Bayesian Latent Variable Model of Economic Activity in Cuba

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What's Really Happening in Cuba?

Cuba forecasts a 1% GDP growth in 2025 despite the economic crisis

Cuban culture books

The regime claims that the 1% GDP growth expected in 2025 will rely on the recovery of tourism, exports, and energy improvements, despite an economy characterized by crises and setbacks.

CUBA

Cuba is a lot poorer than the government reports, a new study shows

By **Nora Gámez Torres**

January 22, 2018 5:56 PM

What's Really Happening in Cuba?

What we know about Cuba's economy

BY DREW DESILVER

Two-thirds of Americans favor an end to the decades-long U.S. trade embargo on Cuba, a January Pew Research Center study found, and the two nations reportedly are making progress on re-establishing diplomatic relations. As the communist government continues to slowly reform Cuba's economy, American businesses – from airlines to law firms – are exploring commercial opportunities on the island nation. But even if the embargo were to be lifted, it's not clear just what sort of Cuban economy those businesses would find.

Getting a handle on even basic information about Cuba's economy is difficult, for a number of reasons. The government still dominates economic activity on the island, both directly and through heavily subsidized state-owned enterprises. National statistics are not always complete or reliable. And Cuba's system of two parallel currencies – one peso for everyday transactions among ordinary Cubans, and a "convertible peso" for the tourism industry, foreign trade and the private sector – combined with multiple exchange rates complicates any international comparisons or discussions about the relative size of different parts of the economy.

Motivation

- Reliable economic data for Cuba is scarce and disputed.
- Traditional indicators (e.g., GDP) are not consistently reported.
- Can we infer economic activity using satellite imagery and open data?

Research Question

Goal

Estimate a latent index of economic activity across Cuba using spatial proxies.

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- Combine nightlights, NDVI, and road density data
- Use a Bayesian model to infer unobserved economic activity

Data Sources

- **Nighttime Lights (VIIRS)**: Proxy for infrastructure & development.
- **NDVI**: Measures vegetation "greenness."
- **Road Density**: Infrastructure connectivity.

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All proxies standardized and aligned to 500m grid. Water masked out.

Bayesian Hierarchical Model

- Latent economic activity z_i per grid cell
- Observed proxies $x_{i,k} \sim \mathcal{N}(\beta_k z_i, \sigma_k^2)$
- Fixed $\beta_{\text{lights}} = 1$ for identifiability
- Spatial prior on z

Graphical Model

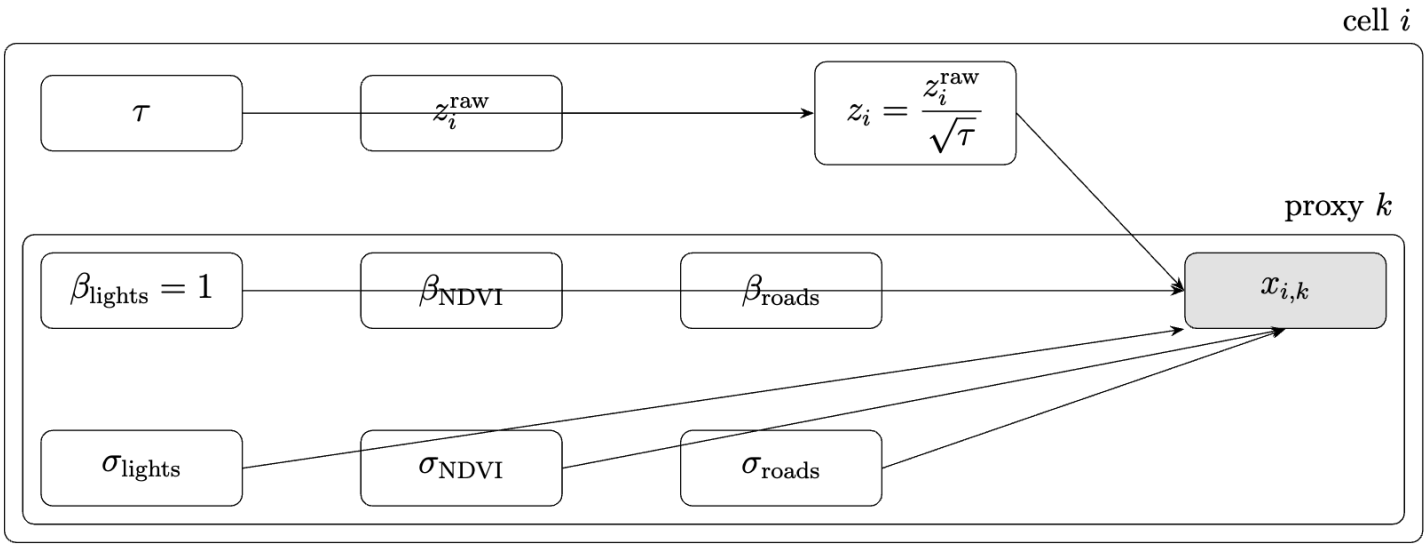
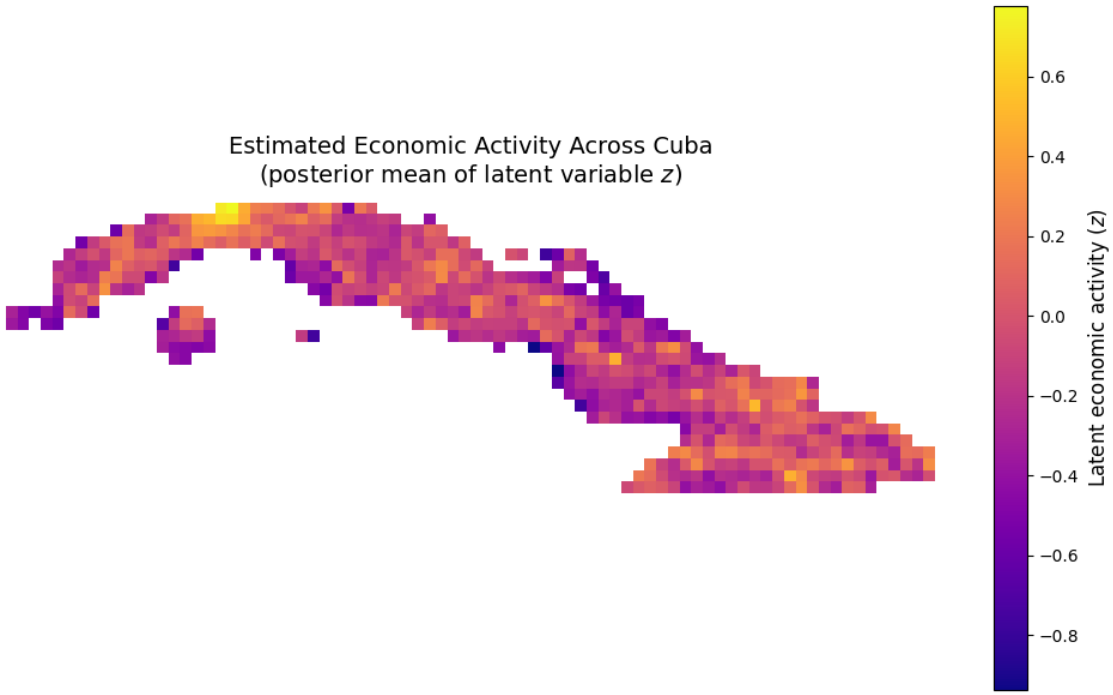


Figure 1: Graphical model of the Bayesian latent-variable hierarchy. Precision τ rescales raw latent draws z_i^{raw} to give spatial latent activity z_i. Observed proxies $x_{i,k}$ have Gaussian likelihood with mean $\beta_k z_i$ and noise σ_k. A fixed loading $\beta_{\text{lights}} = 1$ sets the latent scale.

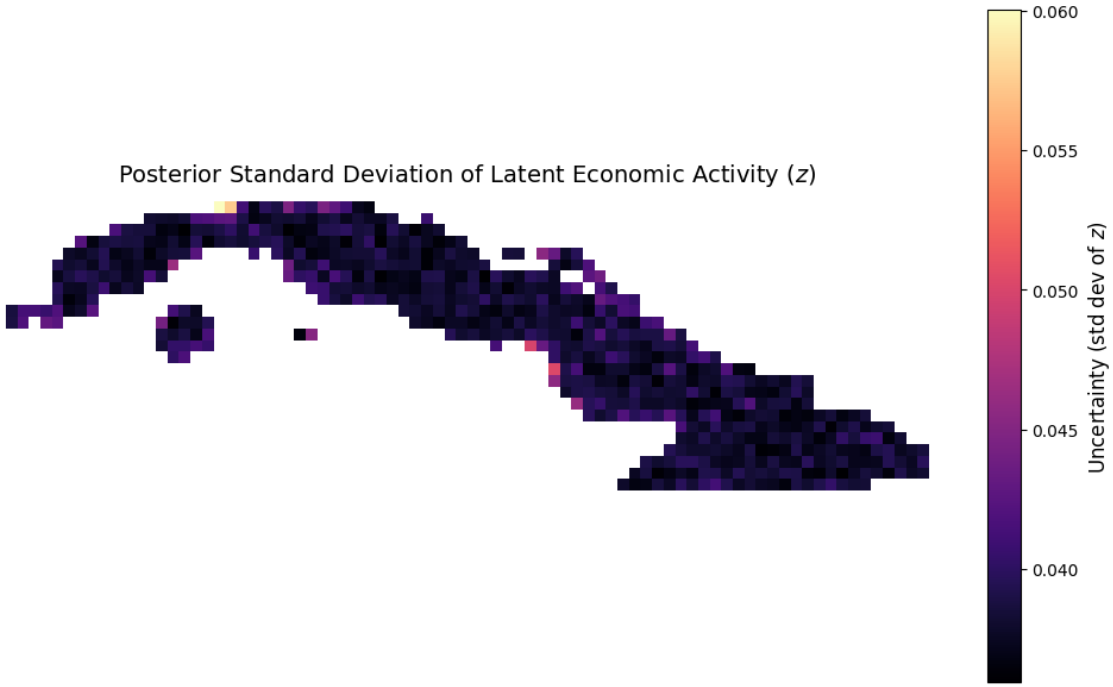
Posterior Results: Cuba (15km Grid)

- Posterior mean of z_i shown below:



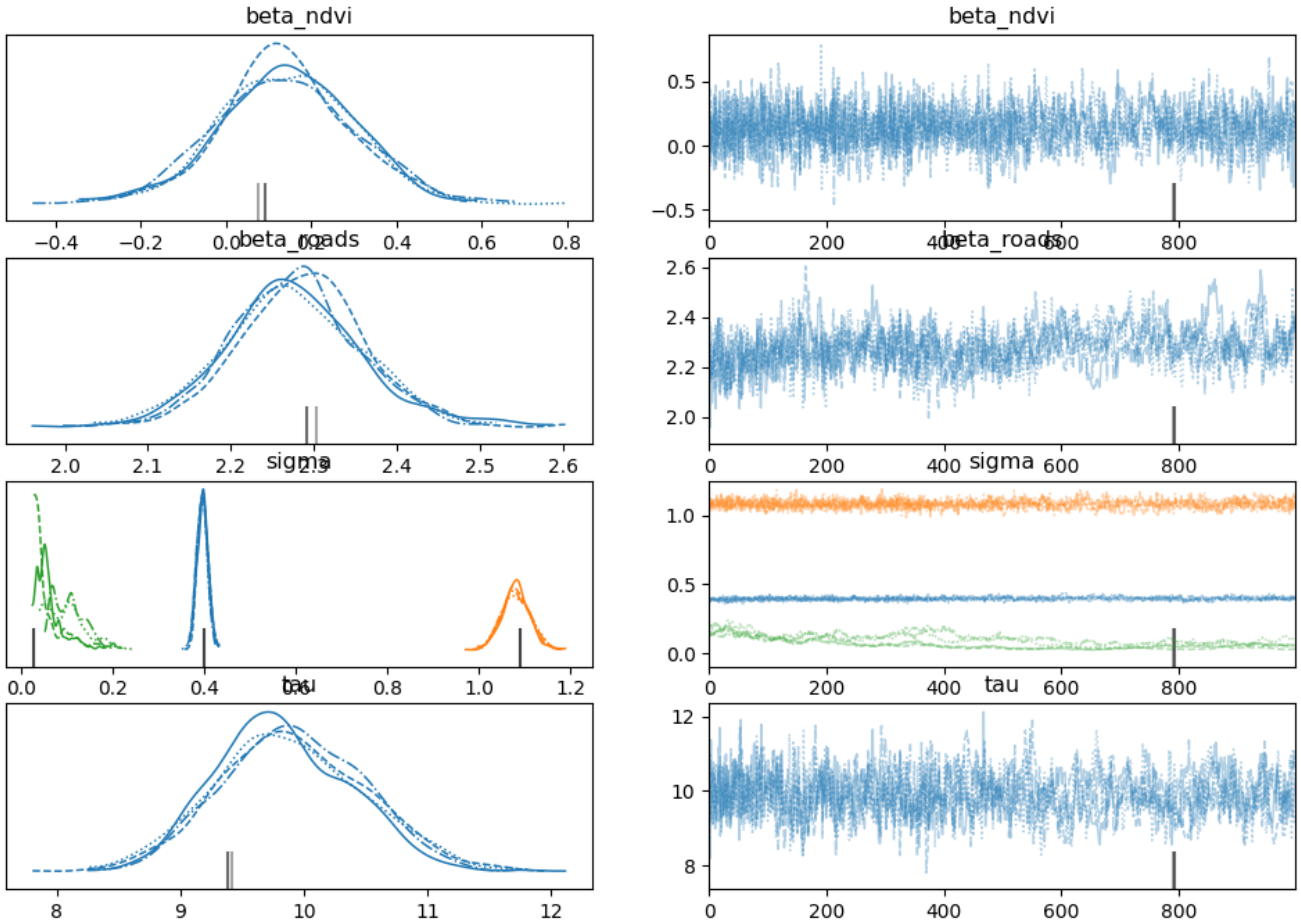
Uncertainty Estimates

- Posterior standard deviation is low (≈ 0.04–0.06)
- Higher uncertainty in urban areas like Havana



Model Coefficients

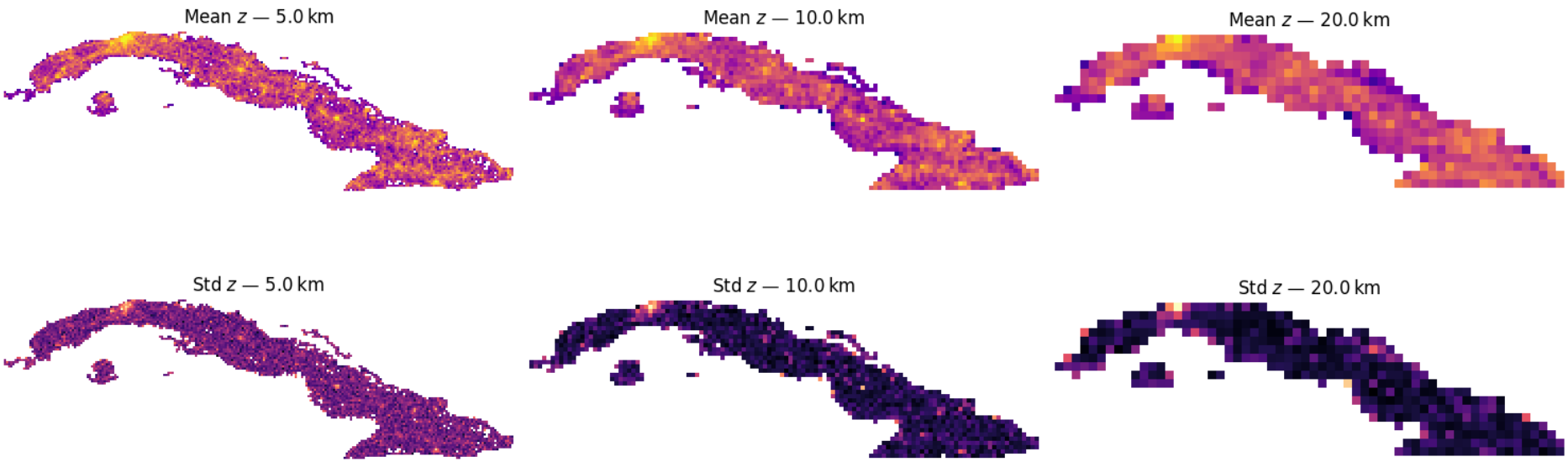
- $\beta_{\text{NDVI}} \approx 0.14$ (weakly positive)
- $\beta_{\text{roads}} \approx 2.29$ (strong positive)
- σ values show road is low-noise; NDVI is high-noise



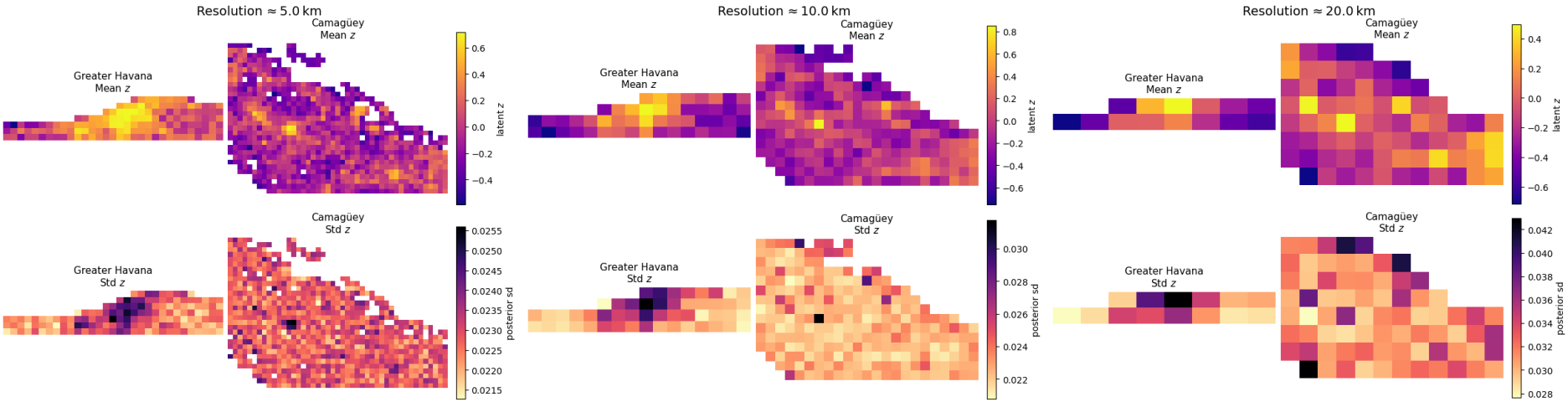
Multi-Resolution Analysis

- Refit model at 5 km, 10 km, 20 km grids
- Observe stable coefficients but varied uncertainty
- β_{NDVI} flips sign across resolutions

Resolution Comparison: Maps



Zoom-In: Greater Havana and Camagüey



Conclusion and Future Work

- Nightlights + roads = best proxies for economic activity in Cuba
- Bayesian model provides uncertainty-aware estimates
- Limitations: No ground-truth calibration, constant coefficients
- Immediate Next Step: Validate model on Dominican Republic
- Future: Add time dimension

Thank You!

Thank you! Questions? Feedback?

References

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