

From Light to Growth: A Study of Night-Time Light as an Indicator of Economic Development*

Growth in Night-Time Light Intensity Correlates ____% With GDP Growth

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This study investigates the relationship between the growth of night-time light (NTL) intensity, as captured by satellite imagery, and GDP growth across countries over a multi-decade period. By analyzing data spanning from 1992 to 2001, we find a strong correlation of [X]% between NTL growth and GDP growth. Importantly, the strength of this correlation varies by the statistical capacity of countries. Countries with high statistical capacity, rated ‘A’ by the World Bank, exhibit a correlation as high as [X]%, while those with low statistical capacity, rated ‘F’, show a correlation as low as [Y]%. These findings highlight the potential of NTL data as a complementary tool for economic analysis, particularly in regions where conventional economic metrics are less reliable or unavailable. (Blank spaces will be filled when project is completed)

1 Introduction

2 Data

We collected data from multiple sources to analyze the relationship between night-time light intensity and GDP growth. The primary dataset is a harmonized global night-time light (NTL) dataset spanning from 1992 to 2018, developed by Li et al. (Li et al. 2020). The dataset combines observations from two satellite systems: DMSP/OLS (1992–2013) and VIIRS (2012–2018). To ensure consistency across years, we addressed differences in spatial resolution and saturation between the two systems by inter-calibrating DMSP data and simulating DMSP-like VIIRS observations. The resulting dataset provides annual Digital Number (DN) values, representing night-time illumination intensity, as GeoTIFF files.

We also sourced GDP, manufacturing share of GDP, and population data from the World Bank’s World Development Indicators (WDI) (The World Bank 2024b), measuring GDP in purchasing power parity (PPP) for comparability across countries. Additionally, we incorporated the Statistical Performance Indicator (SPI), which evaluates national statistical systems across five pillars: data use, data services, data products, data sources, and data infrastructure. (The World Bank 2024a)

*Code and data are available at: <https://github.com/shamayla38/EconomyLightCorrelation>.

2.1 Measurement

The DN (Digital Number) values in the dataset are derived from satellite imagery that captures night-time light emissions. These emissions result from real-world activities such as streetlights, industrial complexes, and residential areas. The satellite sensors detect these light intensities, which are then processed, calibrated, and harmonized to produce standardized measurements. These measurements are ultimately converted into numerical entries representing the brightness of light observed in specific geographical locations, enabling researchers to analyze economic and social activity at various scales. The data set for our analysis includes NTL captured by the Defense Meteorological Satellite Program’s Operational Linescan System (DMSP/OLS) and the Visible Infrared Imaging Radiometer Suite (VIIRS), provides a spatially explicit proxy for human presence. DMSP/OLS, operational since the 1970s, used low-light imaging to detect artificial lights but faced challenges like coarse resolution and sensor saturation (C. D. Elvidge et al. 1999). VIIRS, introduced in 2012, improved spatial resolution and dynamic range, using advanced algorithms to remove noise and non-anthropogenic light sources, resulting in high-quality radiance-calibrated maps (C. Elvidge et al. 2017).

The World Bank datasets, such as GDP, population, and manufacturing share of GDP, are sourced from national statistical agencies and harmonized using internationally accepted methodologies like the System of National Accounts (SNA). GDP is measured through national accounts using production, income, and expenditure approaches, relying on administrative records, business surveys, and sectoral data. Population data originate from national censuses and are updated between censuses using demographic surveys, vital registration systems, and migration records. Data on the manufacturing share of GDP are collected through industrial surveys and administrative records, capturing outputs from manufacturing activities.

2.2 Data Extraction and Cleaning

The data preparation began with extracting night-time light (NTL) intensity values from GeoTIFF files using Python’s ‘Rasterio’ (Gillies et al. 2013–) package. This process involved reading annual TIFF files to obtain Digital Number (DN) values, representing light intensity, along with their corresponding latitude and longitude coordinates. This resulted in a spatial dataset detailing global NTL distribution for each year.

To associate each observation with a specific country, the extracted data were merged with a global shapefile of country boundaries through spatial join techniques. Each latitude-longitude pair was assigned to the country in which it was located, and observations without an assigned country—primarily from international waters—were removed. Subsequently, to create an aggregate annual measure of NTL intensity for each country, all observations within a country were summed to calculate the total light emitted annually.

The World Bank data, including GDP, manufacturing share of GDP, and population, were processed by standardizing country names to ensure consistency across datasets. For instance, discrepancies like ‘Yemen’ versus ‘Yemen, Rep.’ were resolved. The data were then transformed from a wide to a long format using pandas’ ‘melt’ function, facilitating easier merging with the NTL data.

To assess how the correlation between night-time light (NTL) intensity and GDP varies among countries with differing levels of statistical capacity, we first to group countries together based on a measure of each country’s statistical capacity. We used the World Bank’s Statistical Performance Indicators (SPI). We calculated the average SPI score for each country across all the years SPI was available for and assigned grades based on these averages: scores of 80 and above received an ‘A’, scores between 60 and 79 a ‘B’,

Table 1: Sample of the dataset showing key variables used in the analysis

Country	Year	Night Lights (DN)	GDP (PPP)	Manufacturing Share	Population	Grade
Afghanistan	2002	37956	37931379899	18.822752	21000256	C
Albania	1996	54902	17326597422	4.857952	3168033	B
Algeria	1999	1634753	344181000000	34.479053	30346083	C
Angola	1995	47138	72399259721	3.646281	13912253	C
Antigua and Barbuda	1992	4162	1374028894	2.036987	64659	C
Argentina	1992	1427787	656388000000	21.859132	33568285	B
Armenia	2012	160580	35673112560	9.424759	2914421	A

Table 2: Summary Statistics of Data from year 1995 and 2020

	1995 (N=188)		2020 (N=189)	
	Mean	Std. Dev.	Mean	Std. Dev.
DN	1 412 963.5	5 631 142.1	2 971 421.4	9 552 808.9
GDP	369 356 559 423.2	1×10^{12}	776 024 587 843.4	3×10^{12}
Manufacturing	14.8	7.2	11.7	7.0
Population	28 203 251.7	116 005 937.1	38 094 692.1	149 227 259.8

DN refers to total average night-time light intensity emitted by a country in a year, GDP is measured in PPP, and Manufacturing refers to the manufacturing share of GDP.

scores between 40 and 59 a ‘C’, scores between 20 and 39 a ‘D’, and scores below 20 an ‘F’. A glimpse of the dataset is presented in Table 1.

2.3 Summary Statistics

It is more meaningful to examine the summary statistics year-wise to capture temporal variations in the data, as the variance across all years is substantial. Table 2 displays the summary statistics for selected years, showing significant growth in average night-time light intensity (DN), GDP (measured in PPP), and population from 1995 to 2020. An especially intriguing observation is that both night-time light intensity and GDP grew by almost exactly the same proportion—2.1 times—between 1995 and 2020 (DN increased by 2.102 times and GDP by 2.101 times). The summary statistics of the rest of the years are given in appendix.

2.4 Data Description

2.4.1 Night Time Lights Data

Nighttime light (NTL) distribution and intensity often vary significantly by population density, GDP, and levels of urbanization. When comparing countries with similar population sizes and land areas, the disparity in NTL intensity vividly reflects income inequality. A striking example is the contrast between North and South Korea, where South Korea’s GDP per capita is over 50 times greater than that of

North Korea, manifesting in the stark difference in nighttime illumination. In Figure 1, using NASA’s Worldview NTL imagery, this difference of GDP is clearly visible, with South Korea brightly lit compared to its nearly dark northern neighbor. Similarly, Myanmar and Thailand, with comparable populations and land area, show a distinct NTL difference; Thailand’s higher GDP and urbanization are evident in its dense and widespread lighting compared to Myanmar’s relatively sparse illumination.

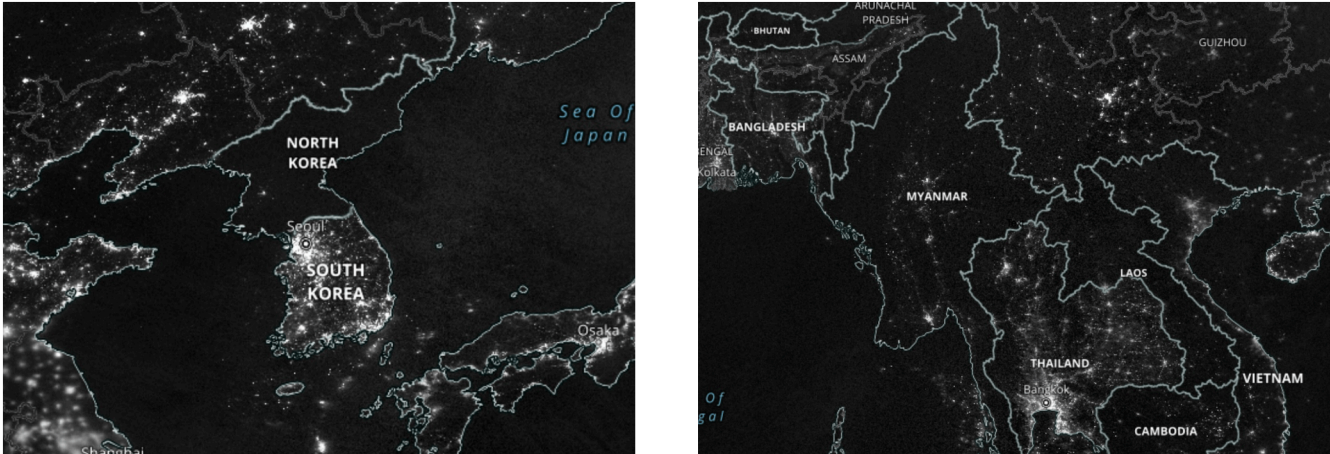


Figure 1: Night-time light intensity highlights stark contrasts in economic development: the profound disparity between North and South Korea, and the significant difference between Myanmar and Thailand. (Source: NASA Worldview)

Total night-time light (NTL) values for countries exhibit a highly skewed distribution due to the presence of a few highly luminous regions. In Figure 2, we observe that after applying a log transformation, this distribution becomes relatively normal, making it more suitable for comparative and statistical analysis

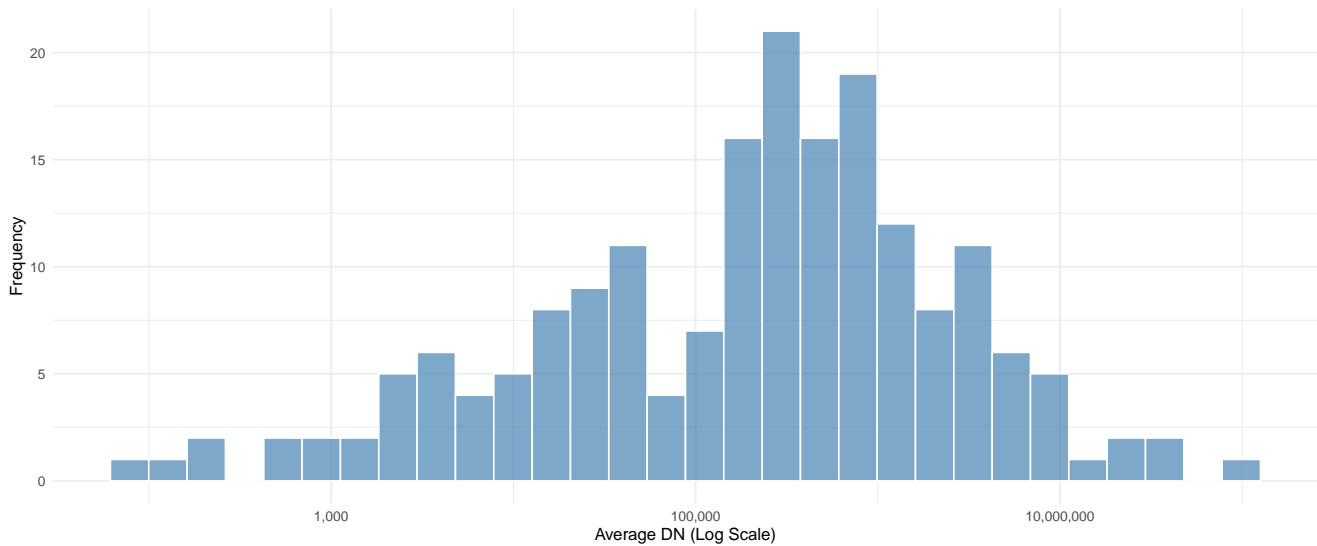


Figure 2: Distribution of log-transformed average nighttime luminosity (DN) by country over the past 30 years, showing variations in average brightness levels across nations.

2.4.2 GDP

To visualise GDP distribution across numerous countries, we categorized them into UN-defined SDG regions and examined the GDP distribution for 2012-2020. The Figure 3 shows that Europe and Northern America have the highest GDP levels, followed by Eastern and South-Eastern Asia and Latin America and the Caribbean, while Sub-Saharan Africa, Oceania, and Central and Southern Asia show significantly lower GDP levels. We would expect similar variations in night-time light intensity, with regions of higher GDP likely exhibiting brighter and more widespread night-time illumination. This connection underscores how night-time light can serve as a proxy for economic activity and development, reflecting the stark differences across regions.

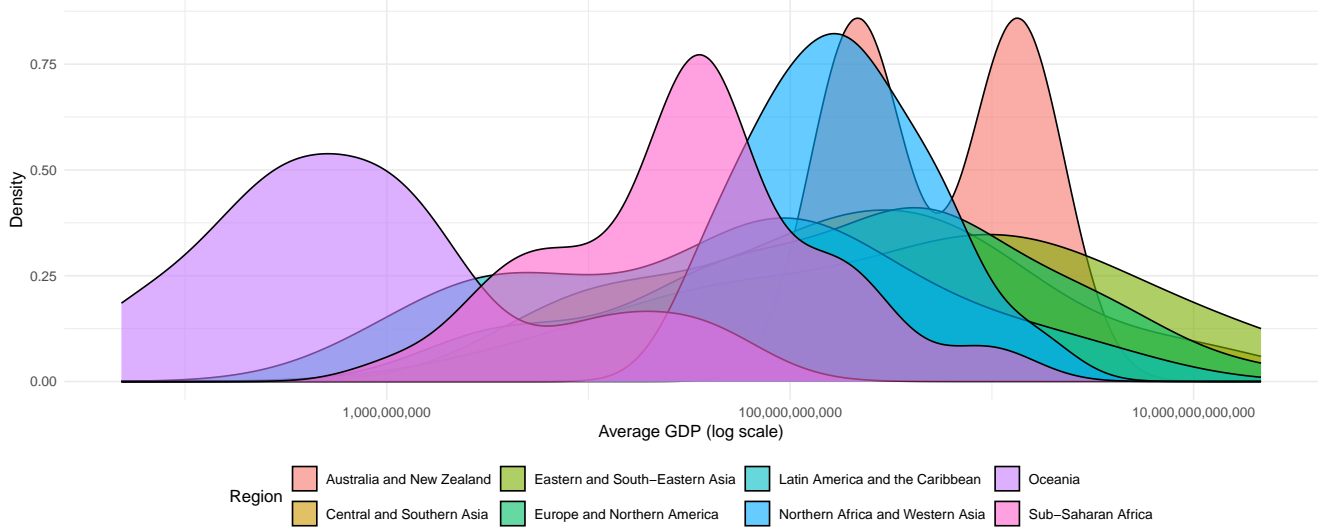


Figure 3: Density plot of average GDP (2012-2020) by region, illustrating Europe and Northern America with the highest GDP, followed by Eastern and South-Eastern Asia and Latin America and the Caribbean, while Sub-Saharan Africa, Oceania, and Central and Southern Asia exhibit significantly lower GDP levels.

2.4.3 Manufacturing Share of GDP of Country

Night-time light intensity is expected to vary with the share of manufacturing in a country's GDP, as higher manufacturing activity typically involves more factories, industrial areas, and infrastructure requiring artificial lighting. Figure 10 in appendix illustrates the manufacturing share of GDP for countries in 2020. Most countries have a manufacturing share below 20%, with a few exceptions such as Puerto Rico, Liechtenstein, and Ireland, which have some of the highest manufacturing contributions. Figure 11 in the appendix presents the manufacturing share of GDP at the beginning of our dataset's time frame in 1992, highlighting how many countries have gradually shifted towards a higher reliance on manufacturing over the years.

2.4.4 Population

Population trends provide essential context for understanding economic activity and night-time light (NTL) intensity patterns. In Figure 4, the total world population is shown to have grown steadily from approximately 4 billion in 1992 to over 7.5 billion by 2020. Figure 5 provides a regional breakdown of

average population across intervals, categorized by UN-defined SDG regions. It reveals that regions like Central and Southern Asia and Eastern and South-Eastern Asia consistently have the highest average populations, while regions like Oceania and Sub-Saharan Africa have significantly lower averages. This demographic variation is critical for analyzing NTL because densely populated regions are likely to exhibit higher light intensity due to concentrated urbanization and industrial activity. Conversely, less populated or sparsely developed regions are expected to have lower NTL levels.

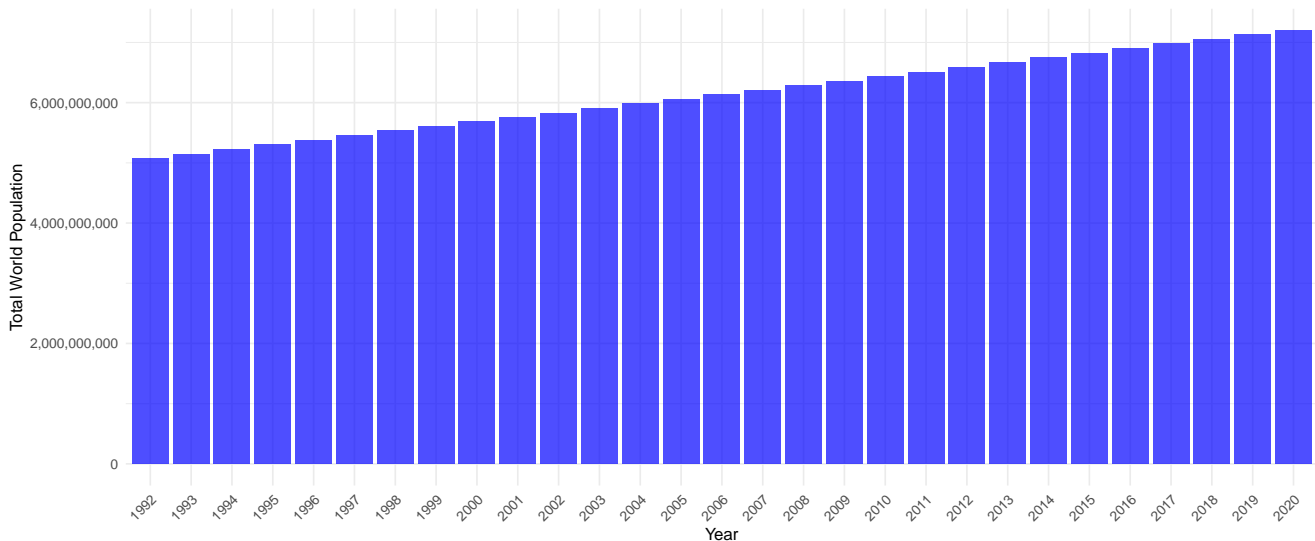


Figure 4: Steady growth of the global population from 1992 to 2020

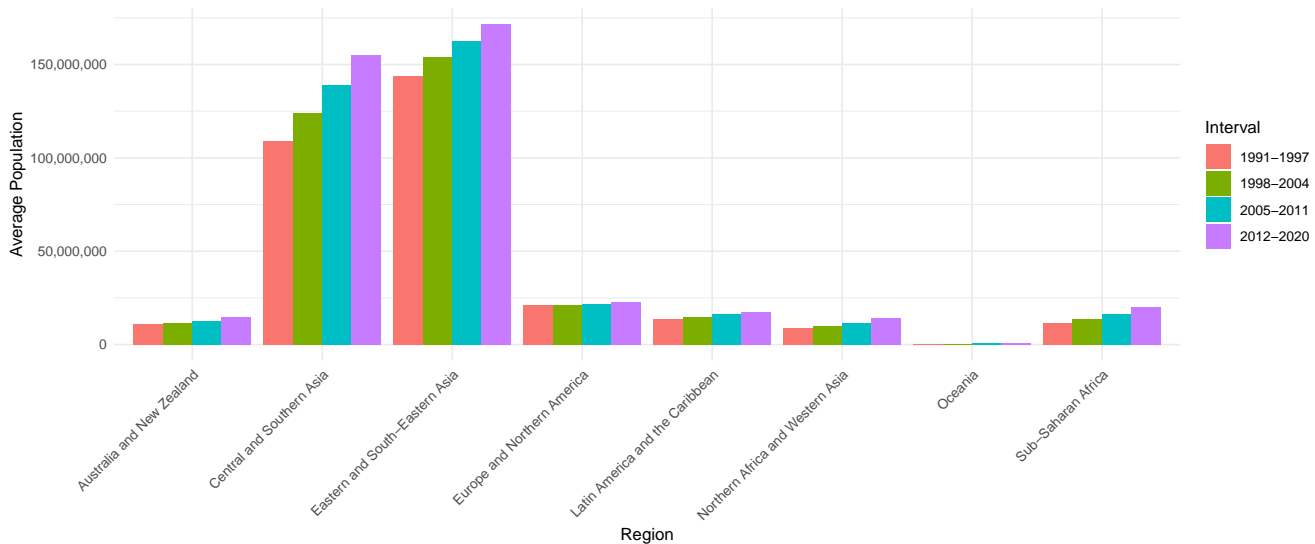


Figure 5: Average population (log scale) across regions for different time intervals (1991–1997, 1998–2004, 2005–2011, and 2012–2020) showing significant population growth in regions such as Central and Southern Asia, Eastern and South-Eastern Asia, and Sub-Saharan Africa over time, with variations across other regions

3 Night lights and GDP

Figure 6 plots the log of DN values against the log of GDP for all countries across 30 years, capturing the relationship between night-time light intensity and economic activity. The scatterplot shows a clear positive correlation, indicating that higher GDP values are generally associated with higher DN values.

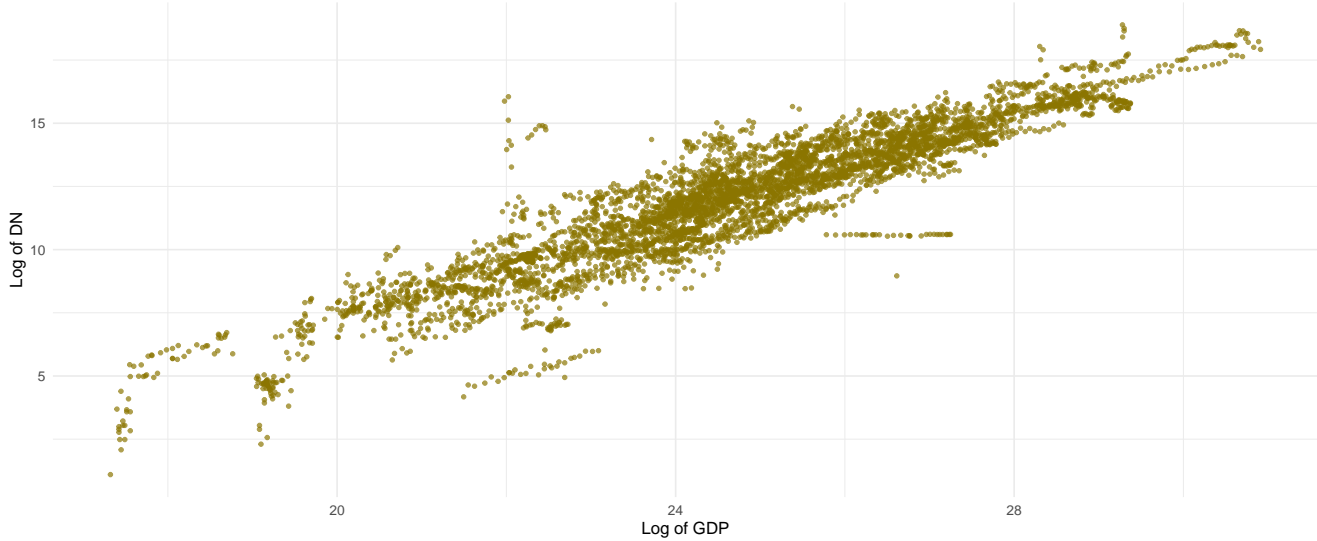


Figure 6: Strong positive correlation between night-time light intensity (Log DN) and GDP (Log GDP), indicating regions with higher GDP levels tend to emit more night-time light

In Figure 7, we observe how this relationship between DN and GDP varies across countries with different statistical capacities. A list of countries categorized by their statistical capacity grades is given in (**tab-grades-countries-latex?**) of the appendix. Countries with higher statistical capacity (graded A and B) exhibit a more tightly clustered and linear relationship, indicating consistent and robust data collection processes. Conversely, countries with lower statistical capacity (graded D and F) show more scatter and variability, suggesting potential discrepancies or weaker data reliability in their national accounts. This shows the intuitive idea that the strength of the DN-GDP relationship can serve as an indicator of the reliability of a country's national statistical systems.

4 Night lights and Population

Larger populations naturally result in higher night-time light emissions due to increased urbanization and economic activity. Figure 1 confirms this with a clear positive relationship between population (log-transformed) and night-time light intensity (Log DN), highlighting how population size contributes to observable brightness from space.

5 NTL and ith Manufacturing Share of GDP

Figure 9 shows the relationship between the manufacturing share of GDP and night-time light intensity (Log DN). The plot shows a weak positive trend for countries with moderate manufacturing shares (up to 20%), where higher manufacturing activity corresponds to slightly higher DN values. However, the relationship becomes less defined for countries with very high or very low manufacturing shares,

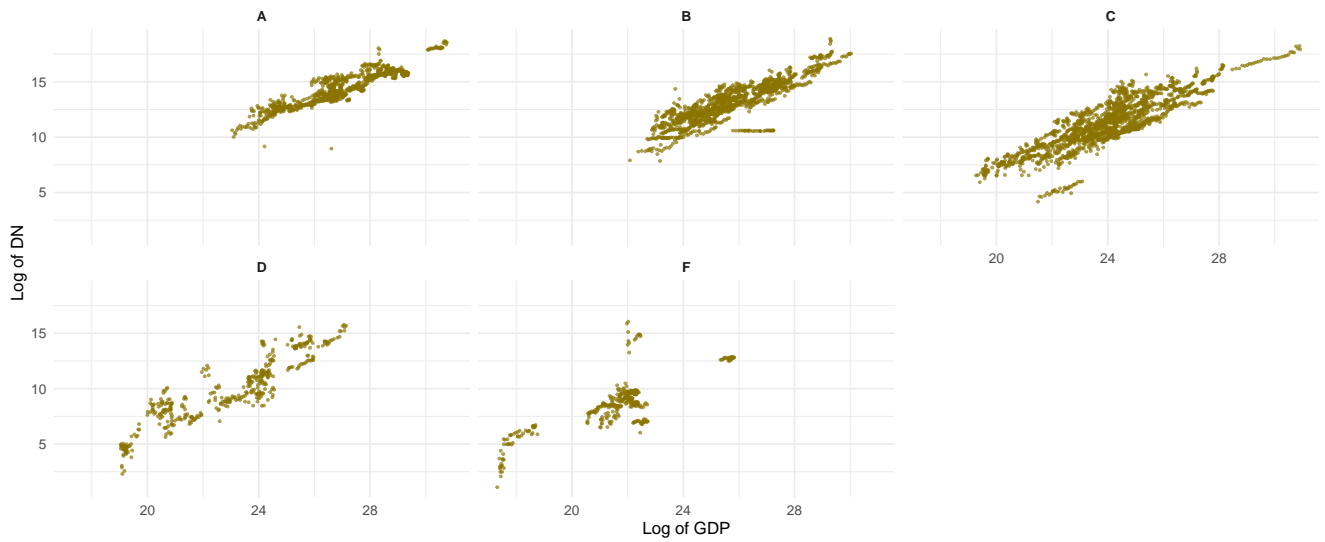


Figure 7: Strength of the correlation between Log DN and Log GDP varies with statistical capacity grades; countries with higher grades (A, B, C) exhibit stronger and more consistent relationships, while lower grades (D, F) show weaker and more dispersed patterns, suggesting the quality of national accounts impacts the NTL-GDP relationship.

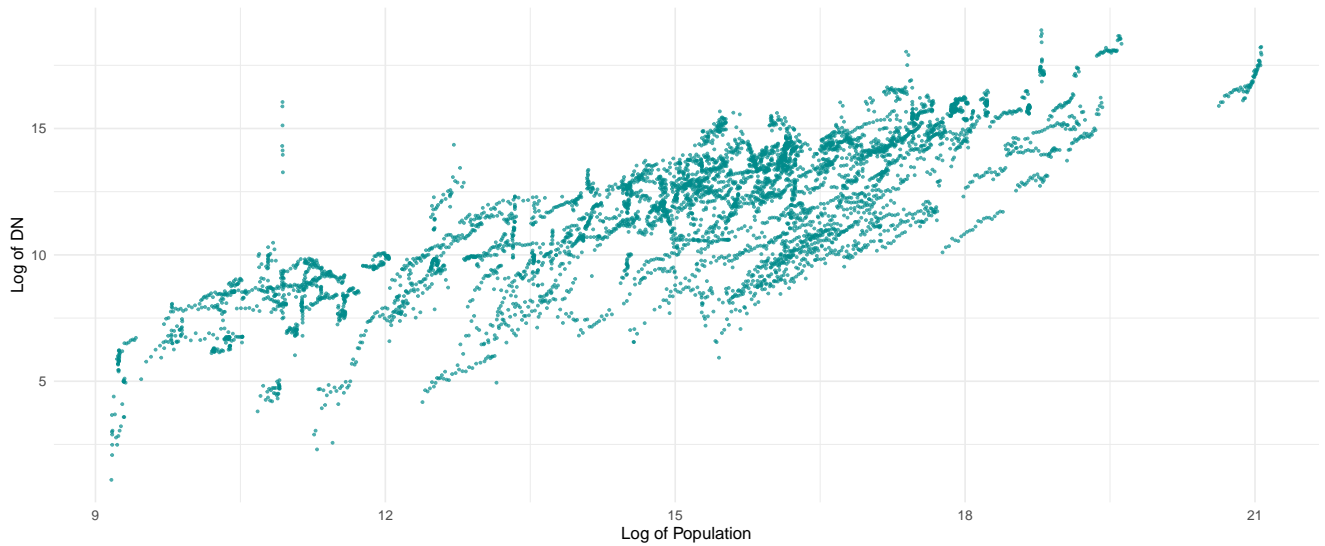


Figure 8: Scatterplot of Population versus DN.

suggesting that other economic activities or structural factors might influence night-time light emissions. This indicates that while manufacturing contributes to night-time light, it is not the sole determinant, and its impact may vary across different contexts.



Figure 9: Scatterplot of Manufacturing Share of GDP versus DN.

6 Appendix

Reference

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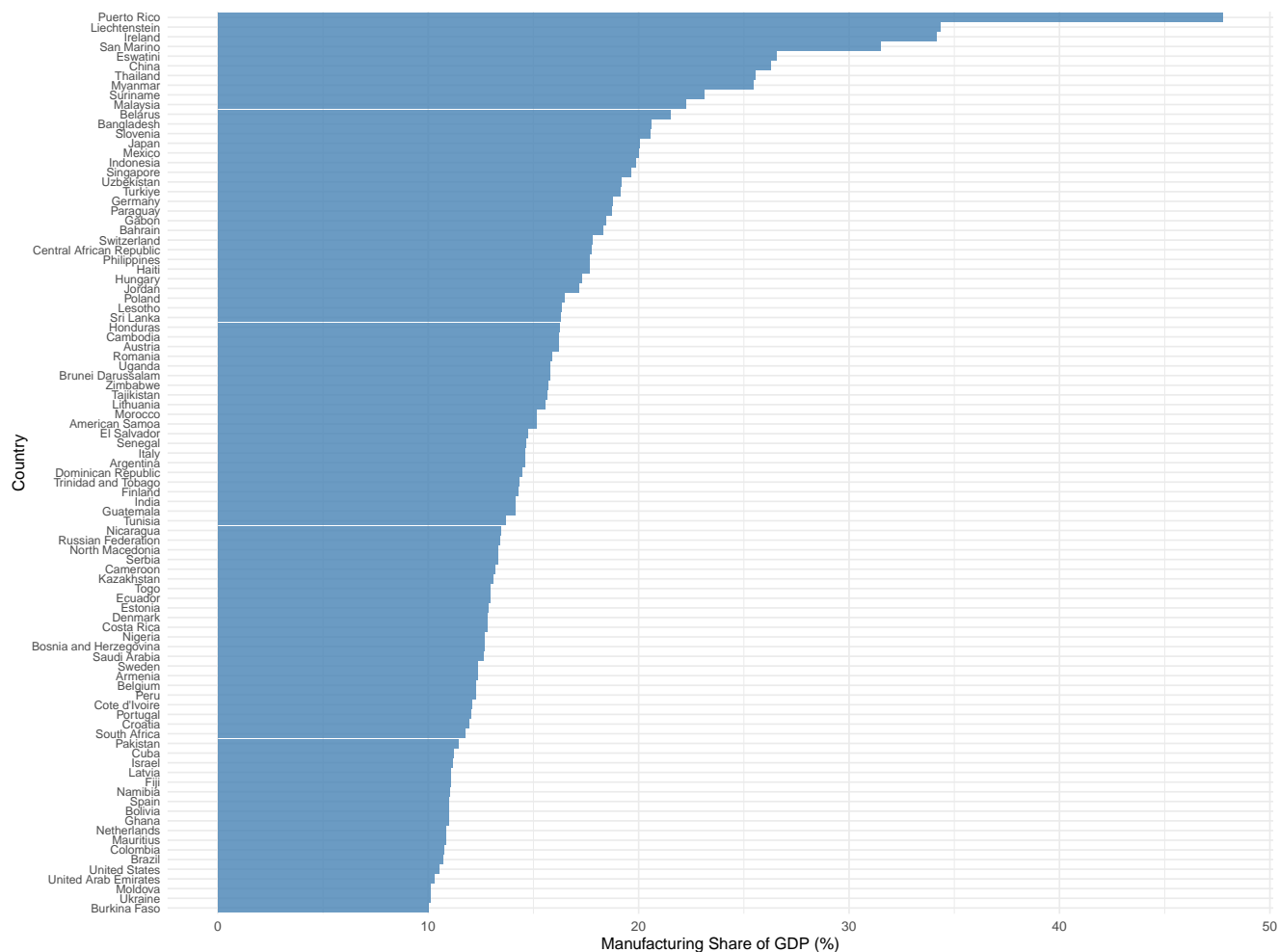


Figure 10: Manufacturing share of GDP for countries in 2020, showing significant variation across nations, with the highest shares observed in Puerto Rico, Liechtenstein, and Ireland. Countries with higher manufacturing shares are expected to exhibit brighter night-time light intensity due to industrial activity.

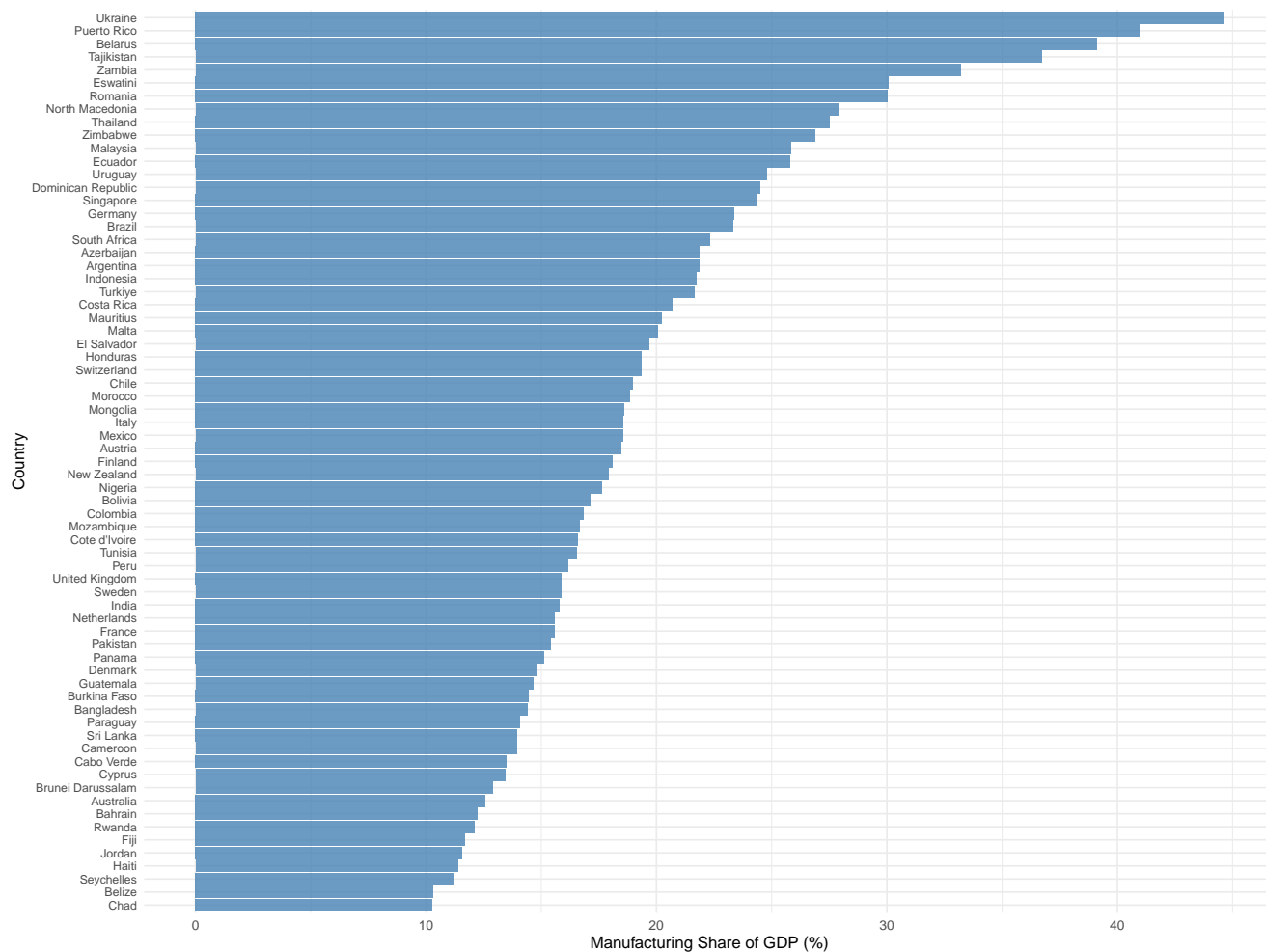


Figure 11: Manufacturing share of GDP for countries in 1992, showing significant variation across nations, with the highest shares observed in Puerto Rico, Ukraine, and Belarus.

Table 3: List of Countries Grouped by Grade.

Grade	Countries
A	Armenia, Australia, Austria, Canada, Chile, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, Turkiye, United Kingdom, United States
B	Albania, Argentina, Azerbaijan, Belarus, Belgium, Bolivia, Brazil, Bulgaria, Colombia, Costa Rica, Croatia, Cyprus, Dominican Republic, Ecuador, El Salvador, Ghana, Guatemala, Iceland, India, Indonesia, Kazakhstan, Luxembourg, Malaysia, Malta, Mauritius, Moldova, Mongolia, Montenegro, Morocco, North Macedonia, Pakistan, Paraguay, Peru, Philippines, Romania, Russian Federation, Rwanda, Senegal, Serbia, Singapore, South Africa, Sri Lanka, Tanzania, Thailand, Tunisia, Uganda, Ukraine, Uruguay
C	Afghanistan, Algeria, Angola, Antigua and Barbuda, Bahrain, Bangladesh, Belize, Benin, Bhutan, Bosnia and Herzegovina, Botswana, Brunei Darussalam, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, China, Cote d'Ivoire, Eswatini, Ethiopia, Fiji, Guinea, Guyana, Honduras, Jamaica, Jordan, Kenya, Kuwait, Lebanon, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Nigeria, Oman, Palau, Panama, Qatar, Samoa, Sao Tome and Principe, Saudi Arabia, Seychelles, Sierra Leone, Suriname, Tajikistan, Timor-Leste, Togo, Tonga, Trinidad and Tobago, United Arab Emirates, Uzbekistan, Zambia, Zimbabwe
D	Chad, Djibouti, Dominica, Equatorial Guinea, Gabon, Guinea-Bissau, Haiti, Iraq, Kiribati, Libya, Marshall Islands, Papua New Guinea, Solomon Islands, Somalia, South Sudan, Sudan, Turkmenistan, Vanuatu
F	American Samoa, Andorra, Aruba, Barbados, Bermuda, British Virgin Islands, Cayman Islands, Central African Republic, Comoros, Cuba, Curacao, Eritrea, Faroe Islands, French Polynesia, Gibraltar, Greenland, Grenada, Guam, Isle of Man, Liechtenstein, Monaco, Nauru, New Caledonia, Northern Mariana Islands, Puerto Rico, San Marino, Turks and Caicos Islands, Tuvalu