REGIONAL ECONOMIC DYNAMICS, NIGHTTIME LIGHTS, AND LAND COVER: INSIGHTS FROM DIMLY LIT ISLANDS

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OUTLINE OF THE PRESENTATION

- Motivation

- Research Question

- Data

- Preliminary Results and Discussion

- Limitations and Possible Extensions

- Conclusions

NIGHTTIME LIGHTS (NTL) ARE A USEFUL PROXY FOR ECONOMIC ACTIVITY

- **There are three main advantages of using remote sensing data to economists:** (1) access to information difficult to obtain by other means; (2) unusually high spatial resolution; and (3) wide geographic coverage (Donaldson & Storeygard, 2016).

- Henderson, Storeygard, & Weil (2012) find that the **structural elasticity of lights growth with respect to GDP growth is close to one** using a panel of 188 countries in 1992-2008.

- Chen and Nordhaus (2019) reveal that the relationship between NTL and GDP is even stronger at subnational scales. **Lights predict about 89% and 61% of the variance in GDP in the metropolitan statistical areas (MSA) and state levels**, respectively, in the United States.

TWO NTL DATA SOURCES ARE WIDELY USED IN THE LITERATURE.

- The **Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS)** stable NTL data can only be collected from 1992 to 2013. It has disadvantages that limit its potential applications, including the absence of on-board radiance calibration, saturation issues, and blooming issues.

- The **Suomi National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite (NPP-VIIRS)** NTL data have better quality thanks to its higher spatial resolution and wider radiometric detection (Elvidge et al., 2013), but its short available time coverage (April 2012 to present for the monthly composites and 2015- 2016 for the annual composites) is a major source of problem for long-term analysis.

The DMSP-OLS and the NPP-VIIRS NTL data products
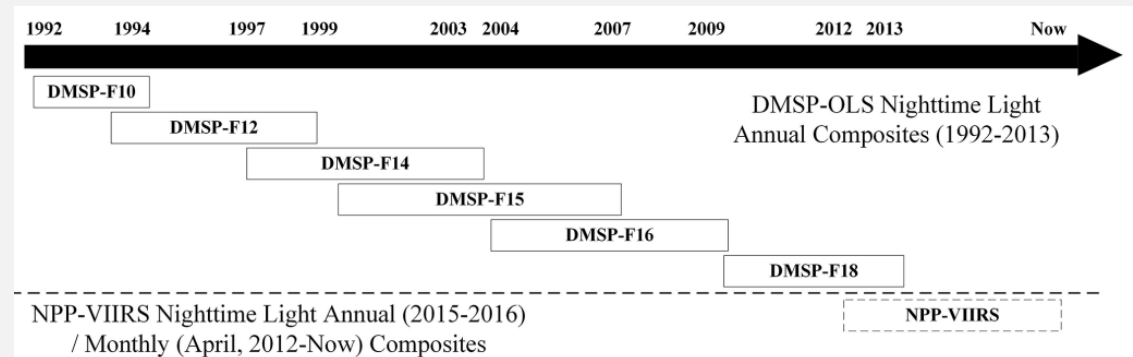
Source: Chen et al. (2021).

ATTEMPTS HAVE BEEN MADE TO INTEGRATE THE DMSP-OLS AND THE NPP-VIIRS NTL DATA INTO ONE EXTENDED SERIES

- Few studies attempt to integrate the two NTL versions into one temporally consistent series by **simulating DMSP-OLS-like series from the much better NPP-VIIRS NTL, thus the resulting extended series inherit the issues associated with DMSP-OLS NTL** (see Li et al. (2020), Zhu et al. (2017), and Li et al. (2017) for examples).

- Since NPP-VIIRS NTL data have a better quality than DMSP-OLS NTL data, **the performance of estimating GDP at subnational scales from a simulated NPP-VIIRS-like series is much higher.**

WHILE IT PREDICTS ECONOMIC ACTIVITY IN URBAN AREAS RELATIVELY WELL, NTL EXPLAIN RURAL ACTIVITIES POORLY

- Economic activities occurring in urban clusters are primarily services, retail, and transportation, among others, which are more likely to be captured by NTL. **Unfortunately, agricultural activities, which emit less observable lighting, are concentrated mainly in the rural sector** (Keola, Andersson, & Hall, 2015).

- **The correlation between NTL and GDP growth is stronger in places where there is less dependence in agriculture** (Bundervoet, Maiyo, & Sanghi, 2015).

- **This poses serious underestimation for developing economies which often have, on the one hand, relatively dimly lit areas at night, and on the other, a larger share of agriculture in total GDP.**

WE CONTRIBUTE TO THE LITERATURE BY USING A NOVEL NTL DATASET AUGMENTED WITH LAND COVER DATA

- **First, we use a novel NTL dataset (Chen et al. 2021) that provides an extended time series (2000-2018) of global NPP-VIIRS-like NTL data from a cross-sensor calibration.** Unlike traditional studies that generate DMSP-OLS-like NTL data, Chen et al. (2021) simulate NPP-VIIRS-like data which have better quality than DMSP-OLS using deep learning technologies.

- **Second, following the approach of Keola, Andersson, & Hall (2015), we augment the NTL data with land cover data**, MDC12Q1, from the Moderate Resolution Imaging Spectroradiometer (MODIS) to capture the economic growth generated by the agriculture sector.

- We study the case of the **Philippines, an archipelagic country composed of dimly lit islands with substantial agriculture gross-value added (GVA).**

AN EXTENDED TIME SERIES (2000-2018) OF GLOBAL NPP-VIIRS-LIKE NIGHTTIME LIGHT DATA FROM A CROSS-SENSOR CALIBRATION (CHEN ET AL., 2021)

- **Unlike the traditional cross-sensor calibration of NTL data by converting NPP-VIIRS to DMSP-OLS-like NTL data, this study built an extended time series (2000–2018) of NPP-VIIRS-like NTL data** through a new cross-sensor calibration from DMSP-OLS NTL data (2000–2012) and a composition of monthly NPP-VIIRS NTL data (2013–2018).

- **Generally, the extended NPP-VIIRS-like NTL data (2000–2018) have an excellent spatial pattern and temporal consistency which are similar to the composited NPP-VIIRS NTL data.**

LIGHTS AT NIGHT, 2018

Source: NTL data from Chen et al. (2021).

MODIS LAND COVER DATA

- **The Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's spacecraft Terra and Aqua produces several interesting suites of imagery with global coverage and high spatial and temporal resolution.** Terra MODIS and Aqua MODIS view the Earth's entire surface every 1 to 2 days and observations are averaged over 8 or 16 days.

- **MDC12Q1 is the MODIS yearly land cover product.** Data are presented in tiles of approximately 1200 x 1200 km with 500 m nominal spatial resolution. We are interested in three land cover classes: IGBP class 10 (grasses/cereals), 12 (croplands), and 14 (croplands/natural vegetation mosaic).
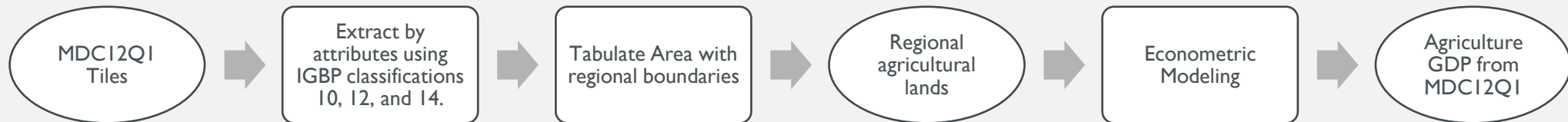
ECONOMIC DATA AND OTHERS

- We use Gross Regional Domestic Product (GRDP) from the Philippine Statistics Authority (PSA).

- For administrative boundaries at the region-, province-, and city-levels, we use the GIS layers from PhilGIS (philgis.org) and GADM (gadm.org).

GEOPROCESSING WORKFLOW
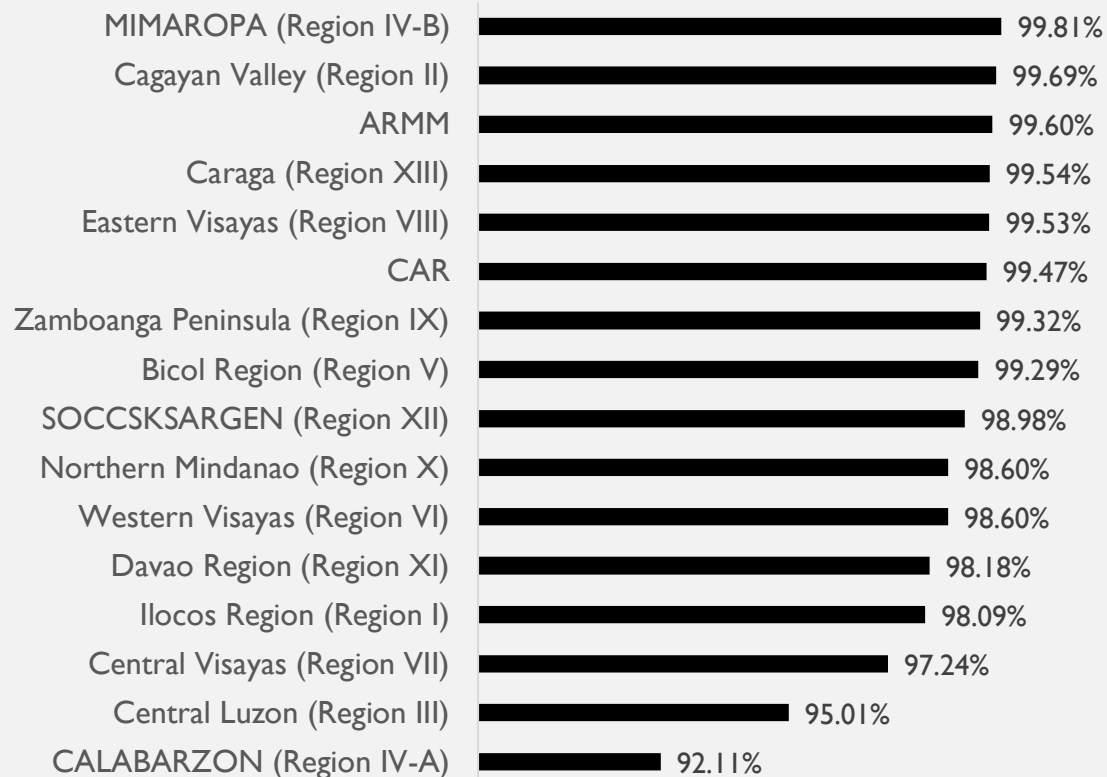
Province-level Non-Agriculture GDP from NTL

Global NTL → Extract by mask using regional boundaries from GADM → Regional NTL → Zonal Statistics → Regional Sum of NTL → Econometric Modeling → Non-agriculture GDP from NTL

Province-level Agriculture GDP from Land Cover Data

MDC12Q1 Tiles → Extract by attributes using IGBP classifications 10, 12, and 14. → Tabulate Area with regional boundaries → Regional agricultural lands → Econometric Modeling → Agriculture GDP from MDC12Q1

THE PHILIPPINES IS COMPOSED OF DIMLY LIT ISLANDS BOTH IN TERMS OF AVERAGE SHARE OF UNLIT PIXELS AS WELL AS AVERAGE PIXEL LIGHTS INTENSITY

Average share of unlit pixels per region, 2000-2018

Region	%
MIMAROPA (Region IV-B)	99.81%
Cagayan Valley (Region II)	99.69%
ARMM	99.60%
Caraga (Region XIII)	99.54%
Eastern Visayas (Region VIII)	99.53%
CAR	99.47%
Zamboanga Peninsula (Region IX)	99.32%
Bicol Region (Region V)	99.29%
SOCCSKSARGEN (Region XII)	98.98%
Northern Mindanao (Region X)	98.60%
Western Visayas (Region VI)	98.60%
Davao Region (Region XI)	98.18%
Ilocos Region (Region I)	98.09%
Central Visayas (Region VII)	97.24%
Central Luzon (Region III)	95.01%
CALABARZON (Region IV-A)	92.11%

Note: Metropolitan Manila's average share of unlit pixels for 2000-2018 is 5.86%.
Source: Author's estimates. NTL data from Chen et al. (2021).

Average NTL pixel intensity per region, 2000-2018

nw/cm2/sr
- 0.01 - 0.09
- 0.10 - 0.40
- 0.41 - 22.75
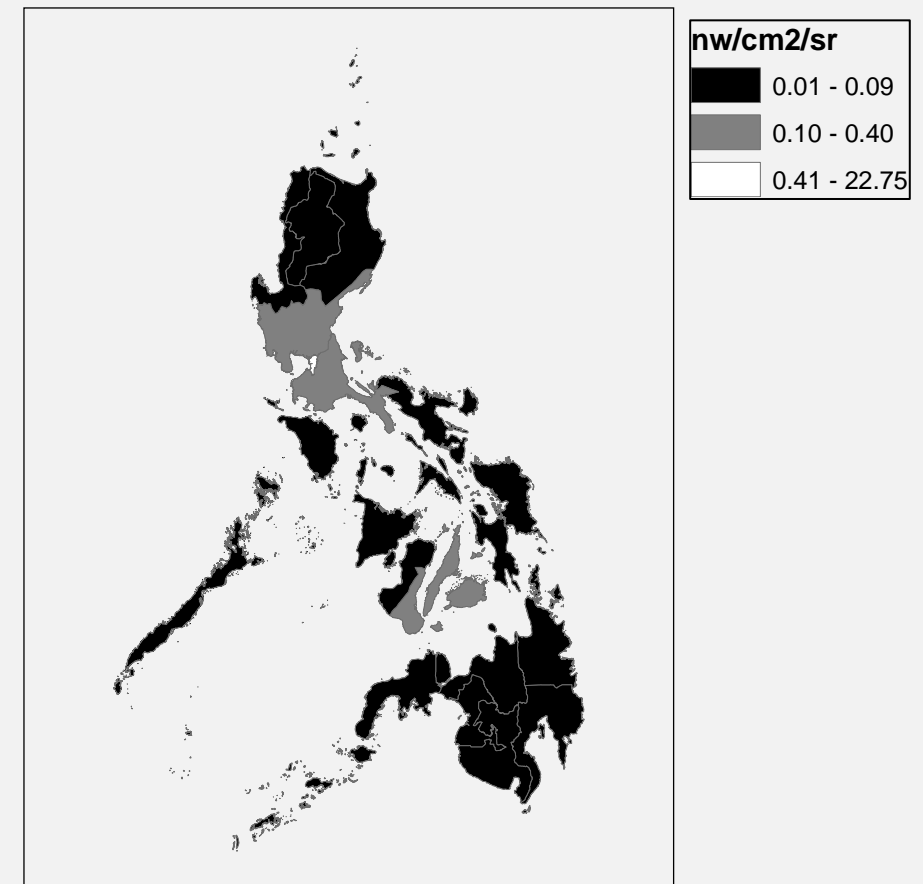
Source: Author's estimates. NTL data from Chen et al. (2021).

AVERAGE SHARE OF CROPLANDS TO TOTAL AREA ACROSS REGIONS AS SEEN FROM ABOVE REMAINS TO BE SIZEABLE.

Average share of croplands area, 2001-2018
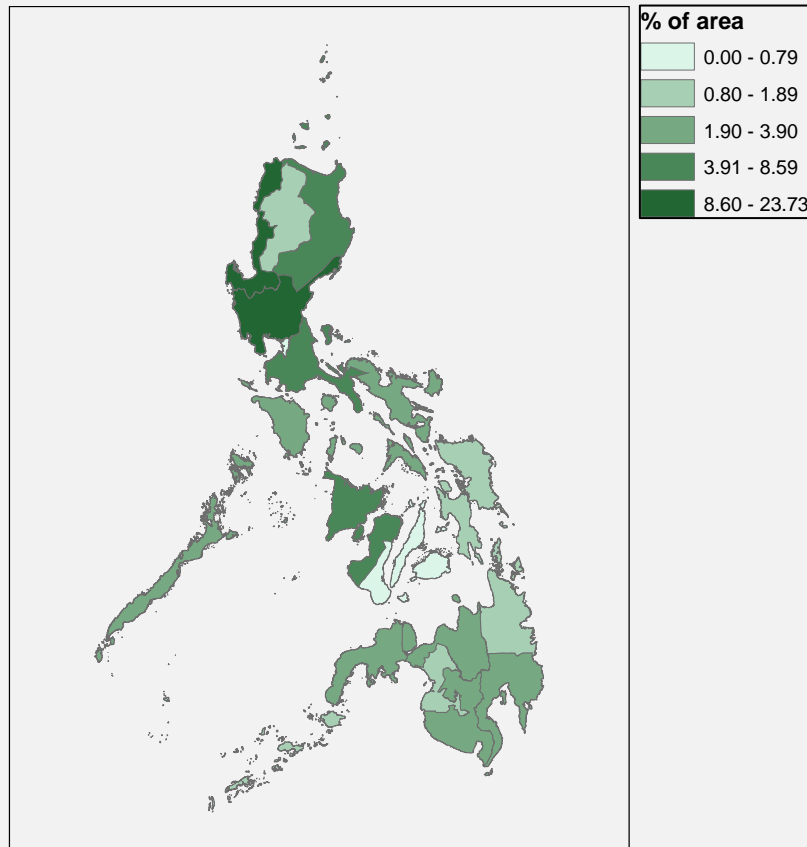
Cross-tabulation of NTL and Land Cover Classes (Keola, Andersson, & Hall, 2015)
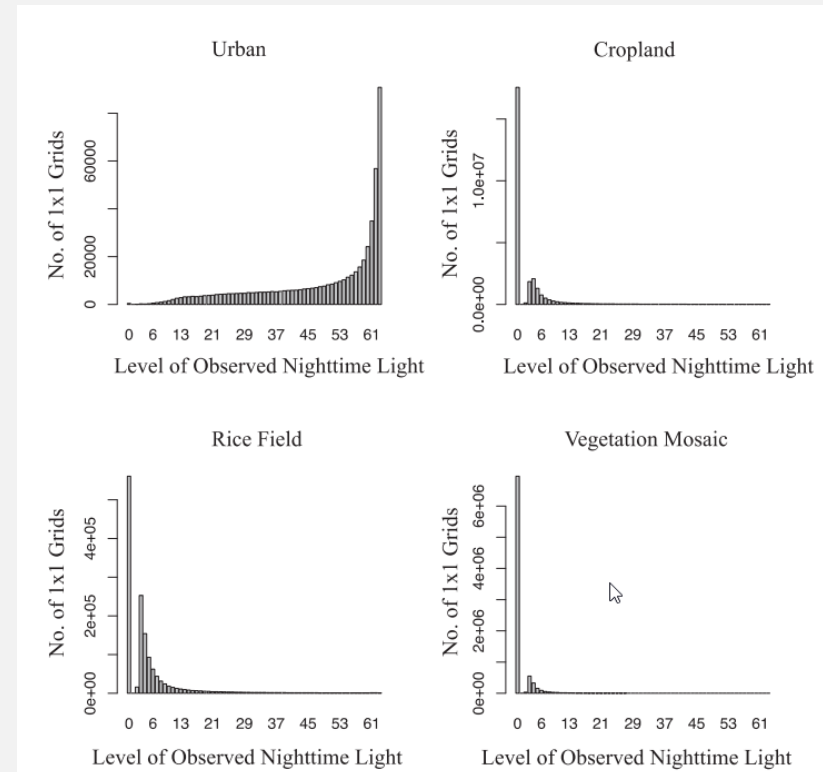
Source: Keola, Andersson, & Hall (2015)

PRELIMINARY RESULTS AND DISCUSSION

- With dimly lit regions on the one hand, and substantial share of croplands to regions' area on the other, can NTL still be a useful proxy for GDP at subnational scales?

- Could we construct GDP measures at the province- and city-levels using NTL and land cover which could be useful in many applications such as granular economic assessment of natural disasters across sectors, analysis of regional inequality, and estimation of the informal sector?

NPP-VIIRS-LIKE NTL DATA PREDICTS NON-AGRICULTURE GDP, INDUSTRY, AND SERVICES, BUT NOT AGRICULTURE

	Log(Non-agricultural GDP)	Log(Industry GDP)	Log(Services GDP)	Log(Agriculture GDP)
Log(Sum of NTL)	0.08***	0.14***	0.04***	0.15
Region fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	130	130	130	130
Within-region R^2	0.97	0.91	0.99	0.21

$**\, p < 0.05\ and\ ***\, p < 0.01$

NPP-VIIRS NTL PREDICTS NON-AGRICULTURE GDP RELATIVELY WELL FOR THE MOST LIGHT-INTENSE REGIONS…

Fit of non-agriculture, industry, and services GDP for Metro Manila
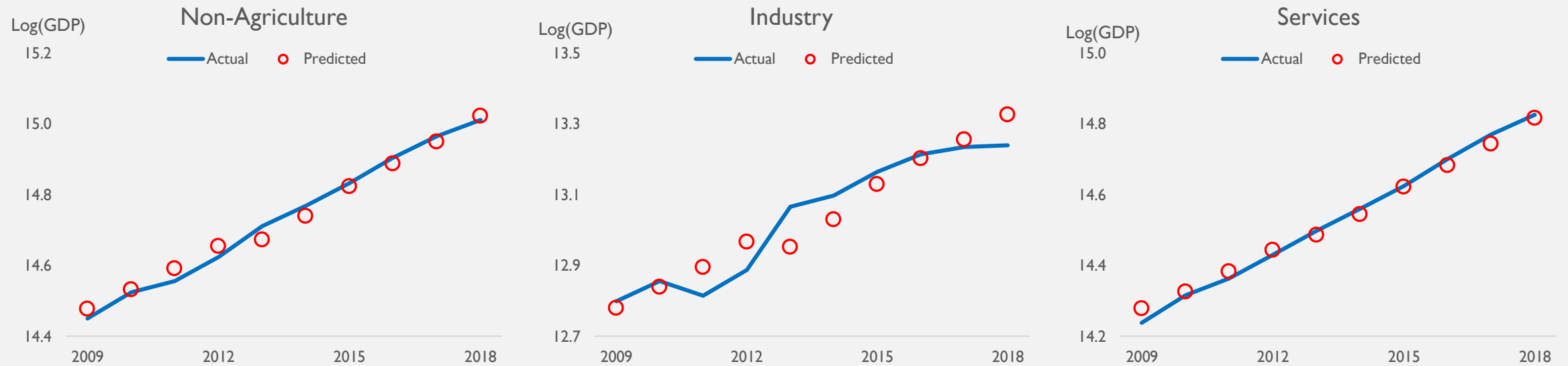
NPP-VIIRS NTL PREDICTS NON-AGRICULTURE GDP RELATIVELY WELL FOR THE MOST LIGHT-INTENSE REGIONS...

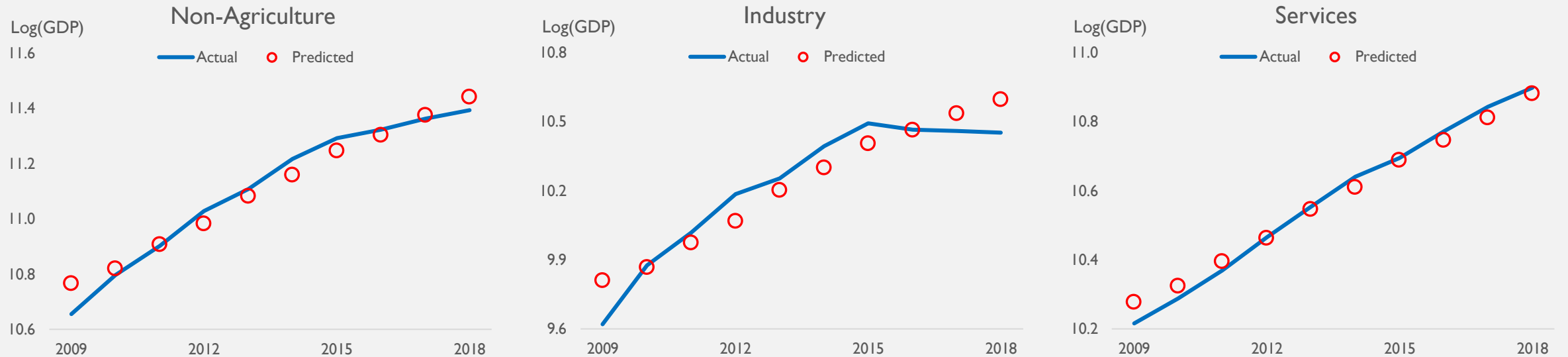*Fit of non-agriculture, industry, and services GDP for Calabarzon (Region IV-A)*
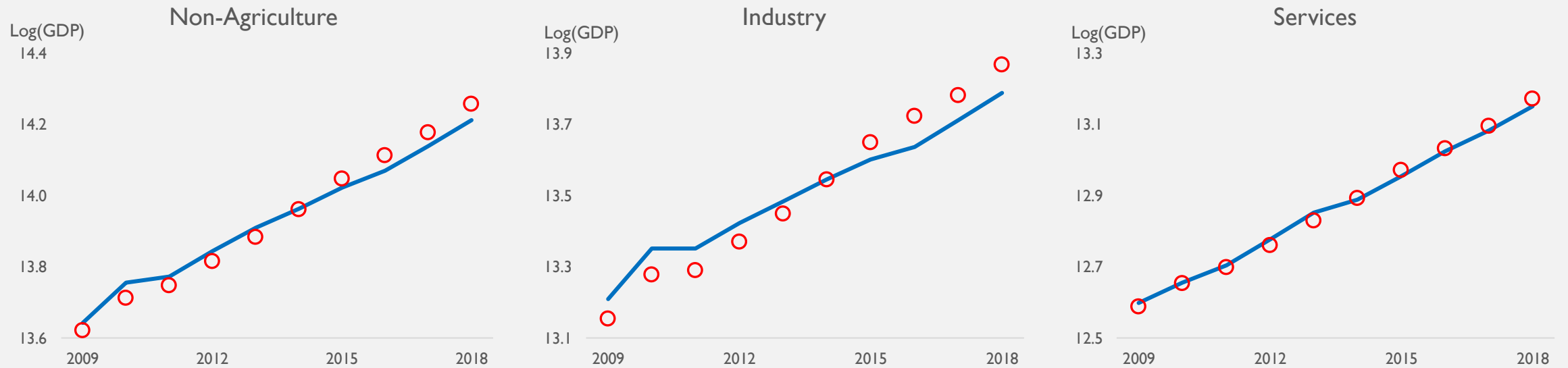
…AS WELL AS FOR DIMLY LIT REGIONS IN THE ARCHIPELAGO

*Fit of non-agriculture, industry, and services GDP for Zamboanga Peninsula (Region IX)*
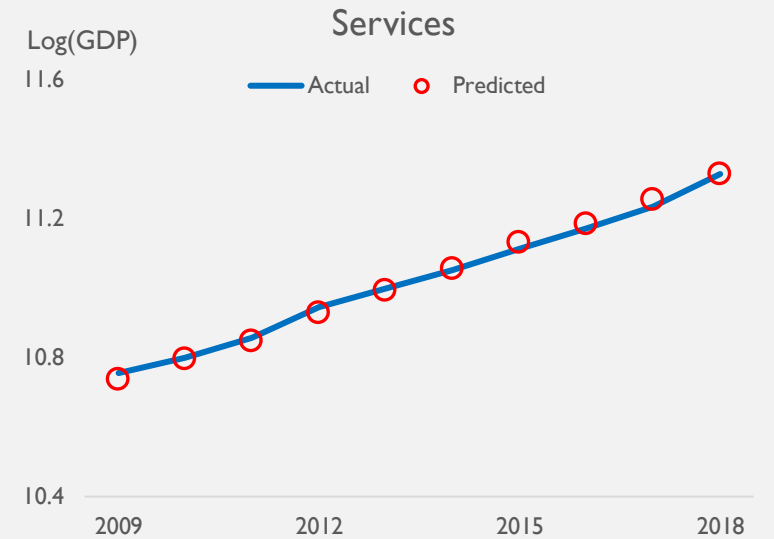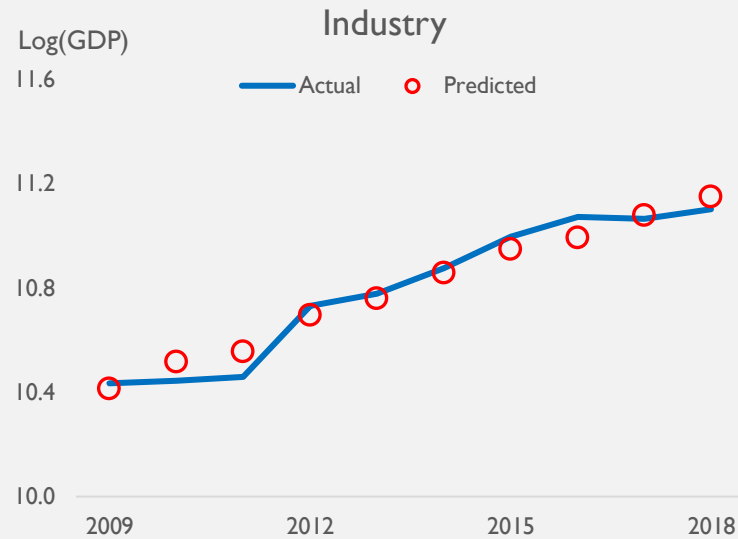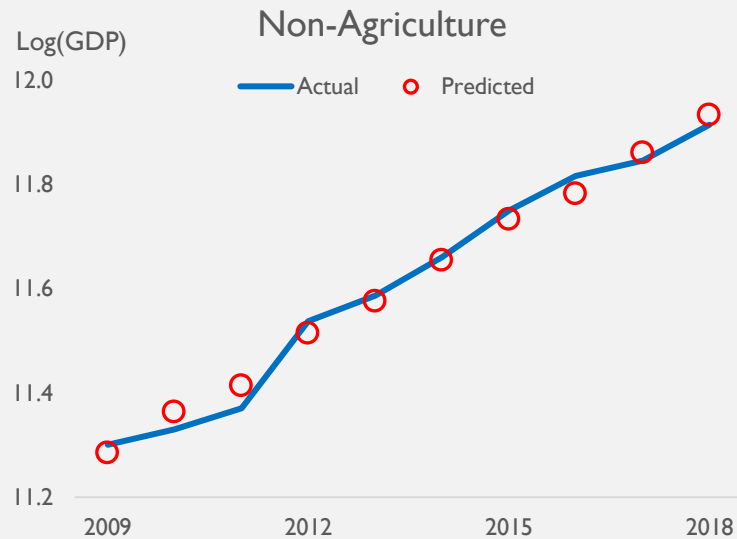
…AS WELL AS FOR DIMLY LIT REGIONS IN THE ARCHIPELAGO

Fit of non-agriculture, industry, and services GDP for Caraga (Region XIII)

HOWEVER, NTL EXPLAINS AGRICULTURE GDP POORLY ESPECIALLY FOR REGIONS WITH LARGE AGRICULTURE SECTOR

*Fit of agriculture GDP for Central Luzon (Region III), Cagayan Valley (Region II), and Ilocos Region (Region I)*
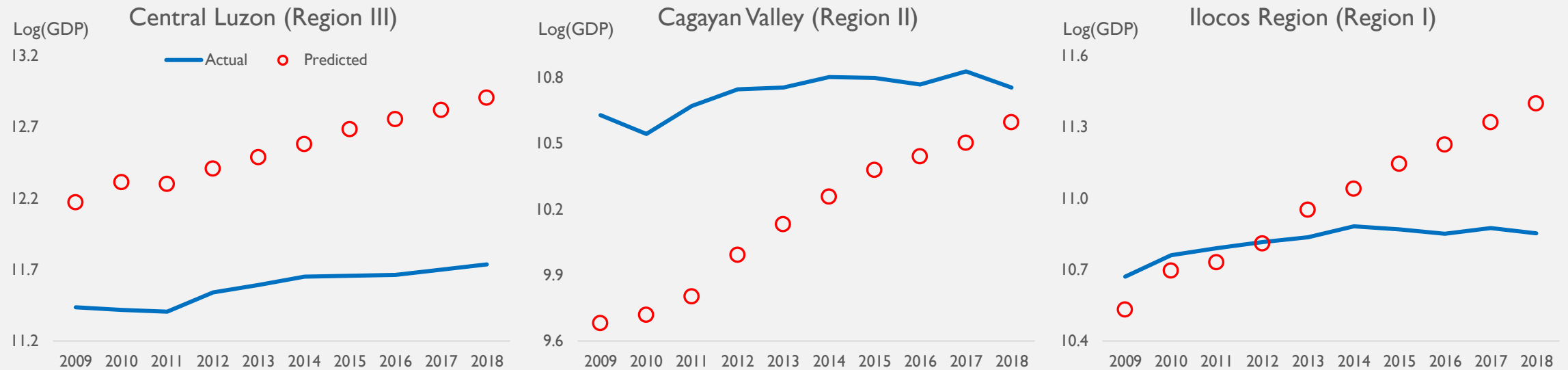
CROPLANDS FROM LAND COVER DATA PREDICTS AGRICULTURE GDP

	Log(Agriculture GDP)	
Log(Sum of Croplands)	0.08**	
Log(Sum of Croplands + Vegetation Mosaic)		0.06**
Region fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	130	130
Within-region R^2	0.22	0.22

$** \, p < 0.05 \text{ and } *** \, p < 0.01$

LAND COVER CAN PREDICT AGRICULTURE GDP RELATIVELY WELL FOR REGIONS WITH LARGE AGRICULTURE SECTOR

Fit of agriculture GDP for Central Luzon (Region III), Cagayan Valley (Region II), and Ilocos Region (Region I)
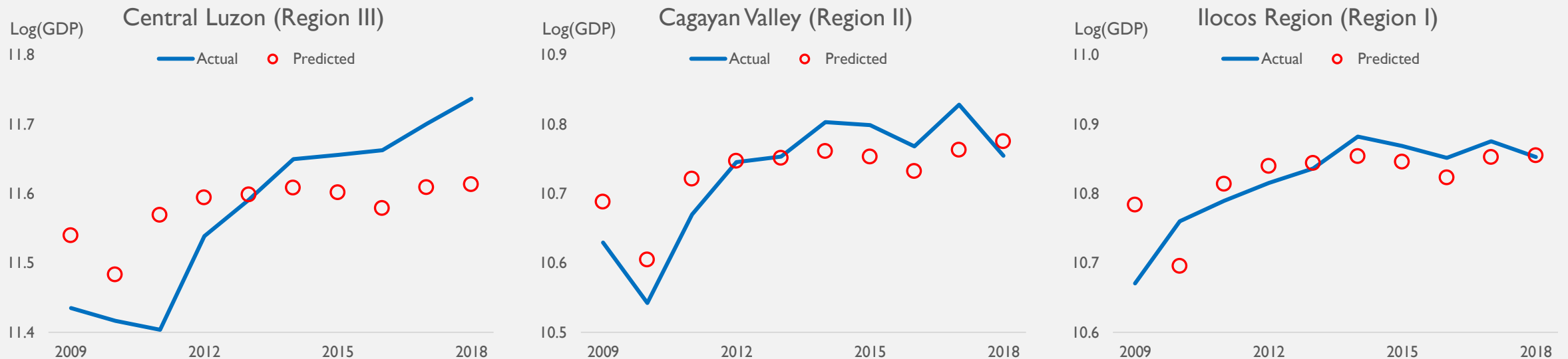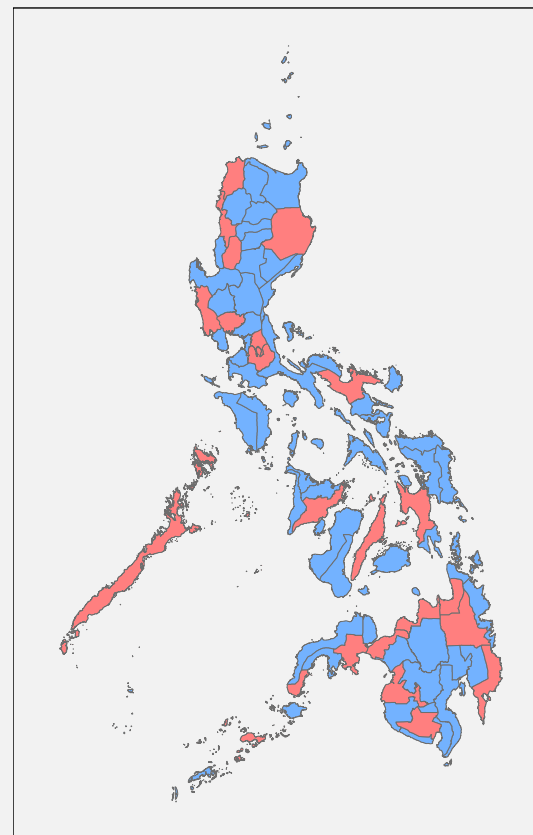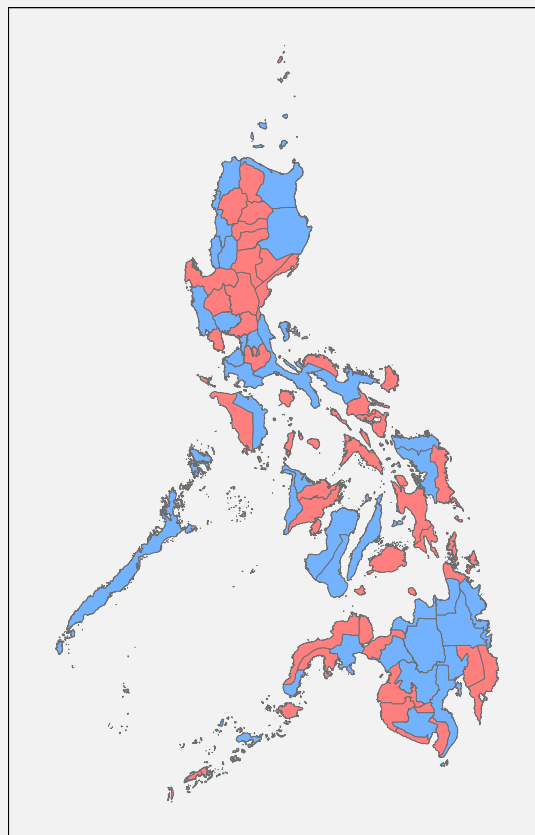
NTL ALLOWS FOR ANALYSIS OF LONG-TERM DYNAMICS OF PROVINCE-LEVEL GDP GROWTH…

Province-level average annual non-agriculture GDP growth in two subperiods

2000-2008

2009-2018

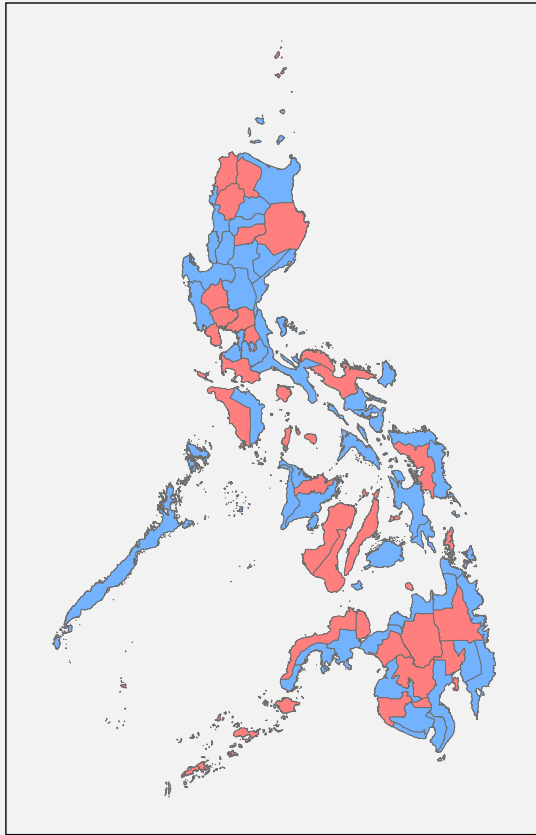**Average annual GDP growth (%)**
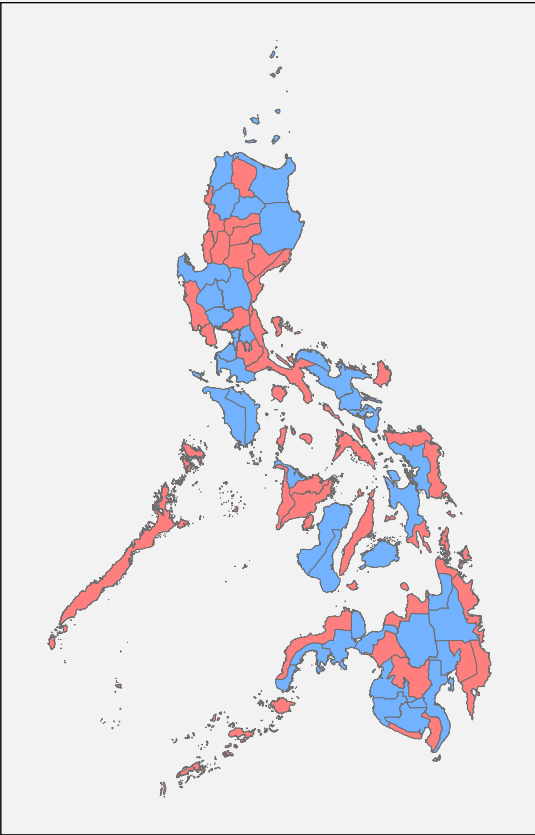
Negative growth

Positive growth

AND LAND COVER FOR ANALYSIS OF LONG-TERM DYNAMICS OF PROVINCE-LEVEL AGRICULTURE GDP GROWTH

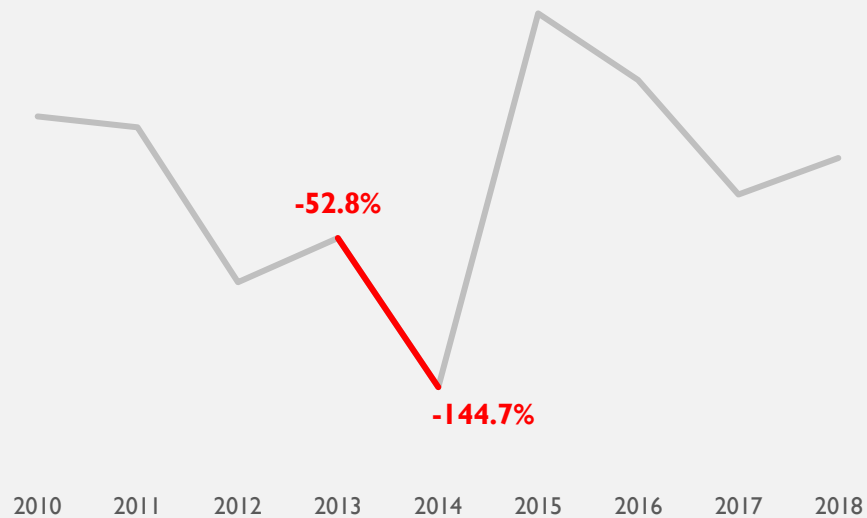*Province-level average annual agriculture GDP growth in two subperiods*

2000-2008   *2009-2018*

Average annual GDP growth (%)
- Negative growth
- Positive growth
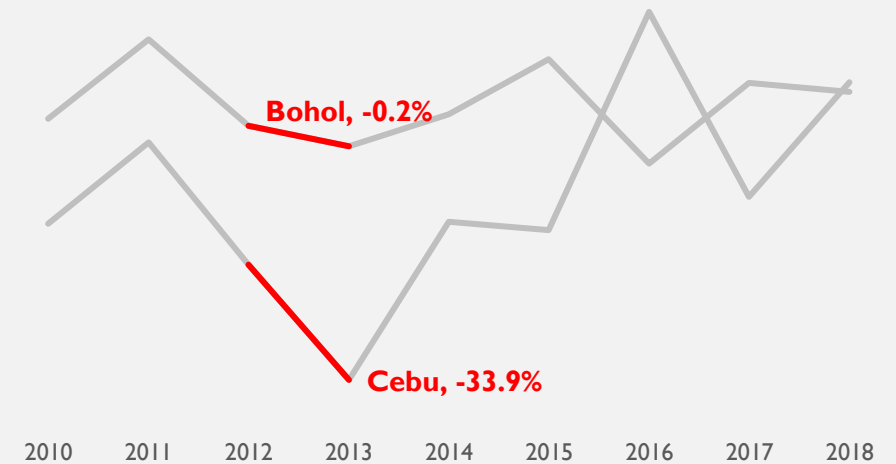
APPLICATIONS: ANALYSIS OF THE IMPACT OF NATURAL DISASTERS ON PROVINCE-LEVEL GDP GROWTH

Non-agriculture GDP growth for *Haiyan-hit* *province of Tacloban*

-52.8%

-144.7%

2010 2011 2012 2013 2014 2015 2016 2017 2018

Non-agriculture GDP growth for *Earthquake-hit* *provinces of Bohol and Cebu*

Bohol, -0.2%

Cebu, -33.9%

2010 2011 2012 2013 2014 2015 2016 2017 2018

LIMITATIONS

- There is no formal distinction between urban and rural pixels in determining which among NTL-lit pixels reflect economic activity. This could be addressed using the Global Human Settlements Layer (GHSL).

- Even with improved spatial resolution and wider radiometric detection, NPP-VIIRS NTL data product still lags against newer NTL products e.g. Luojia NTL recently developed by Wuhan University in 2018.

CONCLUDING REMARKS

- NPP-VIIRS-like NTL can still be a good proxy for GDP at subnational scales **even for dimly lit regions**.

- While it predicts industry and services GDP fluctuations, **it explains agriculture GDP dynamics poorly**.

- Land cover data can be used to **augment NTL in explaining GDP fluctuations in the agriculture sector**.

- Both NTL and land cover data allows for **construction of province-level GDP measures**. Applications include analysis of impacts of natural disasters at the province- and city-levels, assessment of regional inequality, estimation of informal sector, etc.