

Research and application of optimizing economic measurement with night light data

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Abstract:

The essay delves into the strengths and weaknesses of key economic indicators, arguing that a combination of GDP, Human Development Index (HDI), and satellite-based nightlight observations offers the most comprehensive perspective. Nightlight observations in regions like Asia and Ukraine positively correlate with GDP, indicating timely economic dynamics and changes. Using night luminosity images as a proxy for GDP growth quantity and HDI as a proxy for GDP growth quality can enhance our understanding of economic measurement, providing a broader and more nuanced picture of a nation's economic health and vitality.

Keywords: Economic indicators; GDP; HDI; Satellite luminous observations

1. Introduction

Economic analysts and policymakers rely on a diverse array of economic indicators to assess and quantify the performance of a nation's economy. Beyond the traditional metrics like Gross Domestic Product (GDP), government budgets, and money supply, alternative indicators such as the Human Development Index (HDI) and Gross National Income (GNI) have emerged as valuable tools in understanding the economic structure and scale. These indicators provide insights into national and global activities' growth and contraction patterns over time.

The essay aims to delve deeper into the strengths and weaknesses of these key economic indices. When combined with the HDI and satellite-based nightlight observations, I contend that GDP offers the most comprehensive perspective. Notably, the high-frequency, fine-grained nightlight observations, particularly in regions like Asia and Ukraine, exhibit a positive correlation with GDP. This correlation could be a timely indicator of economic dynamics and the aftermath of economic shocks, as suggested by Gibson et al. (2020).

The findings suggest that utilizing night luminosity images, serving as a proxy for the quantity of GDP growth, alongside the HDI, which acts as a proxy for the quality of GDP growth, could significantly enhance our comprehension of economic measurement. This approach provides a broader picture and allows for a more nuanced understanding of the various dimensions that contribute to a nation's economic health and vitality.

2. Measuring the Economic Performance

Using GDP as the sole metric for economic measurement has several limitations. Firstly, GDP primarily focuses on market-based economic activities, overlooking non-market-based ones. This exclusion is particularly problematic in developing countries, where informal production, often uncaptured by GDP, can account for up to 50% or more of the total economic output (Kitchen and Monaco, 2003). Secondly, GDP is susceptible to manipulation by government officials seeking to inflate figures for personal or political gain. Empirical evidence using nightlight data has shown that local government officials in China, for instance, tend to inflate GDP due to promotion incentives (Cai et al., 2022; Chen et al., 2021). Furthermore, GDP may not accurately reflect timely economic shocks, such as those caused by the Covid-19 pandemic or wars. This is because calculating GDP can take months to complete, making it a lagging indicator of economic health (reference). Additionally, GDP fails to capture important positive externalities (such as reduced crime and improved quality of life) and negative (like environmental degradation and increasing inequality), significantly impacting overall well-being. To address these shortcomings of GDP, efforts have been made to develop supplementary indices, such as the Human Development Index (HDI). The HDI goes beyond economic output to incorporate life expectancy, education, and income, providing a more comprehensive picture of human well-being (UNDP, 2018). A higher HDI score typically indicates improved

overall welfare. However, the HDI also has its limitations. Data availability and quality can be problematic for some countries, limiting the accuracy and reliability of the index (Wolff et al., 2011). Despite these weaknesses, the HDI remains a valuable tool in complementing GDP as a measure of economic performance and well-being.

Gross National Income (GNI) is a crucial economic indicator distinct from Gross Domestic Product (GDP). GDP focuses primarily on domestic production, whereas GNI measures the total income accruing to a country, regardless of its geographical location. This distinction makes GNI particularly suitable for countries with significant overseas assets, as it captures profits generated abroad. For instance, profits made by a German manufacturer overseas would be included in GNI, while the output of a Korean-owned factory in Germany would not. As a result, GNI offers a more comprehensive view of a country's economic condition, especially for those with extensive international holdings like Norway. However, it's worth noting that GNI is also highly correlated with GDP, as indicated by Table 1, which suggests that it may inherit some of the limitations associated with GDP. These limitations include the inability to capture non-market activ-

ities and the potential for manipulation by government officials.

Meanwhile, government budgets and money supply serve as key economic policy tools and indicators, primarily used to manage public finances, expenditures, deficits, and inflation. While these tools provide valuable insights, relying solely on them to gauge economic activity can be challenging. The exact balance of these indicators may be politically motivated and not fully transparent, and there is often a complex relationship between economic activities and these policy indicators.

In conclusion, while GDP remains the most widely used measure of economic activity and growth, it has limitations as an indicator of a country's overall economic and social well-being. Similarly, government budgets and money supply, while important policy tools are imperfect measures of the real economy's output and welfare. Therefore, it's crucial to supplement these metrics with alternative measures such as the Human Development Index (HDI) and nightlight luminosity to gain a more comprehensive understanding of a country's economic condition and progress.

Table 1 Comparing multiple economic indices

Index	Formula/Definition	Pro	Con
GDP	$\text{GDP} = \text{Consumption} + \text{Investment} + \text{Government Expenditure} + \text{Net export}$	<ol style="list-style-type: none"> 1. Easily understandable and a key determinant of other economic indicators 2. Widely adopted by governments and financial institutions worldwide 3. Determine an economy's overall size and growth rate, as well as its current rate of growth. 4. The GDP often determines the monetary and fiscal policies of central banks and governments 	<ol style="list-style-type: none"> 1 Subject to manipulation 2. Calculation would take a long time 3. A high economic growth rate does not necessarily reflect a high standard of living
GNI	$\text{GNI} = \text{GDP} + \text{Income earned on all foreign assets} - \text{Income earned by foreigners in the country}$	<ol style="list-style-type: none"> 1. GNI is similar to GDP in some countries. 2. Calculation of a country's income, which includes all income earned by its residents, businesses, and foreign sources 	<ol style="list-style-type: none"> 1. Being subjected to all the shortcomings of GDP, the item's value can be easily overestimated or underestimated. 2. GNI needs to be calculated using purchasing power parity for countries whose current- cities differ

Money supply	The money supply is a country's economy's total currency and other liquid assets.	<ol style="list-style-type: none"> 1. Under direct control of the central bank 2. The monetary policy can be adjusted flexibly according to the inflation rate, the GDP, and other factors 3. Contributes to economic activity by influencing investor expectations, credit market liquidity, and aggregate demand 	<ol style="list-style-type: none"> 1. Different countries have different policy reliability and stability. 2. There may be inaccuracies or incompleteness in the government budget data
Government budgets	A budget estimates a government's expenditures and revenues for a specified period.	<ol style="list-style-type: none"> 1. Implement fiscal policies based on the government budget. 2. Reflect the state of the national economy and the basic circumstances of various construction projects 3. An increase in budget revenue may indicate an increase in economic activity 	<ol style="list-style-type: none"> 1. Different countries have different policy reliability and stability. 2. There may be inaccuracies or incompleteness in the government budget data
HDI	HDI means that people have long and healthy lives, are knowledgeable, and have a decent standard of living.	<ol style="list-style-type: none"> 1. Expand the definition of development beyond economic growth to include other vital indicators of living standards. 2. It is easier to compare the country with other nations 3. Promoting social equity 	<ol style="list-style-type: none"> 1. It is impossible to accurately reflect the economic situation since some factors, such as the employment rate, are ignored. 2. Not taking into account the income disparity between rich and poor 3. Data reliability

3. Using Nightlight to Improve Economic Measurements

3.1 Nightlight offers real-time measurement and mitigates manipulation.

Given the strong correlation between electricity usage and industrial output, nightlight has become a valuable proxy for economic measurement (Chen and Nordhaus, 2011; Gibson et al., 2020). As depicted in Figure 1, which I plotted using QGIS, it becomes evident that there has been a remarkable surge in nightlight intensity surrounding cities like Shanghai, New Delhi, Bangkok, and Seoul from 2014 to 2019. This increase is a testament to these urban centers' growing economic activity and prosperity. On the other hand, Figure 2 offers a stark contrast, revealing a significant reduction in nightlight intensity in major Ukrainian cities. This decrease directly reflects the economic shocks caused by the COVID-19 pandemic and the ongoing conflicts with Russia. The figures presented here offer a preliminary yet compelling argument for utilizing nightlight as a reliable proxy for GDP in gauging economic activity or living standards. By leveraging this innovative approach, we can gain deeper insights into nations' economic health and vitality, allowing for more informed decision-making and policy formulations.

3.2 Correlation between GDP and nightlight

After presenting preliminary evidence that nightlight may serve as a potential proxy for GDP, I empirically investigate the relationship between GDP and nightlight in China as an illustrative case study. To accomplish this, I merge data from the China County Statistical Yearbook with county-level nightlight information covering the period from 2000 to 2021 to estimate the following specifications.

$$\ln(GDP_{c,t}) = \beta \ln(Nightlight_{c,t}) + \gamma_t + \lambda_c + \varepsilon_{c,t}$$

$GDP_{c,t}$ represents the GDP of county c in year t in China, measured in natural logs, while $Nightlight_{c,t}$ signifies the intensity of nightlight in the same county and year, also expressed in natural logs. β , the parameter of primary interest, captures the estimated elasticity of GDP to changes in nightlight. The model also includes year-fixed effects, denoted by γ_t , which account for time-varying characteristics common across all counties, such as interest rates. Additionally, λ_c represents county-level fixed effects, capturing time-invariant characteristics such as altitude and location. To address potential spatial correlation, we cluster all standard errors by county. The results in Table 2 demonstrate a fundamental relationship between GDP and nightlight. Column (1) offers a basic glimpse of this relationship. Columns (2) and (3) present a more robust

analysis, controlling for additional county and year-fixed effects. The findings indicate that, on average, a 1% increase in nightlight intensity corresponds to an 18.2% increase in GDP in China. This relationship is statistically

significant at the 1% level, suggesting that changes in nightlight can serve as a meaningful proxy for explaining changes in GDP.

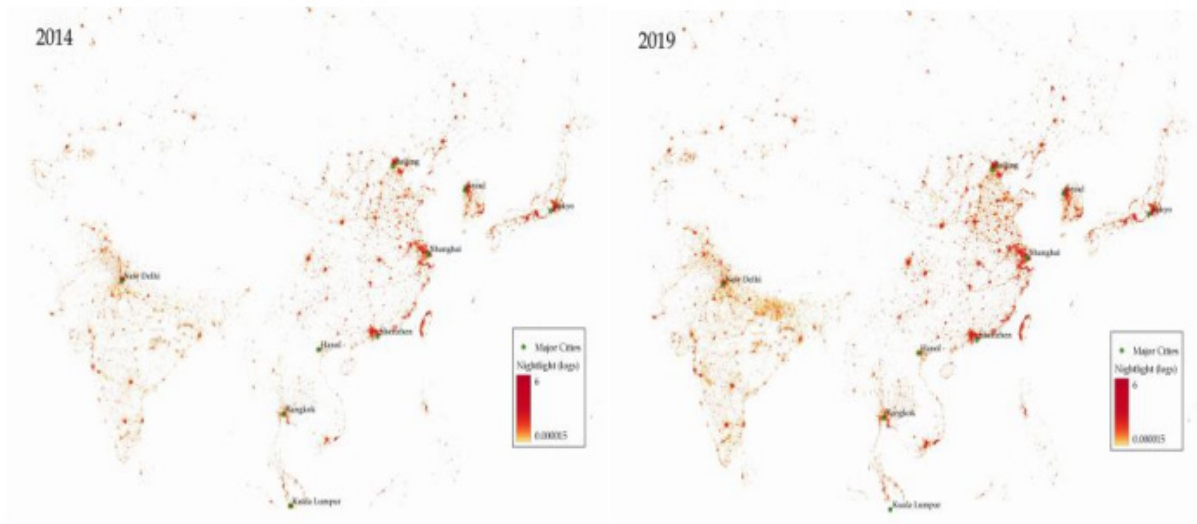


Figure 1: Nightlight in Asia (2014 - 2019)

In summary, this paper highlights several key benefits of utilizing nightlight as a metric for measuring economic activity. Firstly, in contrast to survey-based measures of GDP and GNI, nightlight offers frequent and highly spatio-temporal observations, enabling the exploitation of real-time national output, as illustrated in Figures 1 and 2 and Table 2. Secondly, the satellite light data employed

as a proxy for GDP is observed independently, eliminating potential biases or inaccuracies inherent in traditional measurement methods. Furthermore, the utilization of nightlight can assist in addressing the challenges associated with inaccurate GDP measurements, as it is less susceptible to manipulation by local government officials.

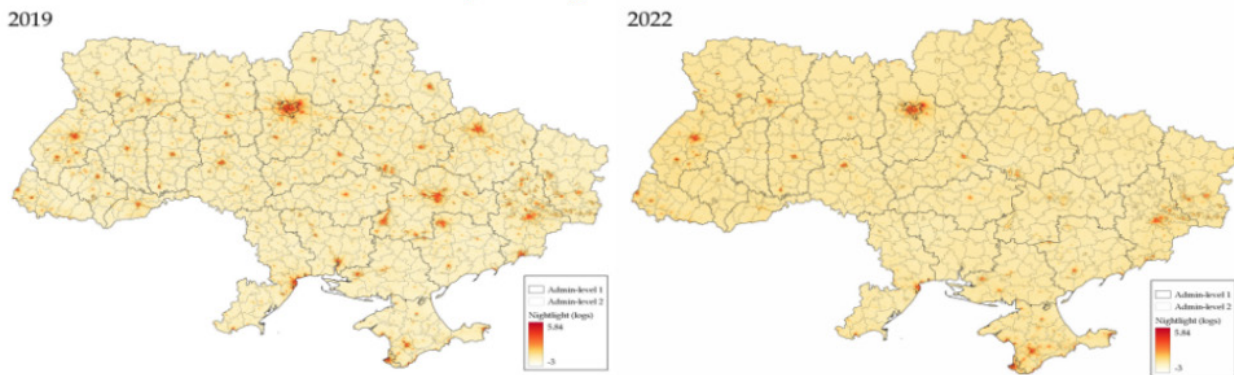


Figure 2: Nightlight in Ukraine (2019 - 2022)

Table 2 Three Scheme comparing

VARIABLES	(1) GDP	(2) GDP	(3) GDP
Nightlight	0.553*** (0.008)	0.483*** (0.008)	0.182*** (0.009)

Constant	13.420*** (0.015)	13.445*** (0.014)	13.554*** (0.003)
Observations	22,403	22,403	22,375
Year FE	No	Yes	Yes

4. Conclusion

Multiple economic indicators, including Gross Domestic Product (GDP), Gross National Income (GNI), Human Development Index (HDI), government budget, and money supply, play a pivotal role in understanding the dynamic evolution of economies and shaping policy responses. However, the accuracy of these indices can sometimes be compromised due to manipulation or the absence of reliable data sources. In this essay, I aim to enhance economic measurement by incorporating high-frequency, fine-grained observations of nightlights. Nightlight appears to be a reliable and effective proxy for economic activity, offering valuable insights into its measurement. By leveraging these observations, we can gain a more comprehensive understanding of economic performance and make informed decisions that contribute to nations' overall health and vitality.

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