Nighttime Light as a Proxy for Regional GDP

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Intro

Utilizing the advantage of granularity by nighttime lights data to capture economic activity at lower spatial level, this study extends the analysis to the provincial level to gain insights from cross-sectional heterogeneity. To generate a comparable analysis with the official province GDP data disseminated by BPS, the nighttime lights data format are also compiled on a quarterly year-on-year basis for 34 provinces in Indonesia spanning the period 2014Q1 to 2024Q4. Later on the analysis, to assess whether the relationship between provincial GDP and nighttime lights changed during and after the pandemic period, we extend the baseline specification by including dummy variables for the Covid-19 period and the post-pandemic period or the scarring effect.

Exploratory

In the previous section (see: Fig. 1), it is seen that Java exhibits a stark contrast compared to the rest of Indonesia. This scatterplot (Fig. L1), clarifies that Java has higher nighttime light intensity. In addition, it also displays that Java relatively has higher provincial GDP compared to other island groups. The data points for Java in blue color are clustered toward the higher end of both axes, indicating higher levels of economic activity and luminosity relative to other regions. Conversely, though the linear trend between nighttime light and provincial GDP are still visible, provinces outside Java show greater dispersion. This implying more variation in the relationship between light intensity and GDP possibly due to differences in economic structure or spatial distribution of economic activities. In regions outside Java, the economic structure is dominated by agriculture, plantation activities, and mining industries. While these sectors contribute significantly to regional output, they produce comparatively low levels of nighttime lights.

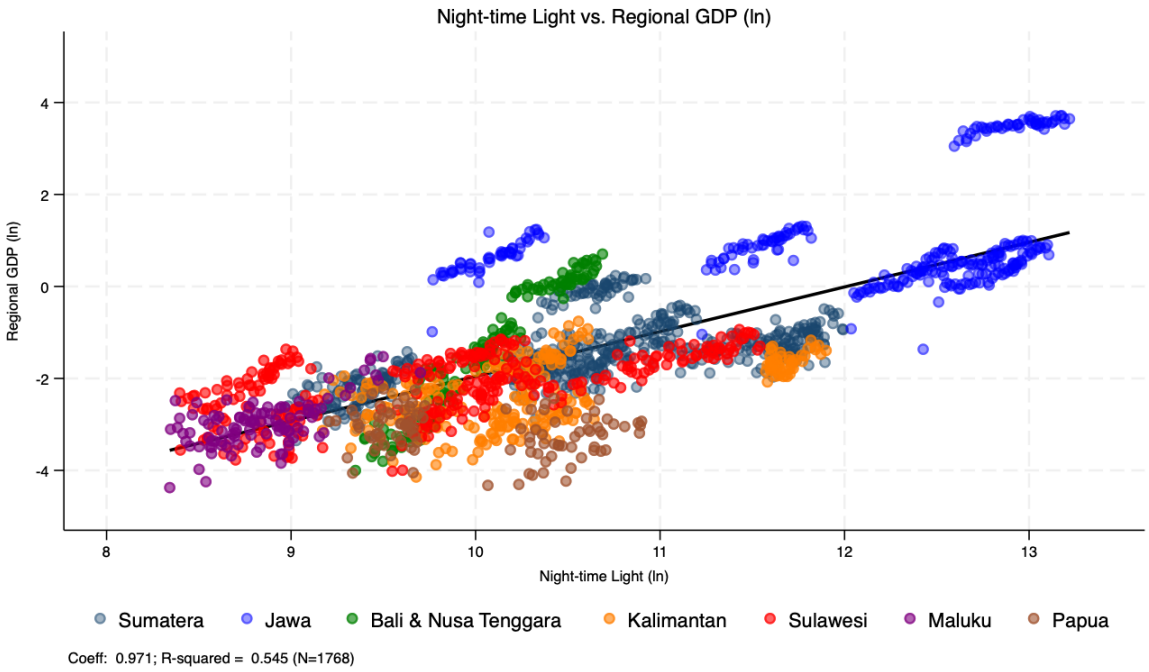

Figure 1: Nighttime-Lights vs. Regional GDP, log

Table 1: Regression results: Provincial GDP and Nighttime Lights

	Ordinary Least Squares			Fixed Effects			Two-way Fixed Effects			Dynamic Fixed Effects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Nighttime Light, ln	0.561***	0.560***	0.560***	0.317***	0.304***	0.205***	0.0649**	0.0649**	0.0649**	0.529***	0.481***	0.478***
	(0.0119)	(0.0118)	(0.0119)	(0.0344)	(0.0318)	(0.0334)	(0.0250)	(0.0250)	(0.0250)	(0.0309)	(0.0270)	(0.0353)
COVID-19 dummy		✓			✓			✓			✓	
Post pandemic (scarring) dummy			✓			✓			✓			✓

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Regression

As the baseline, we estimate the correlation between nighttime lights (NTL) and regional GDP using a pooled Ordinary Least Squares (OLS) model, which captures the overall association between the variables. To extend the analysis, we employ a fixed-effects (FE) model to control for time-invariant provincial characteristics, and a two-way fixed-effects (TWFE) model that advanced the FE estimation by incorporating year fixed effects to account for common shocks affecting all provinces simultaneously.

The regression results show a strong and significant relationship at the 1% level between regional GDP and night-time light intensity across all model specifications. Coefficients from the OLS and fixed-effects models range between 0.97 and 1.3 (see: Table. l1 & Table. l2), and remain positive and stable even after controlling for COVID-19 and post-pandemic scarring effects. In the TWFE model, the COVID-19 dummy indicates negative impacts during 2020–2021 (see: Table. l3), and the scarring control also suggests the same negative correlation for 2022. Year-specific dummies indicate that, despite the deviations observed during the COVID-19 and post-pandemic periods, the overall elasticity pattern between regional GDP and nighttime light intensity remains consistent over time.

To further examine whether this relationship also holds in a dynamic setting, we estimate a Dynamic Fixed Effects (DFE) error-correction model. Unlike the static FE and TWFE specifications, the DFE framework explicitly distinguishes between short-run adjustments and long-run equilibrium dynamics, while still controlling for unobserved, time-invariant provincial heterogeneity. This approach allows us to assess how quickly deviations between nighttime light intensity and regional GDP are corrected over time.

The DFE results provide strong evidence of a stable long-run relationship between the two variables. The error-correction term is negative and statistically significant across all specifications, with magnitudes ranging between 0.48 and 0.53 in absolute value. This implies that approximately 48–53 percent of any short-run disequilibrium between regional GDP and nighttime lights is corrected within one quarter, indicating relatively rapid adjustment toward the long-run equilibrium.

Importantly, the magnitude and significance of the error-correction coefficient remain robust even after controlling for the COVID-19 and post-pandemic scarring periods. This suggests

that, although the pandemic caused temporary disruptions, it did not fundamentally alter the long-run linkage between economic activity and nighttime light intensity. In other words, the shocks observed during and after the pandemic reflect short-term deviations rather than a structural decoupling of the GDP–NTL relationship.

Conclusion

Unlike the previous national-level nighttime lights model, which found no positive or significant relationship between the nighttime light data and GDP, the provincial cross-sectional analysis reveals a different pattern. At the regional level, nighttime light intensity shows a strong and statistically significant correlation with regional GDP across various model specifications, including OLS, FE, and TWFE. The relationship also remains consistent even after controlling for the COVID-19 and post-pandemic scarring periods.

These findings are further reinforced by the Dynamic Fixed Effects (DFE) estimates, which reveal a stable long-run equilibrium relationship between regional GDP and nighttime light intensity. The statistically significant error-correction term indicates that deviations from the long-run equilibrium are corrected relatively quickly, suggesting that shocks—such as those arising during the pandemic—generate only temporary divergence rather than a structural break. Together, the static and dynamic results provide consistent evidence that nighttime light intensity serves as a reliable proxy for regional economic activity at the provincial level.