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Utilizing Night Light Data to Measure Economic Growth: A Case Study of Vietnam

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Abstract: ***Night light data are new data that have recently been exploited to help assess economic growth, map poverty, analyze inequality, and solve many questions that cannot be answered. This study explores the application of night light data as a new method to measure economic growth in the context of traditional measures' limitations. This study examines the correlation between nighttime light intensity and GDP in Vietnam, highlighting the potential of this data to complement conventional economic indicators.***

Keywords: night light data, economic growth, Vietnam, satellite imagery, GDP

1. Introduction

GDP is a traditional metric used globally to gauge economic prosperity. Researchers now use other measures to support and supplement GDP, including methods to measure economic growth using satellite images to capture human activities from outside space. The night light measure is meaningful in measuring consumption growth in countries with little macro information. Henderson (2012) used data on nighttime lighting and demonstrated a positive effect between night lighting levels and economic growth in Mexico and several countries in Africa. Economic dynamics are analyzed through the use of satellite night - light imagery. Henderson (2012) demonstrated that changes in luminosity observed from outer space are positively related to economic dynamism, so the luminosity variable can be used to measure and analyze economic activity.

The connection between night lights and the economy is predicated on their strong correlation with economic activities, even though most of these activities take place during the day. Night lighting can help reflect the spatial expansion of an economy. In developing economies, over time, more areas are illuminated and more bright points begin to be recorded. Furthermore, as rural areas become urbanized, cities become more crowded, infrastructure becomes more modern, the night sky becomes brighter, and stronger light will be recorded by satellites. On the contrary, in underdeveloped areas, bright spots are very limited.
However, the relationship between night lighting and economic development is not always simple. Hu et al (2022) showed that rich countries are indeed brighter than less developed countries, but there is no shortage of exceptions. Japan is a rich country but the night light index is not much brighter than Syria or Arab countries, possibly due to energy - saving habits as well as high population density. The authors also demonstrate that countries in the development stage mainly focus on infrastructure, building bridges and roads, building railway stations, and airports, and upgrading power grids. They all glow at night, making the sky brighter. On the other hand, advanced economies power their economies through technological innovation, and as a result productivity growth often has little related to night light. Night lighting is growing only about half as fast as GDP in advanced economies.

This study aims to investigate the relationship between night light data and economic growth in Vietnam, evaluating the potential of night light intensity as a proxy for GDP measurement. Part 2 is the literature review, part 3 is the current status of the night light index, GDP in Vietnam, and the relationship between the night light index and Vietnam's GDP.

2. Literature Review

Many previous studies have employed various tools to analyze the level of economic development. Young's (2012) study constructed an index to measure the level of development of 56 developing countries using macro data from demographic and health surveys. Good (1994) used the number of letters sent per person as a proxy for production activities in 22 Habsburg sub - regions in the period 1870 - 1910, that is, taking postal activities to measure economic growth.

Global satellite - observed nighttime illumination has emerged as one of the widely used geospatial data products (Amaral et al., 2005; Falchi et al., 2016). These products show locations of artificial light and a measure of brightness as viewed from space. From 1992 to 2013, there was an annual nighttime illumination time series processed from low - light imagery data collected by the Defense Meteorological Satellite Program's Operational Satellite Scanning System of the United States Air Force (DMSP) (OLS) (Elvidge et al., 2010). There are some studies on the application of night light data. Burgess et al (2012) used satellite data to study deforestation in Indonesia. Although forestry is strictly regulated in Indonesia, corruption has led to widespread illegal logging. The authors point out that there are discrepancies between data issued by administrative agencies and actual deforestation data (via satellite images), demonstrating the level of corruption in the country. The correlation between what is recorded by remote sensing and human activity has been observed and demonstrated by Croft (1973) and Doll et al. (2006). In 1997, the first luminosity growth map was presented by Elvidge et al. (1997), and Sutton et al. (2007) demonstrated that such changes could be considered a proxy measure for GDP. Elvidge et al (1997) used night light data to analyze the spatial distribution and characteristics of urban development globally.

Eberner et al (2005) focused on modeling the distribution of per capita income at the local level using night light data. Research has demonstrated that night lighting use is a good proxy for wealth and highlights the relationship between social and economic indicators. Bhandongari et al. (2011) studied in India and used DMSP - OLS to image night light, the authors confirmed the relationship between night light and economic activity. Night light data is used as a cost - effective tool to track economic growth and urbanization. Petricioli (2015) conducted a study showing the collection and processing of nighttime satellite images to estimate the economic growth rate of different Mexican states. Research has shown the importance of using satellite - based approaches to enhance economic analysis at the local level. Chen et al (2011) pointed out the limitations of macroeconomic data sources for several countries and proposed luminosity as a proxy for economic growth measures. Similar results were also demonstrated by Henderson et al. (2012). The night light index is also used to measure economic growth in regions where data is not available or the data is manipulated or interfered with. Bils et al (2001) demonstrated that as light intensity increases, a country's income also increases.

3. Night light data and the economic growth status in Viet Nam

Research data

Nighttime light data used in the study is taken from satellite image data of the earth's surface at night that has been standardized (reduced haze, increased image contrast). These data are based on U. S. Air Force weather satellite observations from space of the brightness of light in different regions of Earth, corrected for random effects such as clouds, moonlight, and firelight (Sutton et al., 2002).

In the 1970s, the U. S. Air Force Defense Meteorological Satellite Program (DMSP) used OLS sensors to detect light clouds. OLS used a photomultiplier tube to achieve a million - fold signal amplification in the panchromatic spectral range. Extremely high light intensities can help detect human settlements. However, the practical use of these observations is negligible because there is no distribution system. In 1992, a digital archive for OLS (Operational Linescan Sensor) night light data collected on Defense Meteorological Satellite Program (DMSP) satellites was established at the NOAA National Geophysics Agency data center (NGDC). Night light images obtained from the DMSP/OLS satellite provide a simple way of global night light images for related research. This data can easily be obtained from the National Geophysical Data Center (NGDC) website, which contains light from cities, towns, and other locations. For many years, DMSP was the sole source of global night light imagery data (Small et al., 2013). However, images collected by the OLS sensor system encounter some problems such as light band noise and difficulty taking low - light images in cloudy conditions. Even so, there is no reasonable substitute for global mapping of night lights.

This situation changed in 2011, with the launch of the Visible Infrared Imaging Radiometer Suite (VIIRS) on the NASA/NOAA NPP Suomi satellite. With advanced nighttime remote sensing technology, (EOG) has collected nighttime satellite images and created the highest quality Global Nightlight map. The Joint Polar - orbiting Satellite System (JPSS), Visible and Infrared Imaging Suite (VIIRS) Day Night Band (DNB) spectrum on the most modern earth observation JPSS satellites has brought about incredible improvements in low - light photography compared to DMSP - OLS. VIIRS provides significant improvements over DMSP in terms of spatial resolution, quantization, and calibration (Small et al., 2013).

The fundamental purpose of both DMSP and VIIRS low - light imaging is to enable the detection of clouds using moonlight rather than sunlight as the illumination source. A wide range of natural and social sciences accrue benefits from the unintended ability of these systems to detect light on Earth's surface. On a moonlit night, DNB images look similar to daytime images with clouds and Earth's surface features visible. A sign that the image was taken at night is the presence of city lights on the ground. In addition, DNB records several other types of phenomena not related to electric lighting, including stray lights, lightning, biomass burning, gas flares, high - energy particle (HEP) detection, gas flares surrounding light sources, and ambient noise.

To create night light data, low - light image data needs to be filtered to exclude low - quality data and irrelevant features through a series of cascading filtering steps before averaging over time. The resulting average radiance product has a null value (zero) in areas where no surface light is detected.

The study used parallel collated data from EOG standardized data. To achieve alignment and consistency between nighttime light data from both the DMSP and VIIRS systems, EOG conducted a synchronization from 1992 to 2021 on a global scale. This process aims to process and convert data from two different observing systems into a single standard, ensuring consistency and visual comparability between different years and regions across the world. Through the use of this synchronized data, data on changes in nighttime lighting from 1992 to 2021 are guaranteed to be consistent and reliable.

Research Methods:

To collect research data, the author downloaded image data of the Earth's surface at night on the EOG website. Data after download will be processed according to the following steps:

Step 1: Read the image file to determine the image structure

Because data about nighttime images of the Earth is stored by EOG in the form of TIF (Tagged Image File Format) files, the research uses Python's Tiffile library to read the data files. Python's Tiffile library has many advantages in reading and processing image files in tif format, including reading and writing structured data. The Tiffile library allows you to read and write image data TIFF formats have a complex structure, including multi - page TIFF and multi - channel color data. Users can access and process individual frames and color channels with ease. This helps researchers classify the different brightness of light spots on each pixel, thereby providing more objective and accurate data. Besides, the Tiffile library also supports converting images stored as TIF files to a data frame, thereby making data processing more optimal.

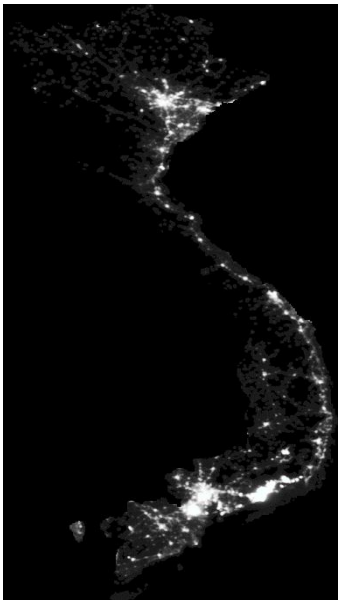


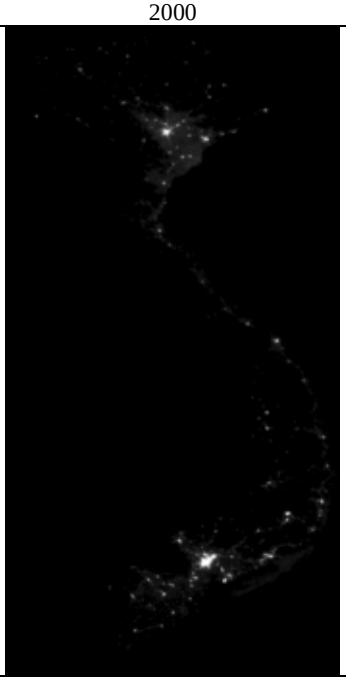
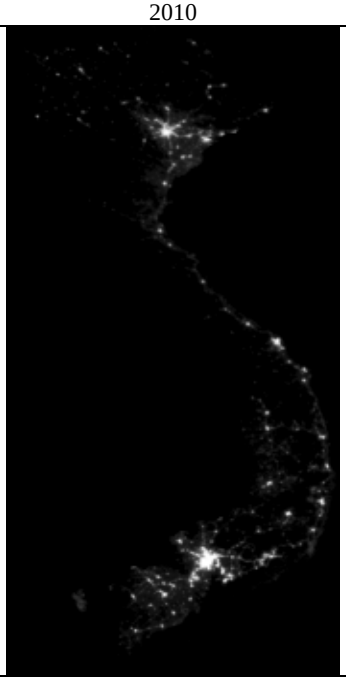
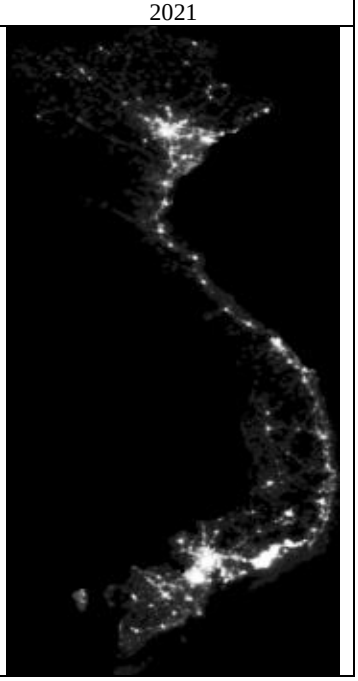
Figure 1: Image of night light on the mainland of Vietnam filtered from satellite images
Sources: World Bank and Python

Step 2: Data processing
After reading the image file of the earth's surface provided by EOG, the researcher found that the image is made up of a matrix with dimensions of 16801x43201, corresponding to the image stretching from latitude 70 degrees North to 70 degrees South and from longitude 180 degrees East to 180 degrees West. Because the scope of the research needs to be carried out on the mainland territory of Vietnam, the study is therefore conducted to determine the position of the mainland territory of Vietnam (excluding islands) in the matrix obtained.

Step 3: Collecting complete data after processing:
After obtaining a complete image of Vietnam's land area, the study calculated the collected light data based on the matrix previously obtained after filtering through the layer.

The results of Vietnam's night light obtained after processing according to the above steps show that over the years, Vietnam's night light has become increasingly clearer and has more bright spots.

Figure 2: Changing night light images in Vietnam over the years

Year	2000	2010	2021
Vietnam			

Source: Python

Via the images of night light spots in Vietnam, it can be seen that over the past 20 years, the amount of night light in Vietnam has improved significantly and impressively. There were very few bright spots from 2000, focusing only on the two largest cities Hanoi and Ho Chi Minh City. By 2010, the number of bright spots had improved significantly. Although the number of light spots at night is still largely concentrated in the two big cities of Hanoi and Ho Chi Minh, there have begun to be many light spots scattered across the country, both in the mountainous and central regions. By 2021, the number of light spots will appear more clearly and spread across all states of the country.

After processing satellite image scans and counting light spots, data on total night light in Vietnam was collected. It can be seen that the total night light data in Vietnam has increased over the years. In the period 2000 - 2010, over 10 years, the number of night lights has doubled. Especially in the period from 2010 to 2021, the total number of night lights in Vietnam has tripled. This shows the rapid development of Vietnam's economy. Rapid and outstanding growth has been recorded from 2014 until now.

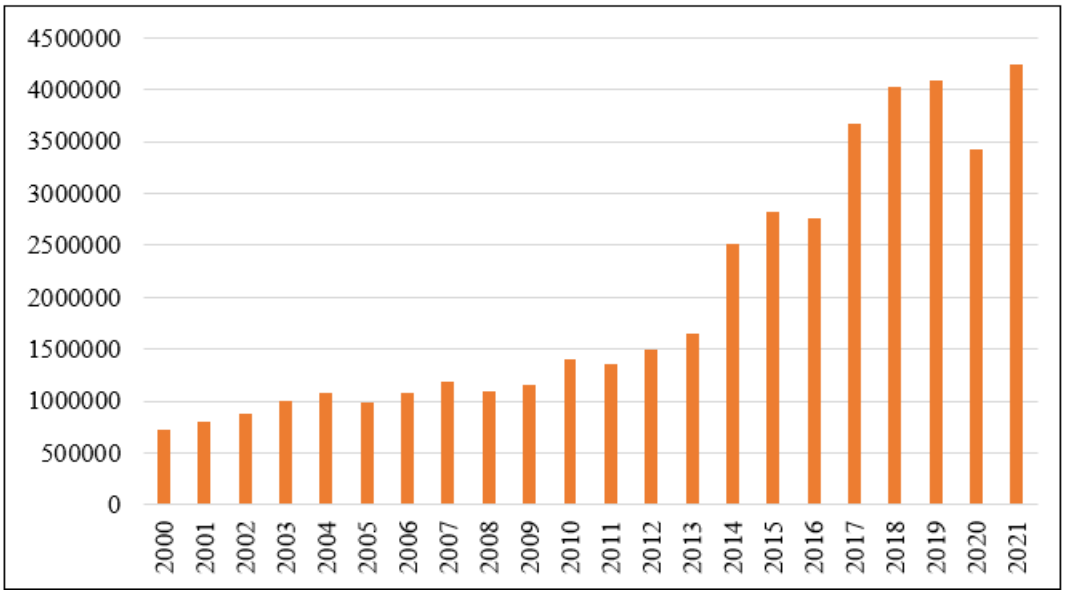


Figure 3: Total nightlight data in Vietnam scanned from VIIRS satellite images
Source: Python

In 2020, total night light data in Vietnam decreased significantly. This is also the time of the Covid 19 with many epidemic prevention measures including social distancing, arts, entertainment, and tourism attractions being closed. In 2021, the whole country entered a new normal state, so the total number of night lights recorded an increase again.

The relationship between night light data and Vietnam's GDP

Night lighting could be used as a measure of economic activity. It can be seen the positive correlation between GDP and night light data (Figure 4).

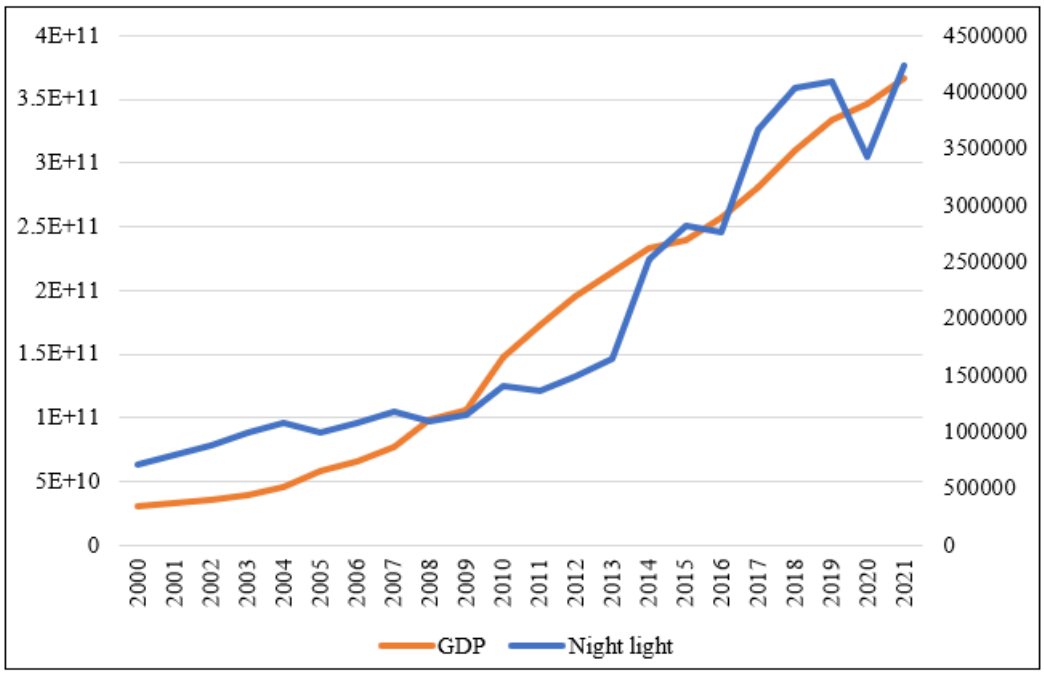


Figure 4: Nightlight and GDP growth in Viet Nam (2000 - 2021)
Source: World Bank, Python

To estimate the effect of night light data on real GDP in Viet Nam, according to López et al. (2024), the following model is used:

$LnGDP_t = \alpha_1 + \beta_1 NLD_t + \varepsilon_t$

In which: a_1: Constant of the model
β_1: regression coefficient
e: residual of the regression equation

Dependent variables

$LnGDP_t$: Ln of national GDP in year *t.*

Independent variables

$LnNLD_t$: Country's night light index in year t

GDP data is taken from the World Bank. The night light index was calculated from Python software as described above. The model regression results give the following results:

Table 5: Model regression results

lnGDP	R - sq	Coef.	P - value
lnNLD	0, 8452	1, 3373	0, 0000

Soucre: Results from Stata

The results of the model show that 85% of economic activity in Vietnam is determined by changes in night light, therefore night light can be used as a proxy for economic growth.1 unit change in GDP is explained by 1.33 units of night light. This result coincides with the research results of Henderson et al. (2012) and López et al. (2024).

4. Conclusion

Satellite images of nighttime lights have contributed to an increased understanding of economic activity. Night lighting can help estimate economic activity in small spatial units over time. Because night light and gross domestic product (GDP) are measured in different units, changes in the night light index cannot be directly converted into unit changes in GDP.

Building on Henderson et al. (2012), and Lopez et al. (2024), economic dynamics are analyzed through the use of satellite night - light imagery. This construction complements the lack of information and measurement of economic dynamism at the local level. The results highlight that luminosity changes observed from outer space are positively related to economic dynamism, so the luminosity variable can be used as a proxy to analyze these changes in Gross Domestic Product (GDP).

The night light data in Vietnam show that Vietnam is getting brighter at night. Empirical research results also demonstrate that the increase in night light data has a positive relationship with economic growth in Vietnam. Thus, night light data in Vietnam can be used as a new measure of economic growth.

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