Estimating GDP growth in Greater Yangon using nightlights data

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Abstract

We provide estimates of GDP growth in Greater Yangon between 1992 and 2013 by exploiting nightlights data. Subnational estimates were derived by calculating the elasticity of luminosity with respect to GDP for Myanmar as a whole using time series luminosity and GDP data and then converting observed luminosity values for Yangon in GDP by applying the national level elasticity estimates. The results suggest that Yangon's GDP grew at an average annual rate of 4.45 percent between 1992 and 2013 and by 11.17 percent per annum during the reform period beginning in 2008. This method may be useful for monitoring urban economic growth in other low and middle income countries.

Key words: Myanmar, Yangon, remote sensing, nightlights, GDP growth

Introduction

In the absence of reliable, sub-national time-series statistics on economic activity in Greater Yangon we developed estimates of growth in output in the region by combining data from a series of satellite images of nightlights in Myanmar between 1992 and 2013 with national GDP estimates covering the same period. The use of nightlights data to estimate GDP in data-scare contexts is now well-established but controversial.

The rationale behind this approach is simple: economic activity requires energy, which can be remotely observed by sensors on satellites as light emitted by objects on the earth's surface at night (e.g. from lights in factories, homes and transport infrastructure). Assuming that light emitted from a region at night and economic output are correlated, changes in the amount of light observed in a region should reflect changes in GDP (Elvidge et al 2007).

Several studies have indeed confirmed such a correlation utilising national level luminosity and GDP data for a large cross-section of countries (Chen and Nordhaus 2011; Henderson, Storeygard and Weil 2012; Nordhaus and Chen 2015). This approach has also been used to measure spatial variation in levels of economic development across regions within individual countries (cf. Gennaioli et al 2013; Michalopoulos & Papaioannou 2013; Alesina, Michalopoulos & Papaioannou 2015). However, there are some important technical limitations when applying this approach at the sub-national level.

The most widely used nightlights data come from the US Defense Meteorological Satellite Program (DMSP). DMSP satellites are fitted with luminosity sensors that have a bounded range of measurement, from 0-63. This restricts the amount of variation in luminosity that can be observed and is particularly problematic a) in areas of high economic density, such as wealthy metropolitan areas, which can emit enough light to saturate the sensor (thereby creating an upper limit on the level of economic activity that can be inferred), and b) in low density areas that may emit such low levels of light that they are not captured by the sensor and mistakenly recorded as having no human-generated luminosity (Bickenbach et al 2016). This technical problem is likely to be attenuated in future research by the launch of new satellites with sensors that can accurately measure a wider range of frequencies, such as the Suomi National Polar-orbiting Partnership weather satellite equipped with the Visible Infrared Imaging Radiometer Suite (VIIRS). However, our analysis relies on the availability of publicly available time-series data, which only the DMSP provides at this point in time.

Other limitations relate to uncertainty with regard to measurement error in both the luminosity data and GDP data. This can obscure the 'true' relationship between luminosity and real GDP and undermine the statistical robustness of the method (see Norhaus and Chen 2015). It is also important to note that a relation of exact direct proportionality between GDP and observed luminosity cannot be established in mathematical terms. Different economic activities will emit different amounts of light, while similar activities utilising different technologies may emit exhibit different light intensities. As a result the elasticity of luminosity with respect to GDP may not be universal but rather country-specific, region-specific and variable over time.

Nevertheless, the accumulated research supports the premise that luminosity and GDP co-vary and that using changes in luminosity as a proxy for changes in GDP can be valuable in contexts where reliable sub-national economic data are missing. Moreover, for the purposes of obtaining a rough measure of change in output in metropolitan areas in low- and middle-income countries, concerns about the bounded nature of luminosity measurements are minimised. Metropolitan areas are less susceptible to lower-bound errors in measurement than rural areas due to the relatively high density of people and hence economic activity; and low- and middle-income countries are less likely to have large numbers of saturated pixels (even in urban areas) than high income countries.

Estimating GDP for Greater Yangon

In order to estimate changes in GDP in greater Yangon we acquired annual DMSP images of nightlights in Myanmar covering the years 1992-2013 and national GDP data from the Penn World Tables version 9 (PWT)(see Feentra et al 2015). As we are interested in the correlation between luminosity and output we use PWT estimates of output-side real GDP at chained PPPs in millions of 2011 US dollars. We then calculated the elasticity of luminosity with respect to GDP at the national level using the time-series data and then applied this equation to the luminosity data from Greater Yangon to derive our sub-national output estimates.

This approach builds on the findings of previous studies but it is tailored and scaled to a sub-national scale of analysis. For instance, in order to prove the correlation of luminosity data with national GDP values, Henderson et al. (2012) assumed that the same value of elasticity can be applied universally (i.e. the same everywhere and over time). Statistically this approach – which is based on the calculation of a normalised value of elasticity - is valid to establish a means of comparison across case studies. Our approach does not compare several case studies, but it does assume that elasticity is consistent within Myanmar, so as to establish a baseline of comparison between luminosity at national level and luminosity observed at sub-national level. The approach is strengthened by the use luminosity data across the longest possible time series (i.e.,1992-2013).

The nightlights datasets (stable lights series), which are available for the whole of the Earth’s surface, were resized to the national boundaries of Myanmar and to the administrative boundaries of the Greater Yangon region. Using the zonal statistics algorithm, the overall luminosity value for the two boundaries was calculated on an annual basis. When two images were acquired by two different sensors in the same year, the luminosity values of the two images were used to produce a mean value image to analyse with the zonal statistic algorithm.

Figure 1 illustrates the trends in national luminosity, greater Yangon luminosity and real GDP between 1992 and 2013. The data were converted to index numbers to facilitate visual comparison of rates of change with 2003 set as the base year.

Overall, these three series exhibit similar trends. There are, however, two obvious outlier years: 2009 and 2010. It is likely that the dip in luminosity in 2009 reflects extensive damage to infrastructure associated with Cyclone Nargis, which hit the country in May 2008. We cannot confirm the date that the 2008 and 2009 images were taken, but we suspect the 2008 image was taken before the cyclone and hence the effect on infrastructure only became apparent in the 2009 image. Conversely, 2010 was an historic election year and one which saw a boom in public spending and strong commodity exports (IMF 2012).

[Figure 1]

It is important to note these outliers because variance and co-variance measures - which the method is based upon - are sensitive to outliers. The influence of outliers propagates to the estimation of the correlation between national luminosity estimates and national GDP estimates, and hence to our estimates of the elasticity of luminosity with respect to GDP. Figures 2 and 3 show the linear correlation between national luminosity and GDP with and without these outlier years respectively. There is a clear linear fit in both cases, confirming the robustness of the method increases with the length of data series and the richness of the sample, but the fit is considerably stronger when the luminosity observations for 2009 and 2010 are excluded—the R-squared increases from .68 to .84.

By applying these equations to the Greater Yangon luminosity scores we estimated real GDP for the city-region. In doing so we assume a) that these equations reflect a true underlying correlation between luminosity and GDP in Myanmar, and b) that the elasticity of luminosity with respect to GDP is the same at national and sub-national scales. These estimates, along with the underlying data, are presented in Table 1. Yangon Estimate A employs the equation shown in Figure 2; Yangon Estimate B employs the equation shown in Figure 3.

[Figure 2 & Figure 3]

Comparing these figures suggests that the estimates produced from the latter model with outliers omitted is preferable. For example, Estimate A suggests that Yangon's GDP was greater than national GDP in 1992 and accounted for over 80 percent of national GDP between 1993 and 1997. This is highly unlikely given the size of Myanmar's population.

[Table 1]

Discussion & Conclusion

Between 1992 and 2013 the total amount of luminosity observed in Greater Yangon more than tripled, from 19841 to 64583. According to our preferred estimates, this suggests that GDP in the region increased 2.5 times from roughly 17,000 million US$ to 44,000 million US$ over the same period. This translates into an average annual growth rate of 4.45 percent. If we consider the more recent period of reform, beginning in 2008 when the constitutional referendum was held, Yangon is estimated to have grown at an average annual rate of 11.17 percent.

While these are plausible estimates of growth for the city they must be treated cautiously. The World Bank ranks Myanmar's statistical capacity below the IDA and East Asian averages, which highlights the potential for significant measurement error. There are also sensor limitations. Strong growth may lead to saturated cells, which can lead to underestimation of growth thereafter. Conversely, multi-scatter reflections (i.e. the same beam of light splitting by reflection is captured by the sensor in multiple cells) can lead to the over estimation of total light. To check this, the earliest and most recent series (F18-2013) of the nightlights data was evaluated in discrete classes and plotted in Figures 4 and 5 below. The results show that very few areas exhibited saturation in 1992, but that a large portion of the built-up area of greater Yangon reached the upper bound value of 63 by the year 2013. This limits our ability to capture further growth in these areas, although the method still remains a potentially valid approach to retrospectively estimating growth in the region monitoring the pace of economic change in non-saturated (e.g. suburban) areas of Greater Yangon in the future.

Overall, our method yields plausible sub-national estimates of growth in Greater Yangon. Given that the DMSP data inevitably exhibit some stochastic variation in the measurement of luminosity, estimating elasticity (and hence growth) with short time series would not be statistically robust. The measurement of luminosity data depend on the sensitivity of the sensor to capture light and it is therefore a technical measure. As all the technical measurements, it is reasonable to assume that errors in the measurement will be systematic. However, random errors can occur both in the measurement (i.e., sensor malfunction) as well as in the processing of the satellite value (i.e., data rendering). A longer time series reduces the statistical significance of random errors.

Besides technical errors, long time series helps to reveal the presence of outliers—i.e. observed luminosity values that are influenced by non-routine events that affect an economy, such as natural disasters. It is also important to monitor sensor saturation over time in national and sub-national estimates to establish the limits of valid empirical inference from this data. Nevertheless it is a method that may be suitable for monitoring economic change in metropolitan areas in low and middle income countries where subnational GDP data are absent and sensor saturation is not widespread.

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Figure 1| Changes in national luminosity, Yangon luminosity and national GDP (2003 = 100)

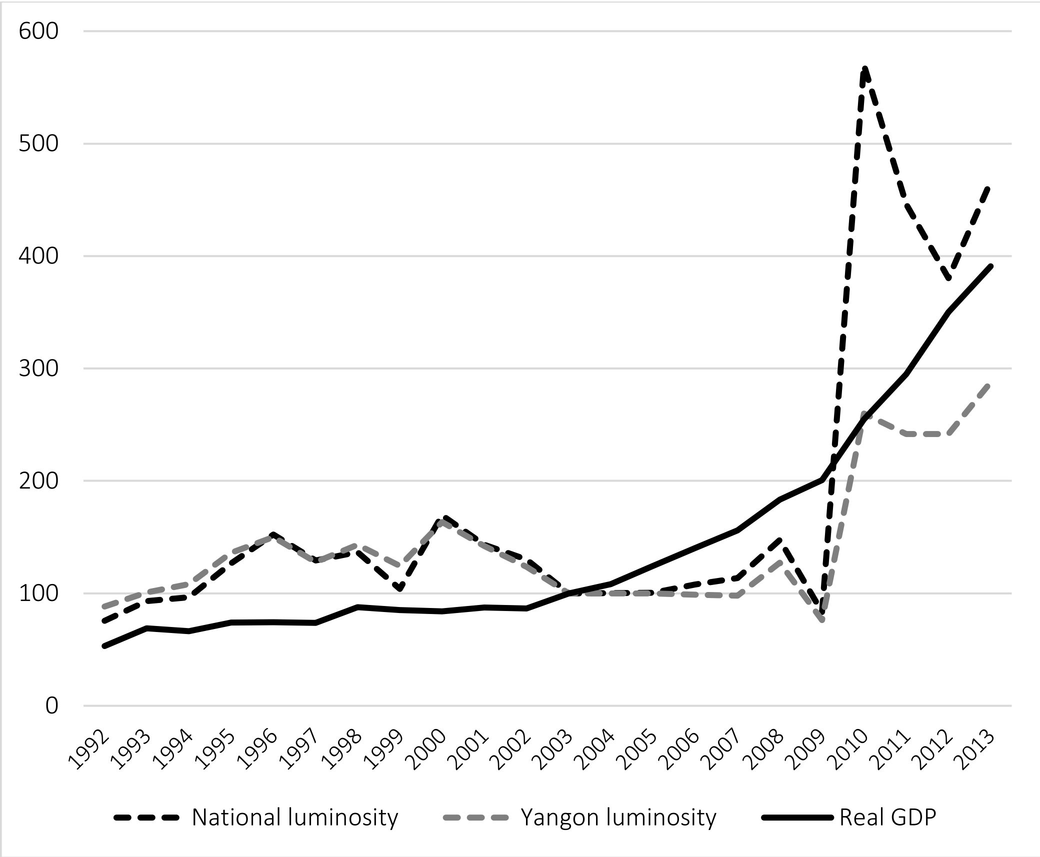

Figure 2 | Luminosity & GDP (all years)

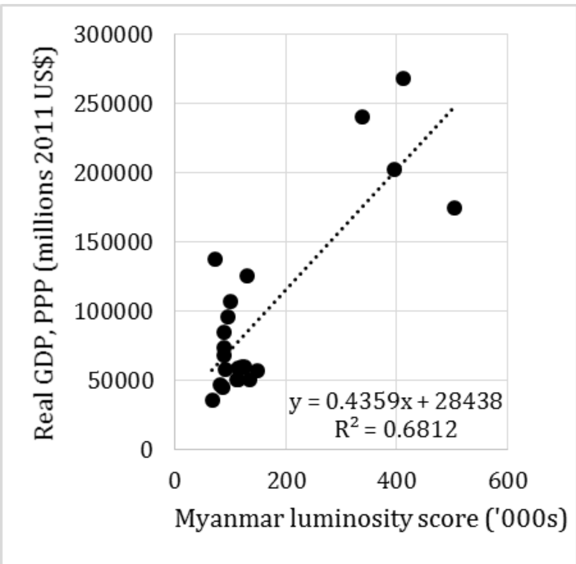

Figure 3 | Luminosity & GDP (ex. 2009 & 2010)

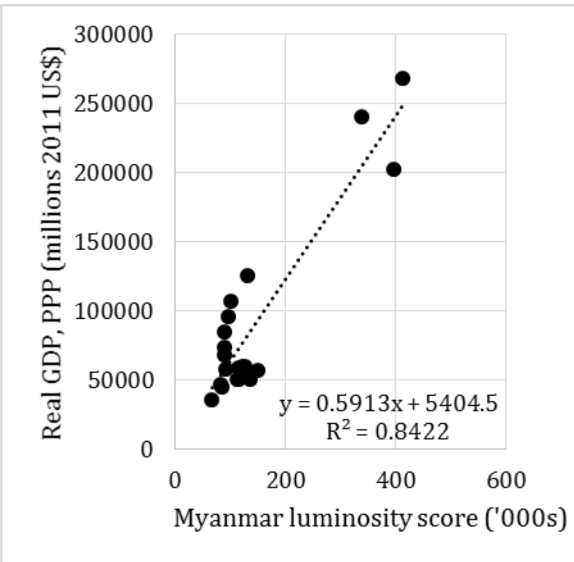

Table 1 | Myanmar Real GDP, Luminosity and Greater Yangon GDP Estimates, 1992-2013

Year	Real GDP (millions 2011 US$)	Myanmar Luminosity Score	Yangon Luminosity Score	Yangon GDP Estimate A	Yangon GDP Estimate B
1992	36467	66930	19841	37087	17136
1993	47334	82332	22610	38294	18774
1994	45600	85465	24262	39014	19751
1995	50913	112085	30529	41746	23456
1996	51099	135018	33671	43115	25314
1997	50653	114514	28712	40954	22382
1998	60200	120903	32143	42449	24411
1999	58412	92162	27941	40617	21926
2000	57632	149940	36697	44434	27103
2001	59988	126827	31867	42329	24247
2002	59475	115118	27743	40531	21809
2003	68644	88567	22448	38223	18678
2004	74172	88806	22406	38205	18653
2005	85341	89106	22401	38202	18650
2006	96302	95588	22167	38100	18512
2007	107126	100648	21966	38013	18393
2008	125765	130582	28573	40893	22300
2009	137864	73779	17108	35895	15520
2010	174954	504669	58360	53877	39913
2011	202453	395084	54265	52092	37491
2012	240380	336961	54279	52098	37500
2013	268314	412884	64583	56590	43592

Figure 4 | Luminosity in Greater Yangon, 1992

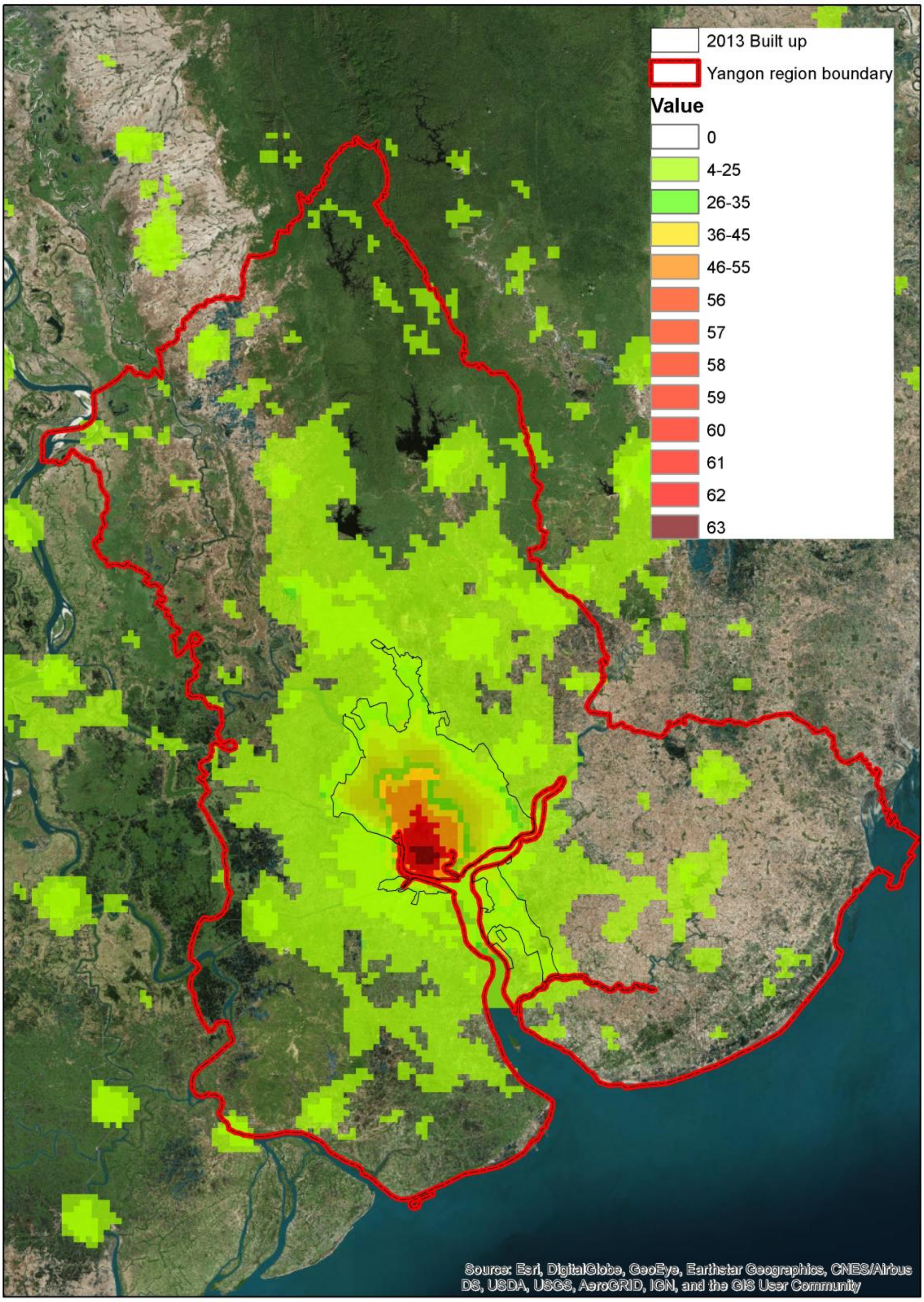

Figure 4 | Luminosity in Greater Yangon, 2013