



ECONOMIC GROWTH IN THE GOLDEN TRIANGLE SEZ (LAOS) USING NIGHTTIME LIGHTS

A REMOTE SENSING APPROACH TO
REGIONAL DEVELOPMENT

Econ 109

Zeya, Lorenzo, Vernon
EUROPA GROUP

Research questions

- 1) What is the relationship between the Lao PDR's official GDP growth and nighttime light growth? Does this relationship highlight informal economy?
- 2) How has the Golden Triangle SEZ developed over the years? Is the growth due to Chinese investments and illegal activities?
- 3) What is the provincial GDP of the Lao PDR provinces?

Motivation

Our project focus on the Lao People's Democratic Republic (PDR). Our goals are to:

- Compare official GDP growth with nighttime light intensity growth (which serves as a proxy for economic activity), to assess whether the official GDP adequately captures the informal economy in the Lao PDR
- Build a time series analysis of the Golden Triangle SEZ expansion, in relation to the increase in criminal activity over the years
- Estimate provincial GDP in the country, which is not available due to lack of official data

Motivation

Addressing these three different aspects is important for both economists and non-economists.

For economists

- Better understanding of development, poverty and growth at a subnational level
- Hidden economies can affect the effectiveness of government programs

For non-economists

- Investors and NGO make decisions based on official data
- It can shine light on inequality and corruption

Background & Context of Lao PDR

- Only landlocked country in Southeast Asia
- One of five active communist countries
- GDP as of 2024: \$16.5 billion
- 7.8 million people
- 18 provinces
- Economic structure: heavily dependent on hydropower exports, mining, and agriculture; growing role of tourism and SEZs
- Economic status: classified as a Least Developed Country (LDC), with limited industrialization; expected to graduate from LDC status by 2026



Background & Context of Golden Triangle SEZ

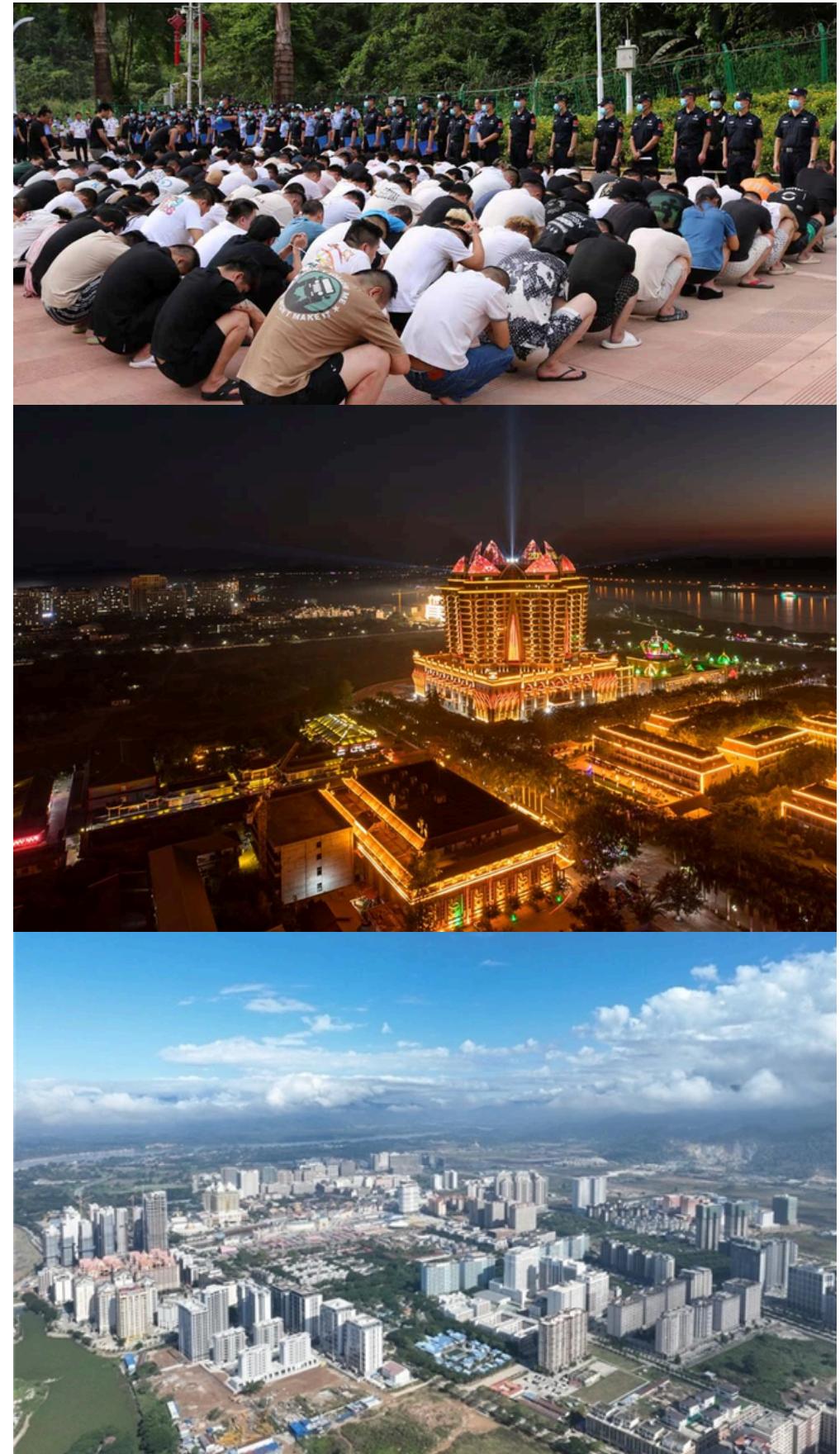
- 3,000-hectare area located in the Bokeo Province, at the border of Lao PDR, Thailand and Myanmar
- Part of the Golden Triangle, once the world's largest opium producing region
- Established in 2007 under a 99-year lease between the Lao government and the Chinese-owned Kings Romans Group



Background & Context

of Golden Triangle SEZ

- Hosts casinos, luxury hotels, real estate developments, and logistics facilities
- Operates largely outside standard Lao's legal and financial regulations
- Accused by international organizations and governments of being a hub for:
 - Human trafficking
 - Drug trade & wildlife smuggling
 - Underground banking & crypto-based money laundering



Literature review

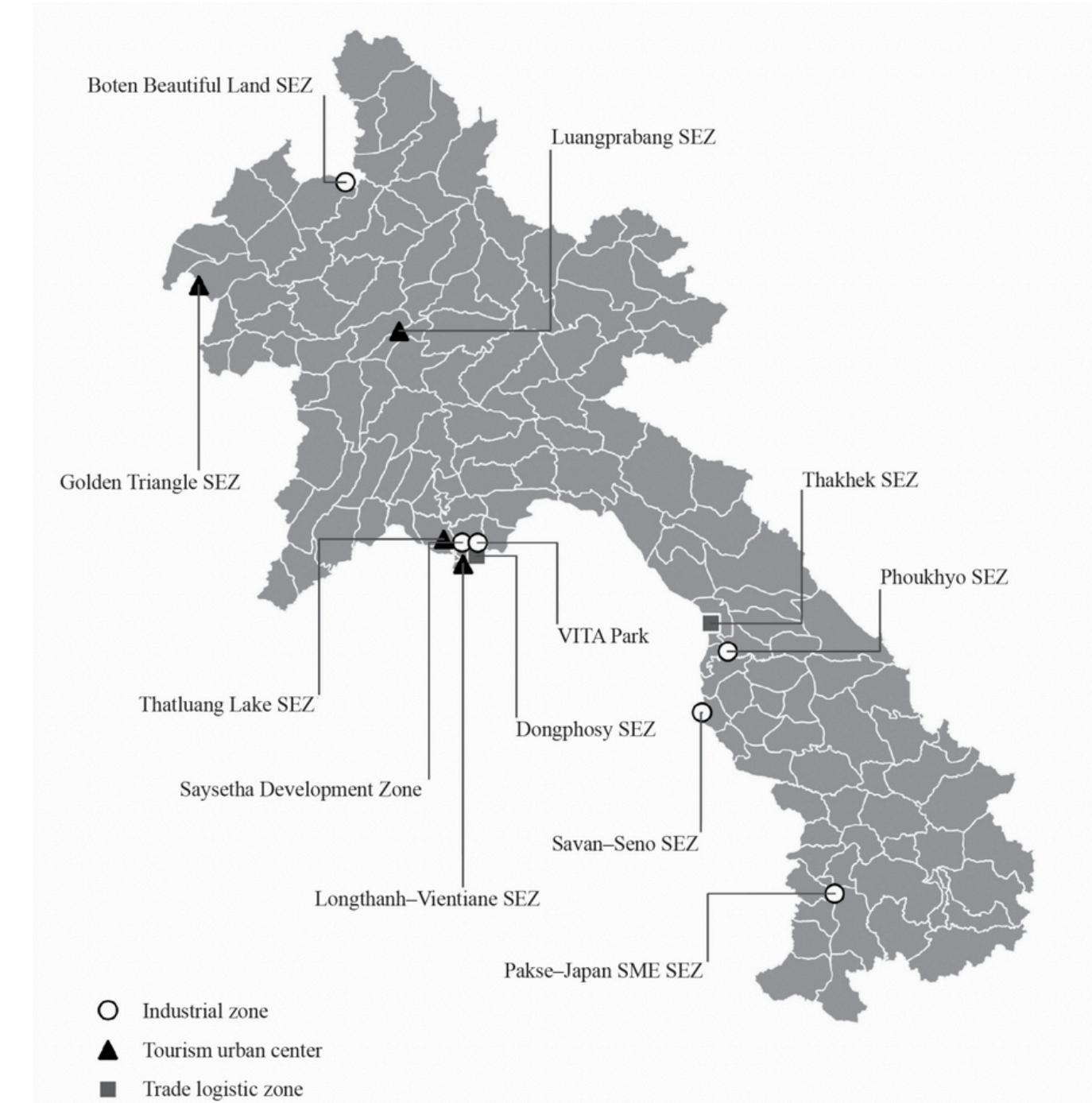
There is little to no existing academic study that measures economic activity in the Golden Triangle SEZ using nighttime light data. Most literature focuses on crime, governance, and informality:

- **UNODC (2024)**
 - Golden Triangle SEZ: a hub for casino-driven underground banking, money laundering, and illicit trade
 - The SEZ is highly visible and developed, but its economic output is largely absent from official statistics
- **Phommachanh (2024)** uses NTL data to estimate SEZ impact in Laos, but:
 - Focuses on national trends, not the Golden Triangle SEZ
 - Does not account for informal or hidden activity (which is key in zones like Bokeo)

Prior global work (e.g., **Henderson et al. 2012**) confirms that NTL correlates with GDP, especially in data-poor countries , but has not been applied to this region or context

Our contribution

- Assess whether changes in the Lao PDR's official GDP are reflected in variations in nighttime lights intensity
- Conduct a time-series analysis of the Golden Triangle SEZ to track changes in economic activity over time, highlighting the influence of Chinese investments and suspected illegal activities
- Estimate provincial GDP based on nighttime light, population and land area



Hypothesis & Assumptions

Hypothesis

- 1) NTL can estimate economic activity in Laos where GDP data is unreliable
- 2) The GTSEZ will show higher NTL intensity than its official GDP suggests
- 3) Growth in the Golden Triangle SEZ is driven by illegal activity and Chinese investments

Assumptions

- 1) Light intensity is linked to economic activity
- 2) SEZ industries generate significant nightlight output
- 3) Official GDP omits informal activities
- 4) Change in NTL mostly reflect real economic changes

Data

1) Nighttime Light Data (NTL)

- **Source:** VIIRS DNB Nighttime lights
- **Files Used:** VNL_v2_npp_2012-2022 (October monthly files)
- **Format:** .TIF raster files from NASA/NOAA VIIRD archive
- **Resolution:** 15 arc-seconds
- **Selection strategy:** 1 month (October) every year to reduce file size
- **Processing:** extracted mean light intensity (avg_rad) for each ROI + used shapefiles to mask provinces and define boundaries
- **Link:** <https://eogdata.mines.edu/products/vnl/>

2) National GDP data

- **Source:** World Bank
- **Link:** <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=LA>

3) Province Boundary Shapefile

- **File:** lao_adm_ngd_20191112_shp.zip
- **Source:** GADM
- **Link:** <https://gadm.org/>

4) Golden Triangle SEZ shapefile

- **Source:** Laos Open Development Mekong
- **Link:** <https://data.laos.opendevmentmekong.net/en/dataset/special-economic-zone-of-laos-pdr/resource/277bb084-fcec-456d-8311-32e452d96f63>

Measurement

Variables:

- Nighttime light intensity (NTL) VIIRS monthly data (october) for 2012-2022
- National GDP

Scale:

- NTL: average radiance measured in nanoWatts/cm²/sr
- GDP: constant USD at provincial level

What they measure:

- NTL → proxy for economic activity and infrastructure development
- GDP → official recorded output at the provincial level

How they help answer our question:

- NTL helps detect hidden economic growth not captured in GDP due to underreporting

Comparing NTL trends in the Golden Triangle SEZ → test whether SEZ driven growth is visible in satellite data

Methodology

Nighttime lights

The nighttime lights satellite images were obtained from the Earth Observation Group (EOG), which derived them from nighttime VIIRS data, an instrument of the Suomi National Polar-orbiting (NPP) satellite. In particular, the information was extracted from monthly cloud-free DNB composite data for Tile 3 (75N60E), using October's monthly average from 2012 to 2022. The total amount of images is 11.

Methodology

Framework & approach

Adapting the Henderson methodology to Laos:

- Core idea: combine VIIRS light intensity, population and geographic area to estimate each province's share of national GDP
- Weighting:
 - Light intensity = 60% (captures urban, industrial, and infrastructure activity)
 - Population = 30% (accounts for non-lighted economic activity)
 - Area = 10% (prevents overconcentration in urban zone)
- Formula → Provincial GDP = National GDP X Weighted Share
- Timeframe: 2012-2022 (11 years x 18 provinces)

Methodology

Processing & implementation

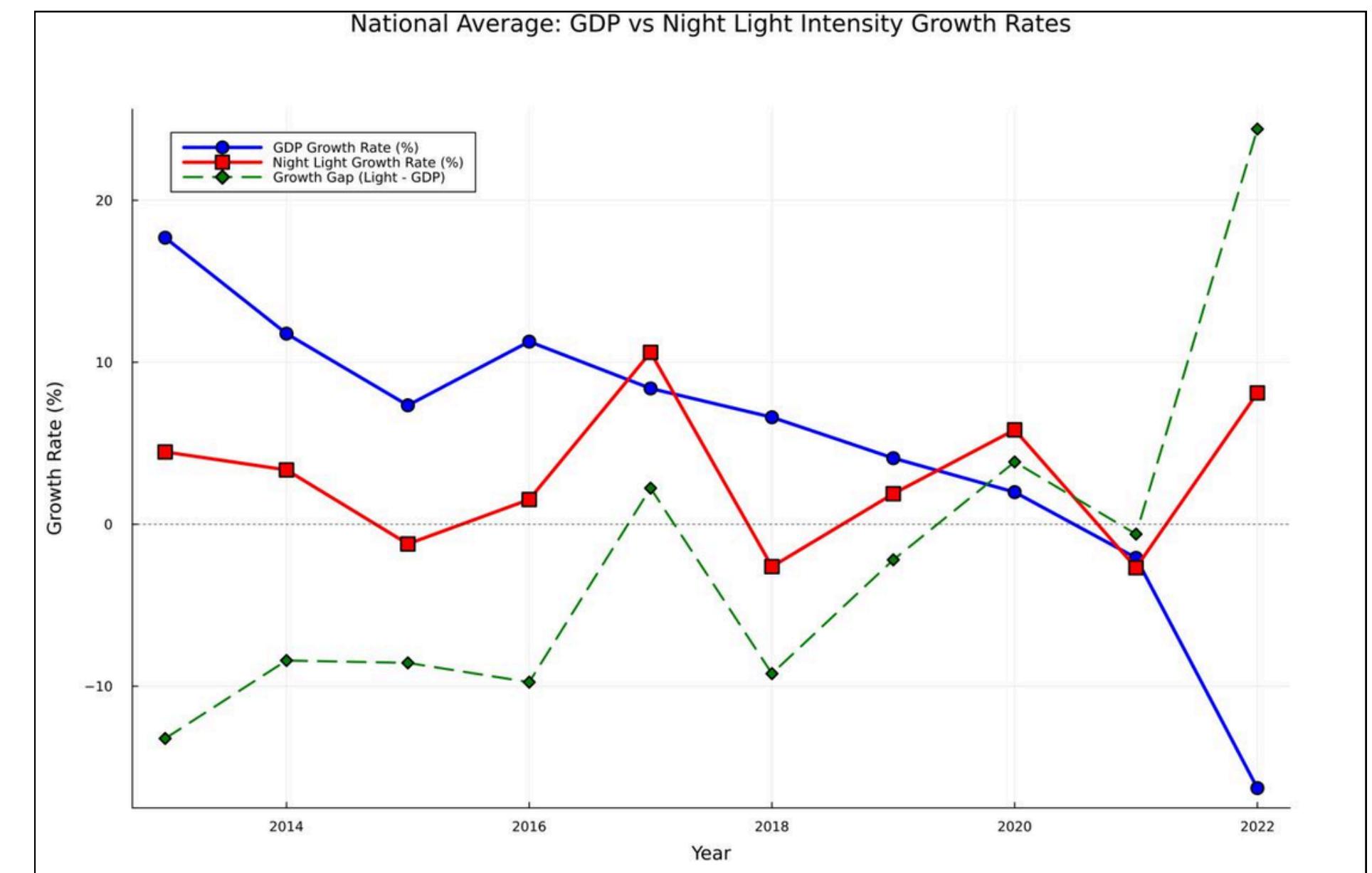
- Data processing steps:
 - a. Acquire VIIRS Nighttime Lights data from the EOG for October each year (cloud-minimized)
 - b. Crop to Laos boundaries and filter for valid pixels (>99.9% coverage)
 - c. Winsorization to reduce outlier effects (clip top/bottom 1% of brightness)
 - d. Calculate provincial shares of lights, population, and area
 - e. Apply weights (0.6, 0.3, 0.1) to estimate GDP distribution
- Validation:
 - Sum of provincial GDPs = national GDP
 - High correlation between light and GDP
- Software: Julia

Results

Relationship between Lao PDR's official GDP growth and nighttime light intensity growth

Between 2012 and 2022:

- Official GDP growth (blue line) is in a downward trend
- NTL intensity growth (red line) has followed a steady trend, ending higher than when it started
- The gap between GDP and NTL (green line) is in an upward trend
- GDP growth coefficient: 1.22
- R^2 : 0.69
- In line with Henderson (2012), this chart suggests that in LDCs like the Lao PDR, GDP may undercount economic activity by not fully accounting for the informal economy
- The informal economy in the Lao PDR is on a downward trend, but as of 2020, it still accounted for 20% of GDP

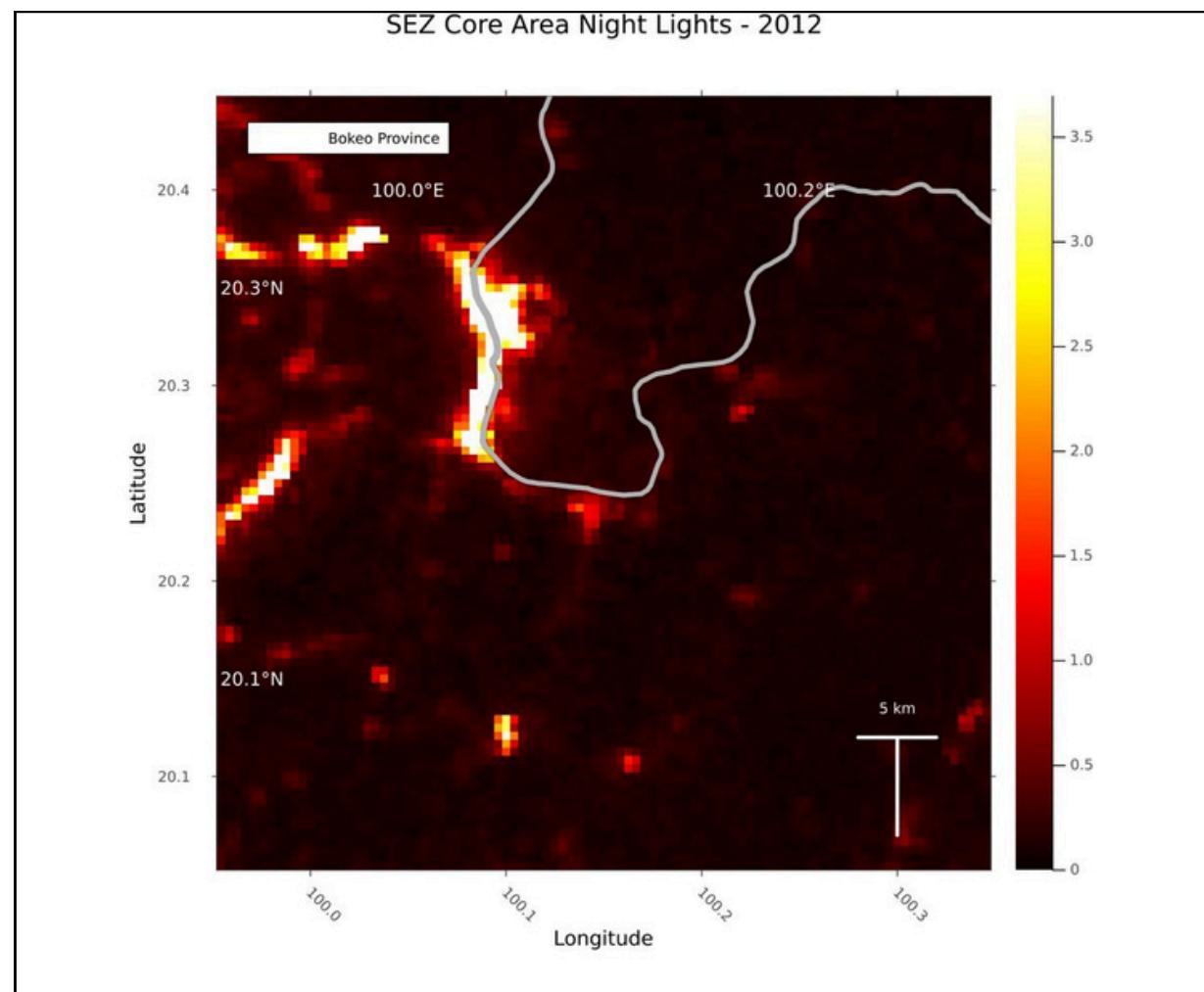


Results

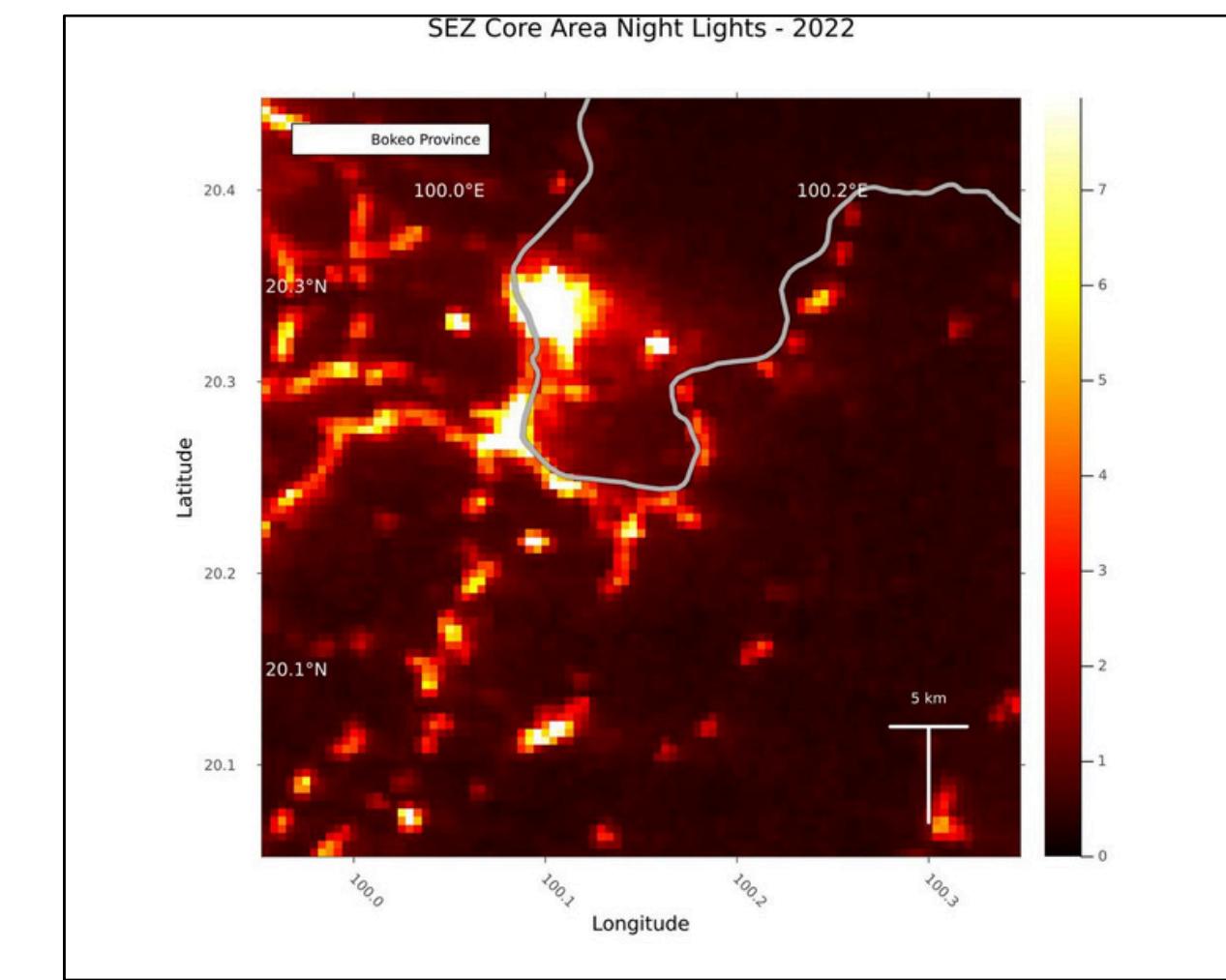
Golden Triangle SEZ development over the years

Between 2012 and 2022

- Substantial increase in both brightness and spatial extent of NTL in the Golden Triangle SEZ
- Emergence of corridors, suggesting expansion of economic activities



2012



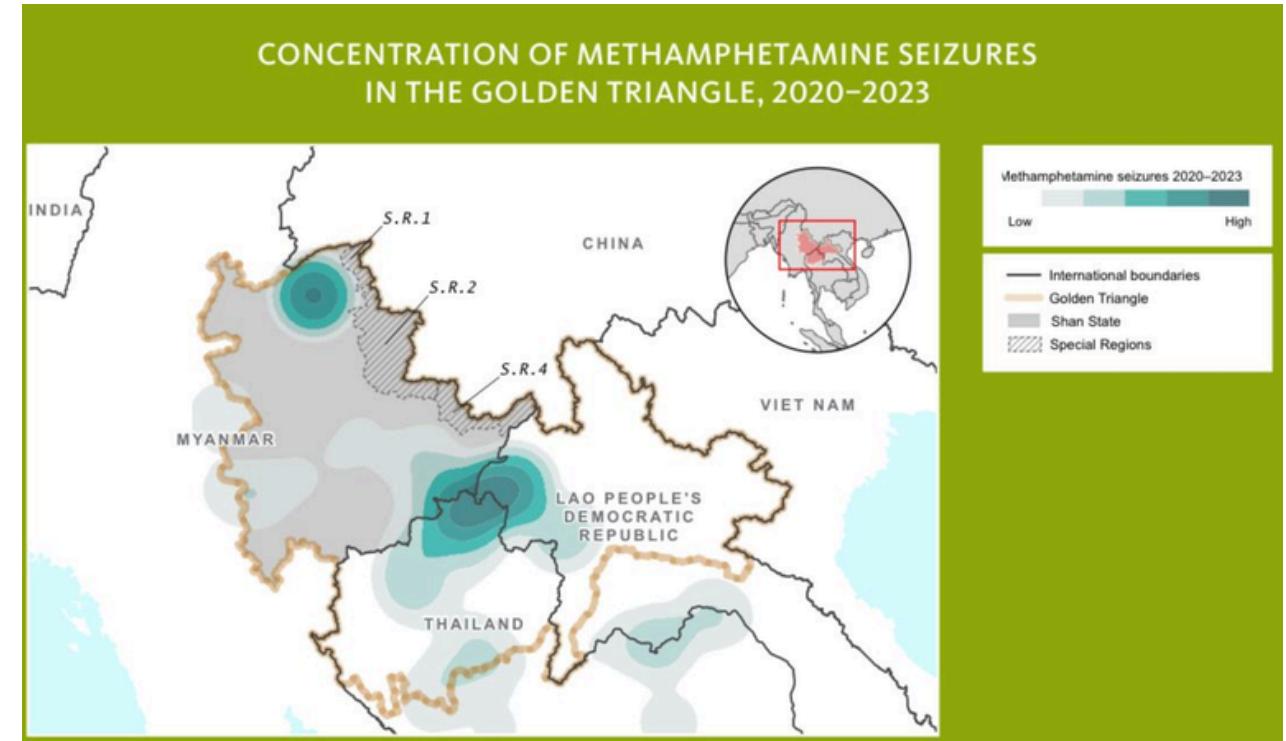
2022

Results

Golden Triangle SEZ development over the years

The NTL intensity growth is due to the spread of casino complexes and other commercial buildings, many of which have been linked to illegal activity:

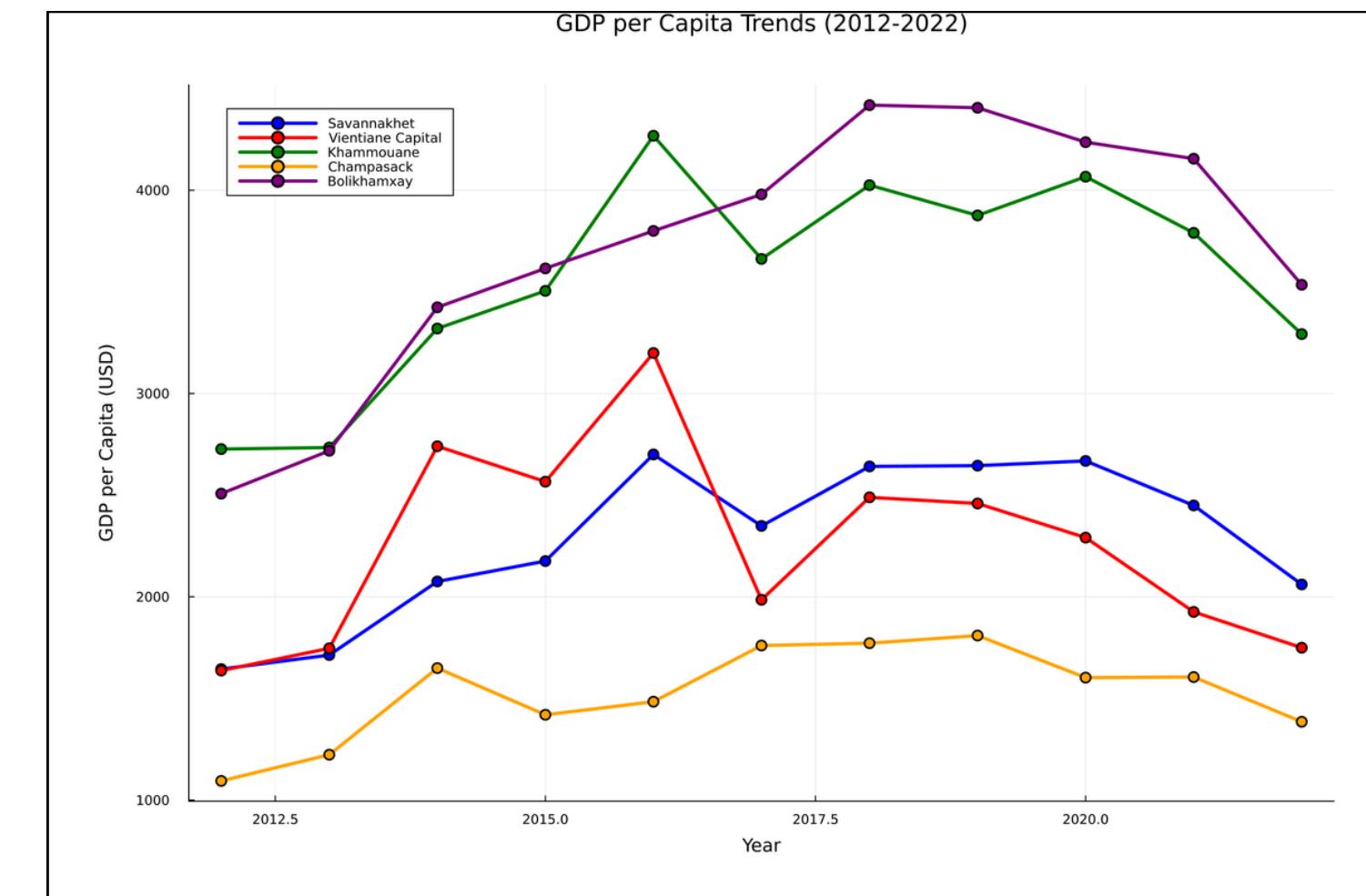
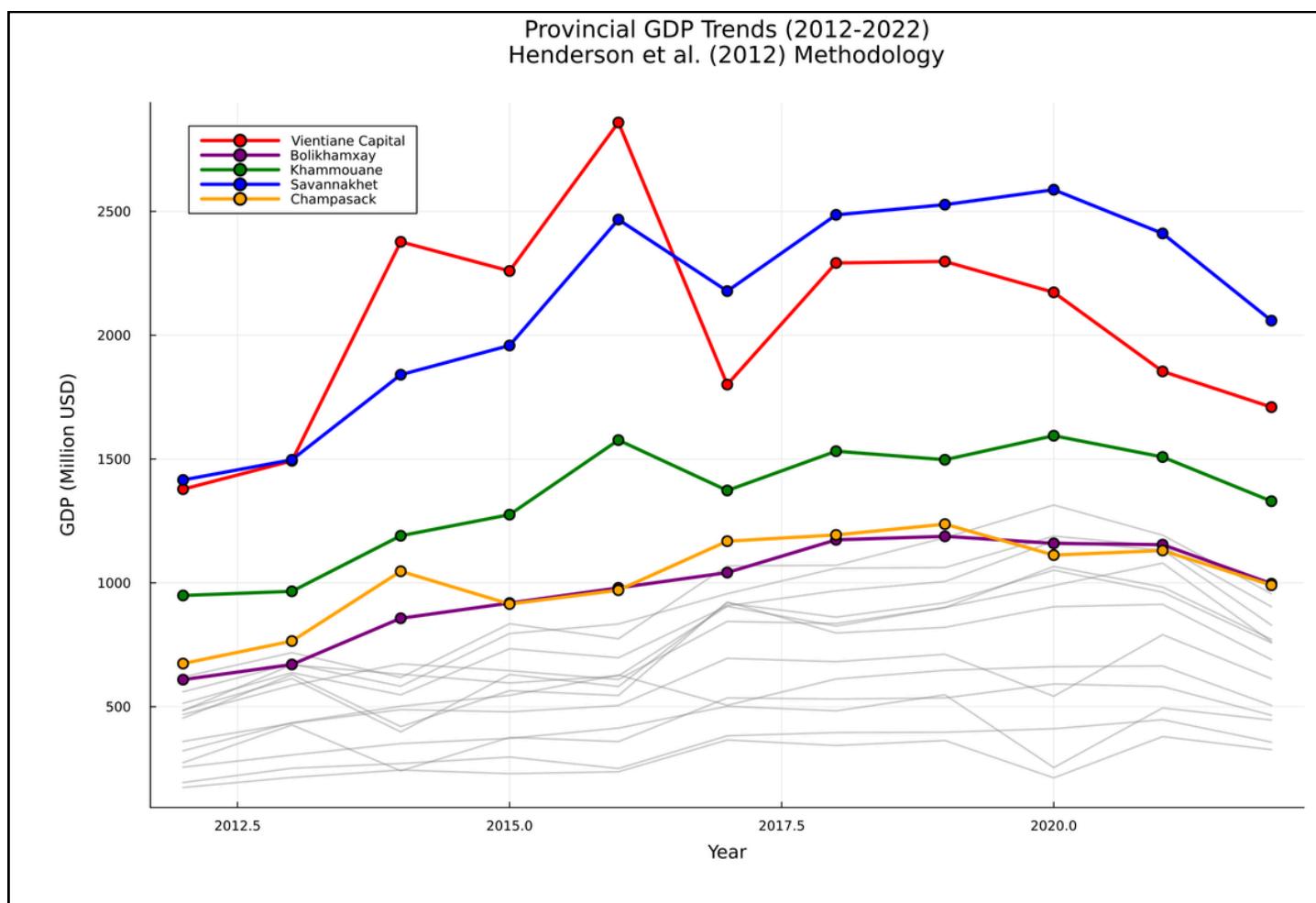
- Metamphetamine seizures have grown fourfold between 2013 and 2022 in the Golden Triangle
- Casinos have emerged as hubs of money laundering, with witness saying they witnessed multiple million dollar cash transactions
- The U.S. sanctioned the owner of the Kings Romans Casino, who is said to run the SEZ as head of trafficking network
- From 2007 to 2022, Lao authorities have rescued more than 1,680 victims of human trafficking from the Golden Triangle SEZ



Results

Lao PDR provincial GDP

- Vientiane Capital dominates total GDP due to concentration of government, services, and infrastructure.
- Savannakhet is second, driven by SEZs and cross-border trade with Thailand.
- GDP per capita highlights smaller provinces like Champasack that perform better on average output per person.
- Both measures show a decline post-2019, reflecting COVID-19's hit to tourism, trade, and investment



Conclusion & next steps

Conclusion

- Nighttime light data reveals economic growth patterns in Laos often missing from official GDP statistics.
- Strong growth signals detected in the Golden Triangle SEZ, driven by both formal investment and hidden/informal activity.
- Provincial GDP patterns show regional disparities - Vientiane Capital dominates total output, but some smaller provinces lead in per-capita terms.

Next Steps

- Extend analysis to post-2022 and use higher-resolution satellite imagery.
- Combine NTL with field surveys to better capture informal sector dynamics.
- Study cross-border trade and SEZ spillover effects to inform policy and investment.

Sources

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