0.29	64
Rural roads	237.92	220.64	114.86	2.13	10.72	0.48	64
Net migration	-0.12	-0.01	0.04	0.47	3.80	-	59

Note: See Table 1 for unit of measures.
C.V.: Coefficient of variation = Mean / Std. Dev.

Finally, Figure 1 provides the kernel density plots of NL intensity in 1992 and 2018 (the beginning and end of the sample period). The mean of the 2018 night lights distribution is higher than the 1992 distribution by a factor of almost five, although the 2018 distribution is more dispersed than 1992.

Figure 1. Night lights intensity, density functions 1992 and 2018



Note: Kernel density estimates for the average night lights intensity. Densities are calculated using an Epanechnikov kernel.

3. Methodology

The convergence analysis[5] is carried out with the most commonly used measures such as beta and sigma convergence. The **unconditional or (beta) convergence** is assessed by regressing night lights (NL) growth on its initial level:

$$y_{iT} - y_{i0} = c + \beta y_{i0} + \epsilon_{iT} \quad (1)$$

where y is the logarithm of NL intensity at time t and the initial period 0 across region i. The ϵ_{iT} are random shocks. If $\beta < 0$, then unconditional convergence exists. A negative coefficient of β implies that

[5] This section is heavily drawn from Basher et al. (2022).

poor areas are growing faster to catch their rich counterparts. The annual rate of convergence is obtained by: (-1) × ln(β + 1)/T.

In comparison, the **conditional convergence** is tested using the regression:

$$y_{it} - y_{i0} = c + \beta y_{i0} + \delta X_i + \epsilon_{iT} \quad (2)$$

where X_i is a set of covariates including region fixed effects to capture unobserved heterogeneity. Equation (A2) is called "conditional convergence" because it reflects the convergence of areas after controlling for initial conditions. A negative coefficient of β implies convergence towards a particular steady state.

The two widely used measures of **sigma convergence** are i) the standard deviation of the logarithm of night light intensity (SDLOG) and ii) the coefficient of variation (CV) of night light intensity. They are calculated as follows:

$$SDLOG_t = [(1/n)\Sigma_i(\ln y_{it} - \ln \bar{y}_t)^2]^{0.5} \quad (3)$$

where $\ln y_{it}$ is the logarithm of NL intensity, $\ln \bar{y}_t$ is the mean value of $\ln y_{it}$ for year *t* and *n* is the number of regions. Whereas:

$$CV_t = SD(y_t)/\bar{y}_t \quad (4)$$

where $SD(y_t)$ is the standard deviation of night light intensity and $\bar{y}_t$ denotes mean value of night light intensity for year *t*. The presence of sigma convergence is then examined using:

$$LD_t = c + \beta \times t + \in_t \quad (5)$$

where LD_t is the logarithm of the measure of dispersion (SDLOG or CV) and *t* is the linear time trend (1 for the first year and 27 for the final year). A negative coefficient for β implies a reduction in dispersion (or convergence) and vice versa. The corresponding annual exponential rate of convergence or divergence can be calculated as $e^{\beta} - 1$.

Finally, the Phillips and Sul (2007) test for convergence clubs is performed by the following "log *t*" regression model:

$$\log\frac{H_1}{H_t} - 2\log(\log t) = c + \beta \log t + \epsilon_t \quad (6)$$

where $H_t = N^{-1}\sum_{i=1}^{N}(h_{it} - 1)^2$ and $h_{it} = \log y_{it} / N^{-1}\sum_{i=1}^{N} \log y_{it}$. Under the null hypothesis of convergence, β must be positive for convergence to hold. Moreover, if β ≥ 2 implies convergence in level, while for 2 > β ≥ 0 corresponds to conditional convergence or convergence in growth rates.

4. Empirical results

Table 3 presents the main results. First, the coefficient on initial NL in the unconditional convergence regression is negative and statistically significant, indicating absolute convergence in NL across districts. The annual convergence rate is 4.57%, implying that it would take about 15 years to eliminate half of the initial NL difference between districts on average. In comparison, the absolute NL convergence rate among 520 Indian districts was 2% over 1996-2010 (Chanda and Kabiraj 2020).

The rightmost column in Table 3 presents the results of the conditional convergence, which extends the unconditional convergence model by incorporating some initial conditions. There is no clear guidance in the literature regarding the kind of predictors to include in the convergence regression. Besides, our choice of initial conditions is limited by the availability of relevant variables at the district level. Nevertheless, the six variables included in the regression can be considered as potential determinants of growth.

Table 3. Beta convergence

	Unconditional Convergence	Conditional Convergence
Initial night lights (β)	-0.709***	-0.972***
	(0.041)	(0.033)
Log pop. density		0.548***
		(0.089)
Literacy		-0.0002
		(0.002)
Mfg. share in output		0.012***
		(0.003)
Log of agri income pc		0.183
		(0.124)
Log of rural road		-0.071**
		(0.033)
Net migration		1.731***
		(0.467)
Division fixed effects (Base: Dhaka Division)		
Barisal		-0.091 (0.063)
Chittagong		-0.079 (0.068)
Khulna		-0.161*** (0.054)
Mymensingh		-0.094 (0.076)
Rajshahi		-0.071 (0.058)

Rangpur		0.111* (0.063)
Sylhet		0.187** (0.072)
Convergence rate[a]	4.57%	13.32%
Half-life[b] (years)	15	5
Observations	64	59

NOTE – Robust standard error is given in parentheses. * $p < 0.1$; ** $p < 0.05$, *** $p < 0.01$.
$a.\ Convergence\ rate = (-1) \times ln\ (\beta + 1)/T$, where T is the number of years under consideration.
$b.\ Half - life =$ log(2) $/convergence\ rate$.

Several points in the table are worthy of comment. First, as expected, the coefficient on initial NL is negative and statistically significant, providing strong support for the conditional convergence. The estimated convergence rate is relatively high at 13.79%, implying that it takes only five years to halve the initial NL gap among the districts. Second, as expected, population density, manufacturing share in output, and net migration positively and significantly affect the growth of NL. In comparison, literacy and agricultural income per capita have a statistically insignificant effect on NL growth. An increase in net migration generates a more than proportionate increase in NL growth, confirming migration's role as a mechanism for reducing spatial income differential (Ozgen et al. 2009). In particular, the estimated conditional beta convergence falls from 13.32% to 9% when net migration is dropped from the growth regression. Such a significant effect of net migration on growth convergence is uncommon in the literature (Ozgen et al. 2009), but not unusual for a large homogenous population of Bangladesh with no barriers to mobility. Moreover, the evidence is consistent with the returns to migration across various quintiles of households among Bangladesh's leading and lagging regions (Sen et al. 2014).

On the other hand, the building of rural roads generates a somewhat counterintuitive result, as one usually would expect more infrastructure to facilitate NL growth across subnational regions within a country. Asher and Novosad (2020) find a similar result for India, where rather than facilitating structural transformation, road building allowed local workers to move to other growth centers. Such mobility of workers itself is a source of convergence (as indicated by the coefficient on net migration), but for Bangladesh, rural road development is also found to be associated with higher school enrollment and reduction in poverty (Khandker et al. 2009). The coefficient on divisional dummies reveals a "North-South" divide where—relative to the benchmark capital division of Dhaka—economic activity among districts located in the north (Rangpur) and northeastern (Sylhet) regions is growing faster than their southern counterparts (i.e., districts in the Barisal and Khulna divisions).

Some authors—see Johnson and Papageorgiou (2020, footnote 19) for a list of papers—pointed out that the inclusion of initial conditions could result in the endogeneity of regressors. The highest correlation coefficient was found between NL growth (the dependent variable) and manufacturing share in output. Consequently, we ran an instrumental variable (IV) regression using the logarithm of agriculture income per capita as an instrument for manufacturing share, as the two have the highest

correlation of coefficient (-0.78) among all regressors. The Durbin-Wu-Hausman test of endogeneity reveals that the null hypothesis of exogeneity of manufacturing share cannot be rejected at the 5% level of significance, indicating that endogeneity is not particularly worrisome in the convergence regression. The speed of convergence of the IV (2SLS) regression was 11.90%, not far from the amount shown in Table 3. The signs of the estimated IV coefficients remain identical to that in Table 3, although their magnitude changed. Moreover, the F-statistic of the first stage regression is above 10, indicating that the instrument is not weak. These results are presented in a table in the Appendix.

The finding of strong conditional convergence suggests that the dispersion of NL growth across districts should fall over time. Table 4 presents the result of sigma convergence using two commonly used measures in the literature. The positive coefficient on time trend indicates a decrease in the dispersion of NL growth over time, with the implied annual rate of reduction approximately 2.5%. A visual representation of the beta and sigma convergence findings is shown in Figure 2.

Figure 2. Beta and sigma convergence, 1992-2018

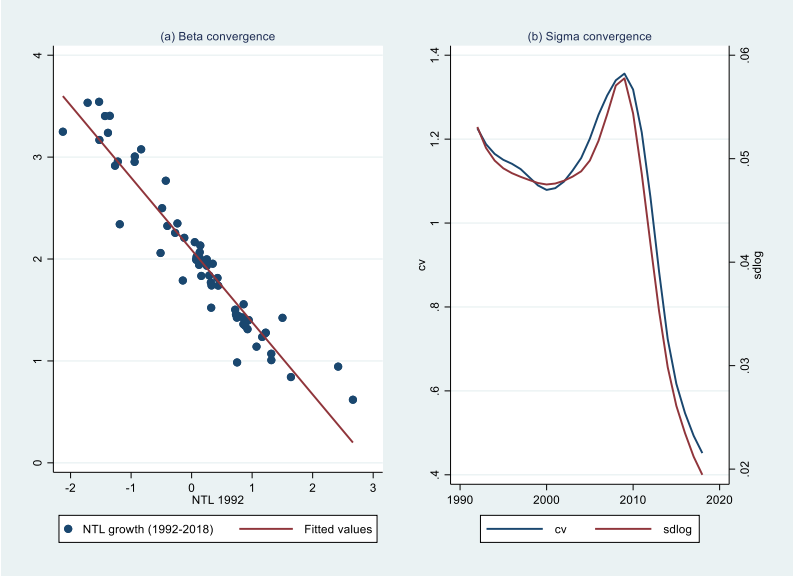


Table 4: Sigma Convergence

	Coefficient of variation	Standard deviation of logarithms
Coefficient on time trend (*b*)	-0.024***	-0.026***
	(0.006)	(0.005)
Annual rate of change[a]	-2.46%	-2.62%
Observations	27	27

NOTE – Robust standard error is given in parentheses. *** $p < 0.01$.
a. Annual rate of change = $e^b - 1$.

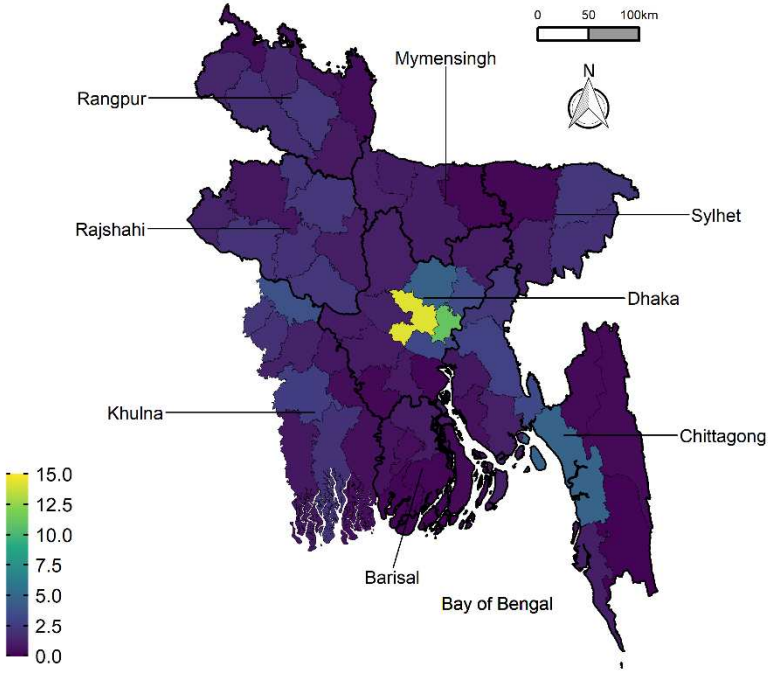
Beta convergence can have low power if the underlying convergence process exhibit multiple basins of attraction, the so-called club convergence (Durlauf and Johnson 1995). The calculated *t* statistic of Phillips and Sul (2007) log *t* regression was 5.76 against the one-sided critical value of -1.65 (5% level), suggesting that the null hypothesis of convergence for the whole panel is not rejected. Moreover, the estimated coefficient for β is greater than 2, suggesting absolute or level convergence. Put differently, there exists a single steady-state toward which the 64 districts of Bangladesh are converging.

4. Conclusion

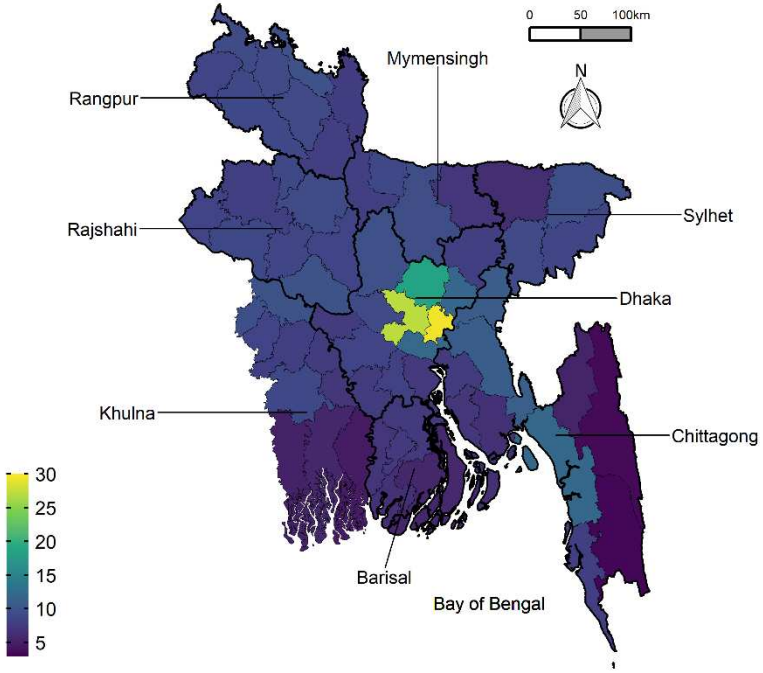
Our analysis of night light across 64 districts of Bangladesh over 1992-2018 shows that regional differences in NL growth, used as a proxy for local economic activity, have been shrinking rapidly. The speed of unconditional convergence is estimated at 4.57% per annum, much higher than the cross-country convergence rate of 2% documented in the literature (Barro 1991). Notably, the finding of absolute convergence is confirmed by the existence of sigma convergence, especially starting in 2010. Along with social progress, the expansion of annual electrification growth rate in excess of 7 percent is a potentially important driver of convergence. The general lesson of our paper is that in a country with homogenous people and improved transportation that lowered barriers to factor mobility, particularly labor mobility, the regional speed of convergence is higher than Barro's 2% per year. Our higher convergence rate is in line with the meta-analysis of Abreu et al. (2005), but as pointed out by Gennaioli et al. (2014), the use of fixed effects and small sample size may raise the convergence coefficients. This development coincidentally occurred during a period when international agencies started to collect satellite night lights data.

Figure 3. Bangladesh night light maps: 1992 and 2018

(a) Night lights in 1992



(b) Night lights in 2018



Note: The maps show how night light (NL) intensity between 1992 and 2018 across 64 districts of Bangladesh. **Notice that the 2018 legend values are double that of 1992.** As depicted on the map, the 64 districts (zilas) are composited into eight divisions.

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Appendix: Additional results

Table A1. 2SLS estimation of conditional convergence

	Conditional Convergence
Initial night lights (β)	-0.959***
	(0.032)
Log pop. density	0.387***
	(0.097)
Literacy	-0.006***
	(0.002)
Mfg. share in output	0.016***
(*Instrumented with agriculture income pc*)	(0.005)
Log of rural road	-0.061*
	(0.033)
Net migration	0.626
	(0.477)
First-stage *F*-statistic	19.54
	(*p*-value 0.00)
Convergence rate[a]	11.90%
Half-life[b] (years)	5.82
Observations	59

NOTE – Robust standard error is given in parentheses. * $p < 0.1$; *** $p < 0.01$.
a. $Convergence\ rate = (-1) \times ln\ (\beta + 1)/T$, where T is the number of years under consideration.
b. $Half - life = \log(2)\ /convergence\ rate$.

Briefly, the results of the IV regression echo that of OLS regression discussed in the main document. We have tried instrumenting net migration with population density or real agricultural income per capita, but these specifications suffer from the problem of weak instrument.