



DEWAN EKONOMI NASIONAL
REPUBLIK INDONESIA

Forecasting Indonesian National and Provincial GDP using Nighttime Light Index

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15 April 2026



Why measure GDP at higher frequency?

- GDP is the anchor variable for most macroeconomic decisions: fiscal planning, monetary policy, private investment.
- Official quarterly numbers are released with **substantial lag** and occasional revisions.
- When the stakes are high, policy makers often need to **nowcast** — infer the most recent quarter from leading or coincident indicators.
- Because GDP is a political signal, there is an incentive to overestimate; *independent* validation is valuable.

Can nighttime lights serve as a credible proxy for Indonesian GDP growth, nationally and provincially?



Why nighttime lights?

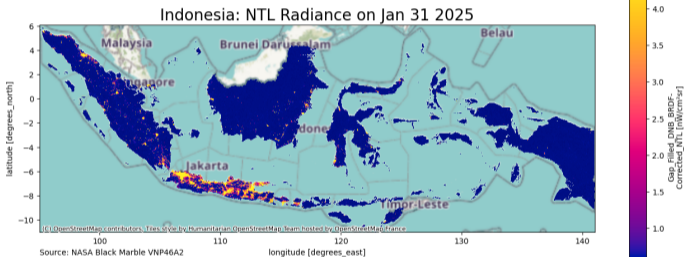
- Satellite-based measure of light emitted from Earth at night: streetlights, buildings, vehicles, commercial activity.
- Literature: Henderson, Storeygard, and Weil (2012), Bickenbach et al. (2016), Martínez (2022) show NTL tracks economic activity globally, including for countries with weak statistical infrastructure.
- Data pipeline from NASA's Black Marble is reproducible and transparent.
- High spatial resolution (500 m) — allows both national and provincial analysis.
- But: is it genuinely useful for **Indonesia**?



Data: NASA Black Marble VIIRS

- Source: NASA Black Marble Standard Product Suite, via `blackmarblepy` (Stefanini Vicente and Marty 2023).
- Daily radiance measurements, cloud-corrected and calibrated.
- We aggregate to monthly (Jan 2012 – Dec 2024) then to quarterly year-on-year log growth.
- GDP data from BPS quarterly real GDP series (BPS 2025), matched by quarter.
- Provincial GDRP from BPS for 34 provinces.

Indonesia seen from space, 2023



- Stark contrast between Java and the rest of Indonesia — mirrors GDP & population distribution.
- Mining and palm-oil regions are visibly darker despite high economic output.

Figure 1: Annual NTL in Indonesia, 2023

National series

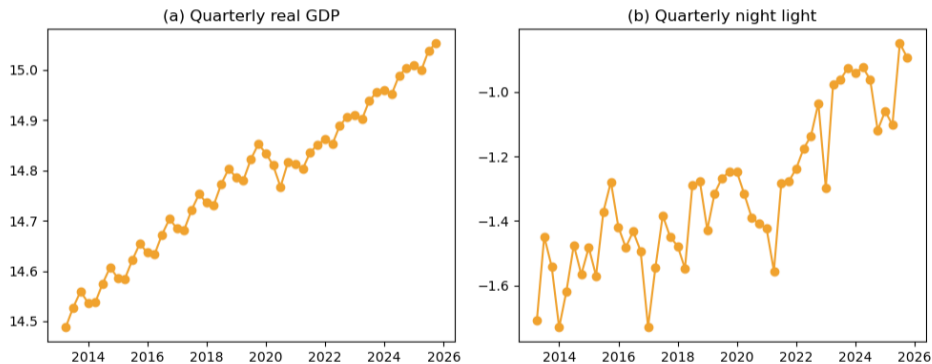


Figure 2: Quarterly real GDP (left) and NTL index (right), 2012–2024



Two layers of analysis

National level

- Bivariate time-series.
- OLS \rightarrow ARDL with lag selection by AIC.
- Six ARDL specifications around COVID/scarring/quarterly dummies.
- Train/test forecast.

Provincial level

- Panel of 34 provinces \times 47 quarters.
- Static: pooled OLS, FE, TWFE.
- Dynamic: DFE, PMG, MG (Pesaran–Shin–Smith).

Are the series stationary?

Augmented Dickey–Fuller tests:

Series	ADF stat	p-value	5% critical	Verdict
log GDP, levels	-0.38	0.91	-2.93	I(1)
log GDP, Δ	-2.97	0.04	-2.93	stationary
log NTL, levels	+1.14	0.996	-2.94	I(1)
log NTL, Δ	-2.77	0.06	-2.94	borderline stationary

Both series look I(1); first differences stationary.

Are they cointegrated?

Two tests, two verdicts:

- **Engle–Granger residual ADF:** reject “no cointegration” at 1% ($p = 0.0003$)
- **Johansen trace test:** fail to reject rank = 0 ($9.45 < 15.49$ at 5%)

With $T = 51$ and two variables, the Johansen test has low power, and the evidence is **borderline** rather than decisive.

ARDL-in-levels (Pesaran–Shin–Smith bounds framework) remains valid whether the series are $I(0)$ or $I(1)$, so we proceed.

Does NTL *lead* GDP? Granger-causality

	lag 1	lag 2	lag 3	lag 4
NTL \rightarrow GDP (p)	0.326	0.007	0.229	0.343
GDP \rightarrow NTL (p)	0.006	0.018	0.007	0.004

- NTL Granger-causes GDP **only at lag 2**.
- GDP Granger-causes NTL at **every** lag, much more robustly.
- Pattern is more consistent with NTL *tracking* GDP contemporaneously than leading it.
- This qualifies the leading-indicator framing.

National: OLS is biased

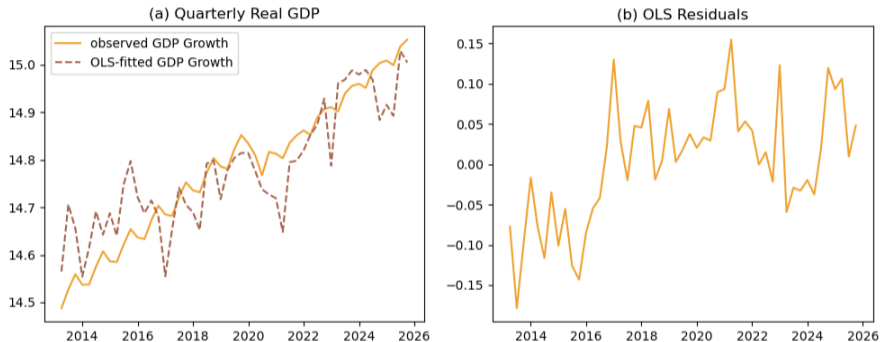
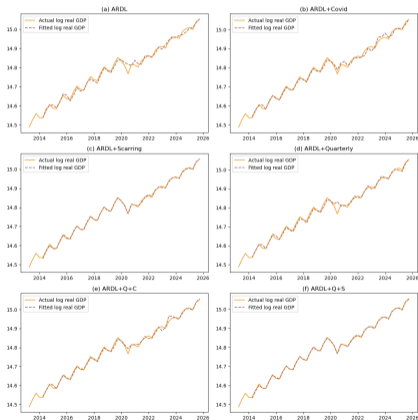


Figure 3: OLS fit and residuals

- OLS coefficient: 0.54^* , **but residuals are systematically biased**: over-predicts pre-2017, under-predicts post-2017**.

National: six ARDL specifications



(a) baseline (b) +Covid (c) +Scarring (d) +Quarterly (e) +Q+C (f) +Q+S.
Specifications with the scarring dummy — panels (c) and (f) — produce the tightest fits.



Reading the ARDL table

- **NTL coefficient shrinks** drastically once dynamics are added: 0.54 (OLS) \rightarrow 0.01–0.08 (ARDL).
- Contemporaneous NTL is significant at 1% in the baseline, only 10% in the preferred ARDL+Scar.
- The scarring dummy is highly significant at all four lags.
- Bulk of the fit comes from **lagged GDP + the post-2020 dummy**, not from NTL.

NTL carries information about GDP, but not enough to be a stand-alone predictor.

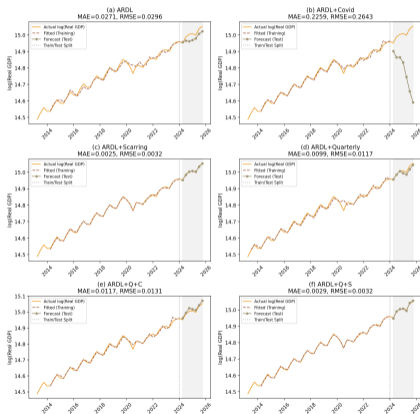


The “scarring” coefficient — handle with care

- The post-2020 dummy coefficient at $t = 0$ is about $-0.02 \rightarrow$ naively, “GDP 2% lower persistently after the pandemic.”
- **Three reasons to discount the 2% number:**
 1. The +Scar spec flips AR coefficients' signs and magnifies the trend — model-fit artefact as much as structural finding.
 2. The dummy absorbs *any* post-2020 shift: BPS methodology changes, commodity prices, reforms.
 3. Identification rests on only ~ 20 post-shock quarters.
- Read as **suggestive**, not a precise estimate of pandemic damage.

Out-of-sample forecast

ARDL Models: Training vs Out-of-Sample Forecast (Test: 2024Q1 onwards)



- +Scar and +Q+S produce the smallest MAE/RMSE.
- But: hold-out window is **only 4–6 quarters**. Too short to make strong forecast-quality claims.
- Rolling/recursive evaluation is future work.

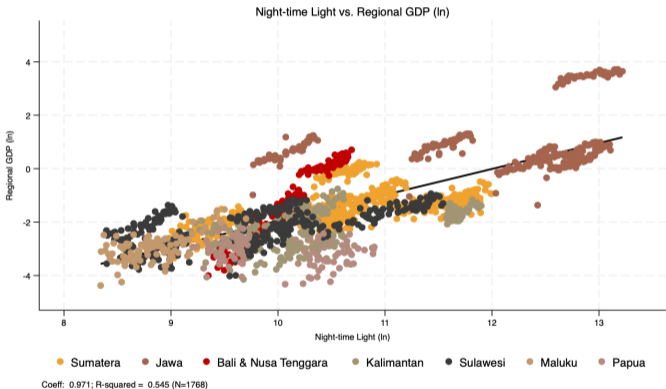
Figure 4: ARDL train/test split: hold-out 2024+

Provincial: static models

	Pooled OLS	FE	TWFE
NTL coefficient	0.56***	0.28***	0.055***
R^2	0.55	0.35	0.85

- Pooled OLS: driven by **between-province** variation (Java vs rest of Indonesia).
- Moving to within-province (FE) and time-controlled (TWFE) shrinks the coefficient by an order of magnitude.
- **TWFE = 0.055** is the most informative: within a province, controlling for common time shocks, NTL has little marginal predictive power.

Provincial cross-section



- Java clusters high on both axes.
- Resource provinces generate lightless output, Agricultural provinces sit somewhere in between.
- The NTL-GDRP *slope* plausibly differs across island groups.

Figure 5: NTL vs GDRP across 34 provinces

Provincial: dynamic estimators

	DFE	PMG	MG
Long-run NTL, baseline	0.332***	0.374	0.486***
Long-run NTL, +Scarring	0.589**	0.426	-0.713
Pooling: short run	common	common	free
Pooling: long run	common	common	free

- DFE (strongest pooling): significant throughout.
- PMG (long-run only pooled): insignificant in baseline.
- MG (fully free): large and positive in baseline, **sign-flipped** in +Scarring.

What this disagreement means

- FE absorbs *intercept* heterogeneity across provinces — not *slope* heterogeneity.
- DFE/PMG impose a common NTL **slope** across all 34 provinces. MG does not.
- When the true elasticity differs across Java / Kalimantan / Sulawesi / Papua, DFE gives a precise average that doesn't represent any particular province.
- MG's sign-flip in +Scarring is not “the true elasticity is negative” — it's the signature of heterogeneity showing up once the pooling restriction is relaxed. *The cross-estimator disagreement is itself the finding.*

What about the ECT slowdown?

- Baseline DFE: $ECT = -0.0374 \rightarrow \sim 6.75$ years to adjust.
- +Scarring DFE: $ECT = -0.0169 \rightarrow \sim 14.75$ years.
- Tempting interpretation: **hysteresis** — the pandemic permanently slowed recovery.
- But: adding a scarring dummy mechanically *redefines* equilibrium, so part of the ECT drop is a specification artefact.
- We flag this as consistent with hysteresis, not a causal identification.
- Separating observation costs number of observations.

What we find

- NTL is **positively and generally significantly** correlated with Indonesian GDP.
- Most raw-OLS association is **between-province** rather than time-series: TWFE coefficient is ~ 0.05 , not 0.56.
- There is a clear structural break in GDP around 2020, and accounting for it materially improves forecast fit.
- Pattern of provincial estimator disagreement points to **genuine slope heterogeneity** across islands.

What we do not find

- Evidence that NTL is a strong **stand-alone** predictor — the ARDL forecast is driven by lagged GDP and the post-2020 dummy.
- Robust Granger-causal evidence that NTL **leads** GDP (only lag 2 works).
- A clean causal reading of the **2% scarring** estimate (dummy absorbs any post-2020 shock).
- Convincing evidence that the **adjustment speed** has changed (ECT slowdown is partly a specification artefact).
- Cross-estimator agreement in the provincial panel — pooled estimates likely paper over heterogeneity.



Takeaway

NTL for Indonesia is best framed as:

1. A **complement** to official GDP in nowcasting pipelines, not a substitute.
2. A **between-province** indicator of structural variation.
3. An **imperfect** crisis signal — NTL diverged from GDP precisely during the 2020 shock, where independent validation is most valuable.

Useful, but not a magic wand.



Thank you

Paper and reproducibility repo:

- Main paper: github.com/den-econ/nitelite
- Python pipeline (national): `appendix.ipynb`
- Stata pipeline (provincial): `stata/Do/Nighttime Light_Reg.do`
- Data: NASA Black Marble (Stefanini Vicente and Marty 2023), BPS (BPS 2025)

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THANK YOU