Blog article - Team Europa

Title

Abstract
The Lao People's Democratic Republic (PDR) is scheduled to graduate from the Least Developed Country (LDC) category by 2026, marking steady economic growth and a shift toward a higher development status. Yet access to reliable provincial and sectoral GDP figures remains limited, making it difficult to carry out in-depth subnational analysis.
To track where growth is happening, this column uses nighttime lights and population data to map national GDP across provinces and the Golden Triangle SEZ. The findings show rising luminosity outpacing softer official growth and a sharp intensification in the SEZ. These trends might be missed by standard statistics amid limited subnational reporting.

Motivation
Gross Domestic Product (GDP) is widely used to measure economic growth, but in developing countries it is often unreliable. Limited government capacity to collect reliable data and the large role of informal economic activities make both GDP and price indices highly uncertain (Deaton and Heston, 2010). Errors can be substantial, with margins up to 30 percent in standard datasets (Chen and Nordhaus, 2011). Since GDP is rarely available at the subnational level, researchers have turned to proxies such as electricity use and household surveys (IMF, 2006; Young, 2009). In this context, Henderson et al. (2012) proposed the use of nighttime lights as a detailed proxy for measuring economic activity. In their paper, they show, for example, that changes in light intensity are strongly correlated with GDP growth across countries, and that nighttime light data can help improve estimates in countries where official statistics are weak or inconsistent.
Our initial motivation was to study economic activity in the Golden Triangle Special Economic Zone (GTSEZ). However, any meaningful comparison proved difficult because no reliable provincial GDP data exists for the Lao PDR. This highlighted the broader challenge of subnational measurement. In order to address this, we decided to first compare the evolution of nighttime lights growth with national GDP growth in the Lao PDR, and then use nighttime lights, population, and area data to construct provincial GDP estimates for each of the country's provinces.
We aimed to assess whether official GDP adequately captures the informal economy in the Lao PDR and to estimate provincial GDP, which is currently unavailable due to a lack of data. Addressing these gaps is important for both economists and non-economists, since investment decisions, government programs, and the work of NGOs all depend on the reliability of such information. Furthermore, addressing this helps better understand development, poverty, and growth at a subnational level, potentially shining light on inequality and corruption.

The Lao PDR and the Golden Triangle Special Economic Zone
The Lao PDR (also known as Laos) is the only landlocked country in Southeast Asia. It shares borders with five countries: China to the north, Vietnam to the east, Cambodia to the southeast, Thailand to the west, and Myanmar to the northwest. Laos is one of only five communist

countries in the world. As of 2024, its national GDP was $16.5 billion. The country is divided into 18 provinces, which together are home to 7.8 million people. Classified as a Least Developed Country (LDC) by the United Nations, Laos is expected to graduate from this status in 2026. Its economy relies heavily on hydropower exports, mining, and agriculture, while tourism and Special Economic Zones have become increasingly important in recent years.

Among these zones, the Golden Triangle Special Economic Zone (GTSEZ) in Bokeo Province stands out. Created in 2007 under a 99-year lease to the Chinese-owned Kings Romans group, the zone sits at the junction of Laos, Thailand and Myanmar which was once the world's most notorious opium producing region.Today, it has been transformed into a casino-driven enclave with hotels, restaurants, logistic hubs and real estate developments catering largely by the Chinese tourists and investors.

The GTSEZ is, however, more than a story of rapid development. International organizations often describe it as “a state within a state.” In 2018, the U.S. Treasury sanctioned the Kings Romans group for alleged involvement in money laundering, trafficking, and other illicit activities. At the same time, the Lao government promotes the zone as a magnet for foreign investment and regional integration. This tension makes the GTSEZ one of the most secretive and controversial zones in SouthEast Asia.

For our project, the GTSEZ offers a unique opportunity to study growth in a place where official statistics are either missing or unreliable.On paper, The Zone barely shows up in provincial or national GDP figures. But at night, satellite imagery reveals a dramatic surge in brightness along the Mekong, suggesting far more activity than reported. By combining nighttime lights with population and geographic data, we treat the GTSEZ as a case study to show how remote sensing can uncover both formal growth and hidden, informal economies that are otherwise invisible in Laos’s official data .

Data and approach

To study economic activity in Laos, we rely on a mix of official statistics and satellite imagery.The challenge is that provincial GDP data is either unavailable or incomplete. This makes it difficult to understand how growth is distributed across the country, or to access special cases like the Golden Triangle SEZ.

Our solution was to use nighttime lights (NTL) as a proxy for economic activity. Satellite sensors, first from the U.S. Air Force’s DMSP program and more recently from NASA/NOAA’s VIIRS system, record the intensity of light visible from space. Previous research has shown that brighter areas tend to correspond to greater economic output- especially in developing countries where data is weak.

For Laos, we compiled:

- Nighttime light data (VIIRS annual composites, 2012-2022)
- Population data (adjust for per-capita comparisons)

- Geographic boundaries for all 18 provinces
- National GDP totals from the World Bank and Lao government reports

We then distributed national GDP across provinces in proportion to their light intensity, a method used in earlier work by Henderson et al (2012). This allowed us to create provincial GDP estimates for each year, even though no official GDP series exists.

Finally we zoomed in on Bokeo Province and the GTSEZ. By drawing a bounding box around the SEZ, we tracked its light growth relative to the rest of Laos. This comparison gave us a way to see whether the SEZ is experiencing unusually rapid growth.

Data Processing Steps

The steps we took to process the data were:

1. Spatial extraction: VIIRS rasters were cropped to Laos boundaries (100°-108°E, 13.5°-22.5°N) and masked using administrative shapefiles to isolate provincial territories.

2. Winsorization: to reduce the impact of outliers from gas flares, fires, and sensor anomalies, we applied winsorization at the 1st and 99th percentiles of non-zero light values for each year. This technique caps extreme values while preserving the overall distribution of luminosity.

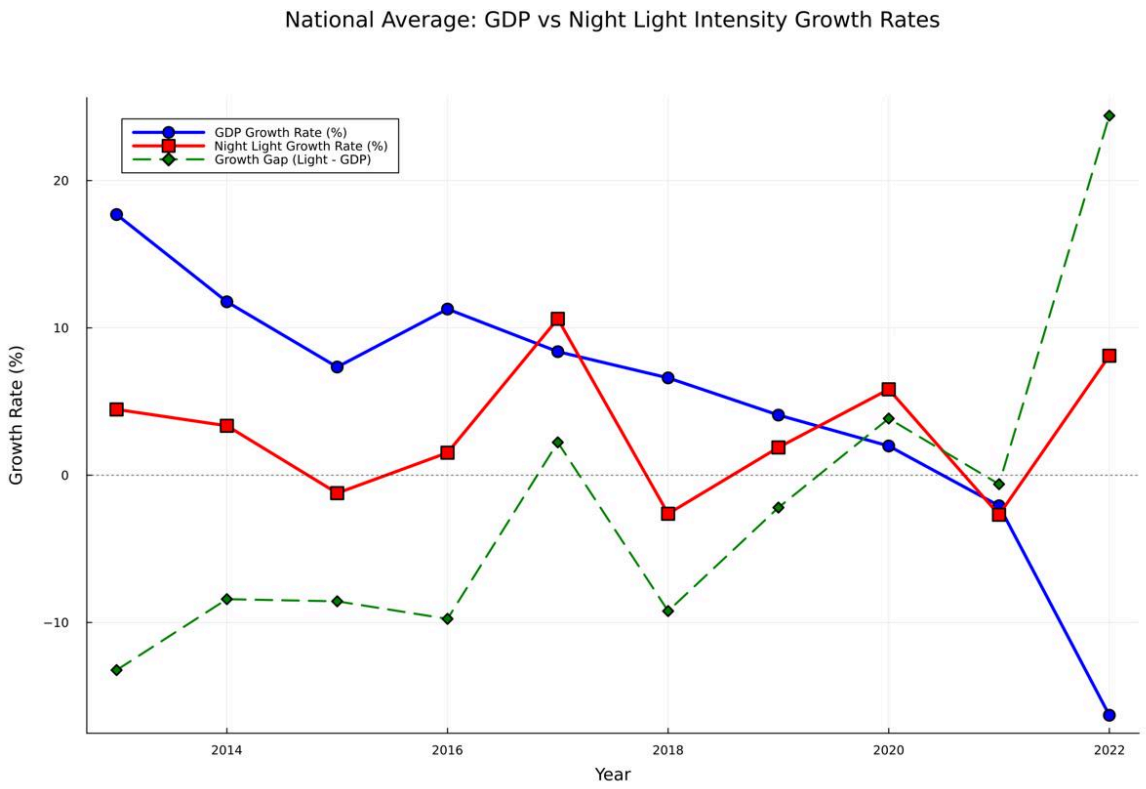
3. Zonal statistics: for each province-year combination, we calculated:
   - Total light intensity (sum of all pixel values)
   - Mean light intensity
   - Number of lit pixels (pixels with radiance > 0)
   - Standard deviation of light values

4. Regression analysis: we estimated the elasticity of GDP with respect to nighttime lights using log-linear regression:

$$log(GDP) = \alpha + \beta \times log(Light) + \varepsilon$$

Where β represents the light elasticity of GDP. For our sample, β = 0.814 with $R^2 = 0.559$, indicating that a 1% increase in light intensity corresponds to approximately 0.81% increase in estimated GDP.

National pattern: GDP vs NTL growth

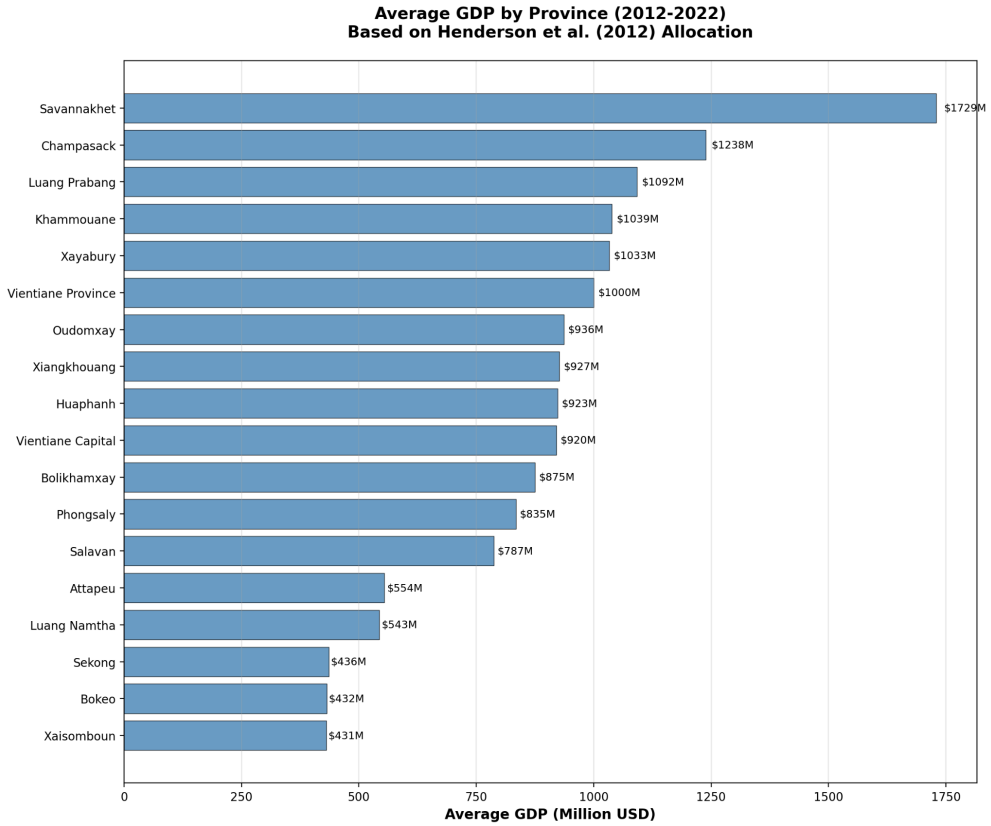


Between 2012 and 2022, the relationship between the Lao PDR's official GDP growth and nighttime light (NTL) intensity growth reveals important insights into the country's economic measurement. While official GDP growth shows a downward trend over this period, NTL intensity growth has followed a steadier trajectory, ultimately ending at a higher level than where it began.

The gap between the two indicators has widened, with the difference between GDP and NTL growth showing a clear upward trend. This divergence is supported by the regression results: the GDP growth coefficient of 1.22 and an R-value of 0.69 indicate a reasonably strong correlation between GDP and NTL growth, but also suggest that NTL captures dimensions of economic activity that official GDP statistics may overlook.

Consistent with Henderson et al. (2012), these findings suggest that in Least Developed Countries (LDCs) such as the Lao PDR, GDP may undercount total economic activity by failing to fully capture the informal economy. While the informal sector in Laos has been on a downward trajectory, it still accounted for about 20 percent of GDP as recently as 2020. This highlights the value of nighttime lights as a complementary measure, particularly in economies where informal activity remains significant.

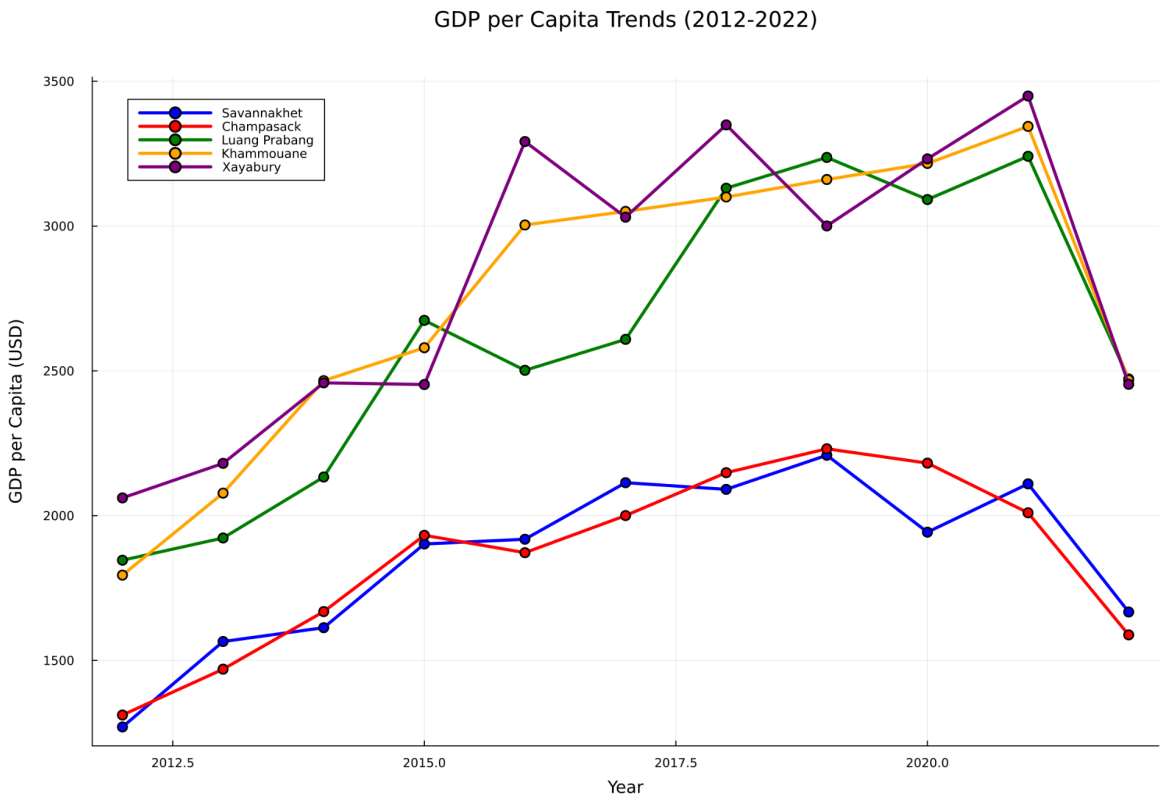
Estimating provincial GDP



Our provincial GDP estimates reveal how uneven growth is across Laos. Vientiane Capital clearly dominates total GDP. This is not surprising - as the political, commercial, and service hub of the country, it concentrates government offices, banks, universities, foreign investments and urban infrastructure. Its glow in nighttime lights is steady and dense, reflecting both administrative activity and growing urban consumption.

Savannakhet stands out as the second major growth center. Located along the East-West economic corridor, it connects Laos to Thailand and Vietnam, making it a strategic hub for trade. Its SEZs have attracted manufacturing, logistics, and cross-border commerce. After 2017, Savannakhet's GDP even surpassed Vientiane's at certain points - showing that trade-driven provinces can rival the capital's dominance when integration and border flows are strong.

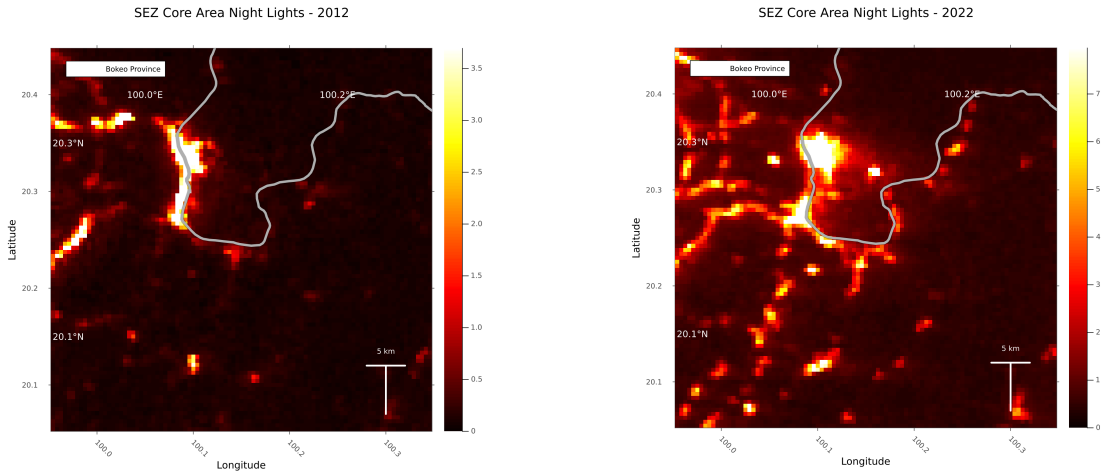
When we shift from total GDP to GDP per capita, the story changes. Smaller provinces like Champasack in the south and Bolikhamxay in the center move up the rankings. Champasak benefits from tourism around the UNESCO World Heritage site Wat Phou and the Four thousand Islands, while Bolikhamxay leverages agriculture and cross-border trade with Vietnam. These cases highlight that smaller provinces may not generate the most output overall but can provide relatively higher standards of living for their residents.



Both total and per capita GDP, however, show a clear downturn after 2019, largely due to the covid-19 pandemic. Tourism collapsed, border trade slowed, and investment projects were delayed. This left a noticeable dip in the trajectories, particularly in provinces more dependent on tourism and cross-border activity.

What makes these findings important for a project is that they aligned with the patterns in nighttime light data. Vientiane's steady brightness reflects its administrative dominance, while Savannakhet's rising lights along the border corridor capture trade and SEZ activity that official statistics often miss. Smaller provinces show weaker lights but, when adjusted per person, tell another story of relative prosperity.

The Golden Triangle SEZ



From 2012 to 2022, nighttime lights show how the Golden Triangle SEZ expanded from a single bright spot into a wide, connected network. Corridors of light now follow the main roads and border crossings, showing how the zone has scaled up and drawn in nearby settlements.

This growth comes from the rapid casino and hotel development under the Kings Romans concession, which brought in new infrastructure, services, and tourism. But the lights don't only represent formal investment. International reports linked the SEZ to money laundering traffic and other hidden activities.

From space, the Golden Triangle SEZ shines brighter every year- but the glow isn't just about prosperity. It reflects both the rapid construction of hotels, casinos and border infrastructure, and the hidden economies that operate behind them. The mix of formal and informal growth is exactly what makes the SEZ such a fascinating case for us.

Interpretation and limits

Our findings suggest that nighttime lights provide valuable insights into Laos's subnational economy, particularly in data-scarce regions like the Golden Triangle SEZ. The consistent gap between light growth and GDP growth supports the hypothesis that official statistics undercount informal economic activity, which recent estimates suggest comprises 20-30% of Laos's economy.

However, several limitations warrant consideration. First, nighttime lights primarily capture electricity-consuming activities and may miss agricultural or daytime-only economic sectors. Second, the relationship between lights and GDP may vary across development levels and economic structures. Third, our provincial GDP estimates depend on the accuracy of the weighting scheme, which may not perfectly reflect local conditions.

The winsorization technique, while reducing outlier influence, may underestimate activity in the brightest areas like central Vientiane or the SEZ casino district. Additionally, changes in lighting technology (such as LED adoption) can affect luminosity independent of economic activity.

Next steps

Our analysis stops in 2022, but there is much to uncover. A natural step for us is to extend the data window beyond 2022 using higher resolution nighttime light imagery, which would allow us to capture more recent trends and post covid recovery dynamics.

At the same time, nighttime lights alone cannot fully reveal the complexity of Laos's economy. Pairing satellite data with on the ground survey would make it possible to better capture the role of the informal sector, which is a defining feature of the Golden Triangle SEZ and many other provinces.

Another promising direction is to study cross-border dynamics. The SEZ sits at the intersection of Laos, Thailand and Myanmar, and much of its activity depends on cross-border trade and investment. Analyzing these spillover effects could provide insights not only for Laos but also for the wider Mekong region.

Ultimately, the goal is to show how satellite- based tools can complement official statistics in data scarce countries. By combining luminosity, surveys and trade patterns, future research can provide a cleaner, more independent picture of where growth is happening, who it benefits, and what risks may accompany it.

Methods and notes

Our analysis relies on three primary data sources:
Nighttime Lights Data: We utilize VIIRS (Visible Infrared Imaging Radiometer Suite) annual composite data from 2012 to 2022, specifically the avg_rade9h band which represents average radiance values. The VIIRS data provides superior spatial resolution and radiometric calibration compared to the older DMSP-OLS system, capturing light emissions at approximately 750-meter resolution.

Administrative and Population Data: Provincial boundaries were obtained from the Lao National Geographic Department (2019 shapefile release). Population estimates for each of Laos's 18 provinces were based on 2020 census data, with annual growth rates of 1.5% applied for temporal adjustment.

Economic Data: National GDP figures in current USD were sourced from World Bank Development Indicators for the period 2012-2022.
Methodological Framework

Following Henderson(2012), we distribute national GDP across provinces using a weighted combination of three factors:

GDP Allocation Formula:

$$\textbf{\textit{Provincial GDP}}_i = \textit{National GDP} \times \textit{Combined Weight}_i$$

Where Combined Weight for province i is calculated as:

$$\begin{aligned}\textbf{\textit{Combined Weight}}_i = {} & 0.6 \times (\textit{Light}_i/\textit{Total Light}) + \\ & 0.3 \times (\textit{Population}_i/\textit{Total Population}) + \\ & 0.1 \times (\textit{Area}_i/\textit{Total Area})\end{aligned}$$

This weighting scheme reflects the empirical finding that nighttime lights capture approximately 60% of economic activity variation in developing countries, while population and area provide additional distributional information.

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