Electricity usage as a proxy for measuring wealth in Nigeria (Project Summary)

1. Introduction

Poverty eradication is a pressing challenge, with countries striving to reduce poverty levels, evident from its designation as the first sustainable development goal. Towards achieving this goal, poverty alleviation programmes, including cash transfers, microfinance, and rural employment guarantees, have been initiated across developing countries. Nevertheless, such programmes require monitoring and evaluation to understand the impacts of these initiatives and ensure accountability and transparency, adjustment of shortcomings, and scaling of solutions. In monitoring and evaluating such initiatives, direct or indirect approaches are often used. Direct approaches typically involve physical surveys, which can be resource-intensive (i.e., finance, personnel). Given the resources surveys often demand, alternate (indirect) approaches that demand fewer resources are employed. The indirect approach entails using proxies or indicators to monitor the impacts of a specific project. This project draws from this approach to assess if electricity usage could function as a proxy for measuring wealth in Nigeria.

2. Aim

Electricity use signifies the presence of economic activities that generate income for individuals. In other words, the higher the presence of electricity in an area, the higher the likelihood of income-generating activities. Given this concept, this project aimed to assess how electricity usage could serve as a proxy for determining wealth levels in Nigeria. It explores electricity usage across four years (2012, 2015, 2018, and 2021) in rural and urban areas within Nigeria to assess its function as a proxy for wealth.

3. Methods and Data

3.1 Demographic and Health Surveys (DHS)

The Demographic and Health Surveys (DHS) are household surveys providing data on various monitoring and evaluation indicators regarding population, health, and nutrition.[1] These surveys are nationally representative.[1] An important indicator provided by the DHS is the Mean Wealth Index (MWI). The MWI is an indicator of wealth for a particular household and is computed based on asset ownership (e.g., bicycles, refrigerators, televisions).[2] For this project, the MWI served as the wealth variable for which electricity usage is to serve as a proxy. Also, individual households were categorised into clusters for this project, which entailed grouping them into urban or rural clusters based on information from the DHS survey. For the complete methodology for creating these clusters, please see the R script in my GitHub.

3.2 Visible Infrared Imaging Radiometer Suite (VIIRS) Nightlight Satellite Data

The VIIRS nightlight data measures global daily visible and near-infrared light used in earth system science.[3] VIIRS data often serves as a proxy for electricity use, with bright pixels in VIIRS images indicating electricity use and darker pixels indicating little to no use. The brighter a pixel, the higher the pixel's

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[1] The Demographic and Health Surveys (DHS). Accessed December 30 2023. https://dhsprogram.com/Methodology/Survey-Types/DHS.cfm

[2] The Demographic and Health Surveys (DHS). Accessed December 30 2023. https://dhsprogram.com/topics/wealth-index/#:~:text=The%20DHS%20wealth%20index%20categorizes,a%20household's%20cumulative%20living%20standard.

[3] EarthData. "Nighttime Lights." Accessed December 30 2023. https://www.earthdata.nasa.gov/learn/backgrounders/nighttime-lights#:~:text=The%20Visible%20Infrared%20Imaging%20Radiometer,Earth%20system%20science%20and%20applications

value. Hence, higher pixel (nightlight) values suggest higher electricity use. This study employed VIIRS images to measure electricity use across four years with three-year intervals (2012, 2015, 2018, and 2021). To extract the pixel value of the DHS clusters, spatial data of the DHS clusters were imported into the ArcGIS software, overlain on VIIRS images and extracted. The extracted pixel (nightlight) values served as a proxy for electricity use within the clusters.

4. Results

4.1 Distribution of Urban and Rural Clusters

The dataset comprised a total of 1,382 clusters. As illustrated in **Figure 1**, rural clusters made up a larger share of the dataset. Rural clusters totalled 806, while urban clusters totalled 576 in the dataset. Given that these clusters were derived by consolidating individual households from the DHS dataset, more rural households were surveyed. **Figure 2** disaggregates the urban and rural clusters at the state level in Nigeria. Lagos State, with 49 urban clusters, accounts for the highest number of urban clusters. Anambra (32), Oyo (30), and Abia (28) States also comprised high urban clusters. In contrast, Akwa Ibom (34), Jigawa (34), and Benue (33) States accounted for the highest number of rural clusters (***Figure 2***).

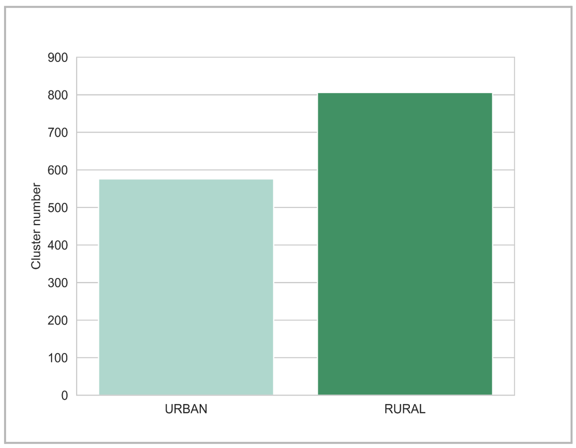


Fig 1. Distribution of urban and rural clusters.

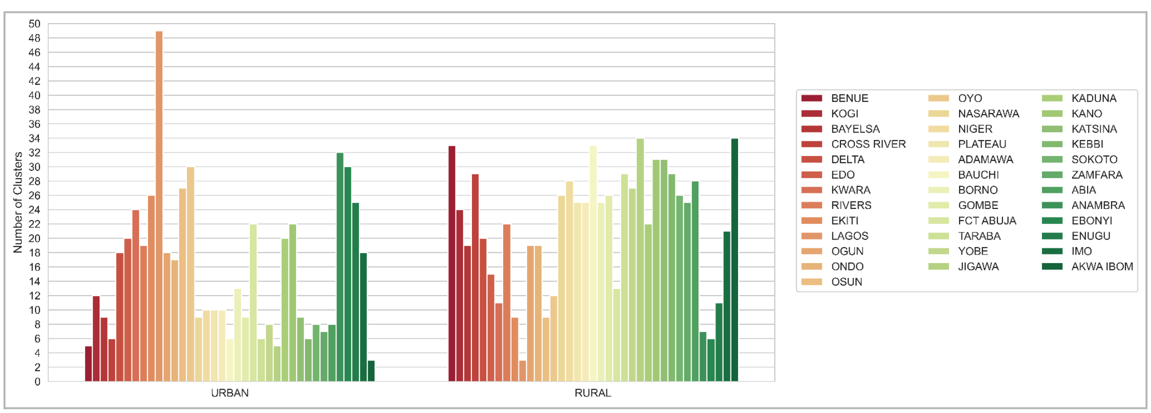
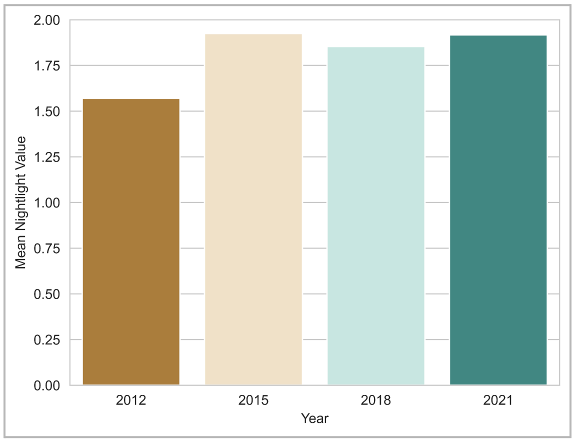


Fig 2. Distribution of urban and rural clusters across Nigerian States and its FCT (Federal Capital Territory).

4.2 Distribution of Nightlight Values (Electricity Usage)

The mean nightlight value across the years of consideration shows a general rise (***Figure 3***). **Figure 3** highlights that the average nightlight value across all clusters was about 1.6 in 2012. This value experienced an increase to 1.9 in 2015 but dipped slightly to 1.8 before returning to 1.9 in 2021 (***Figure 3***). The general increase in mean nightlight value between 2012 and 2021 translates into a higher increase in electricity usage within the clusters. To explore this increase in electricity usage across urban and rural clusters, **Figure 4** presents the mean nightlight value within each cluster group across each year.



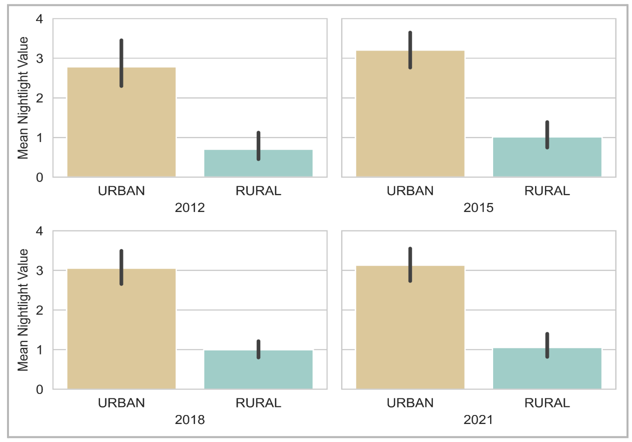


Fig 3. Mean nightlight value across four years.

Fig 4. Mean nightlight value across clusters for four years.

Overall, urban clusters demonstrate a higher mean nightlight value than rural clusters. With commercial activities primarily occurring in urban areas, electricity demand and usage are often higher than in rural areas. Nevertheless, both urban and rural clusters demonstrate higher electricity usage (i.e., nightlight value) between 2012 and 2021 (***Figure 4***). The mean nightlight value of urban clusters was around 2.8 in 2012, growing to 3.2 in 2015 and remaining relatively stable till 2021. For rural clusters, the average nightlight value stood at 0.7 in 2012 but rose to 1 by 2021 (***Figure 4***). Although there has been a general increase in electricity usage at the cluster level (i.e., urban and rural), ***Figure 5*** explores if a similar pattern has occurred at the state level.

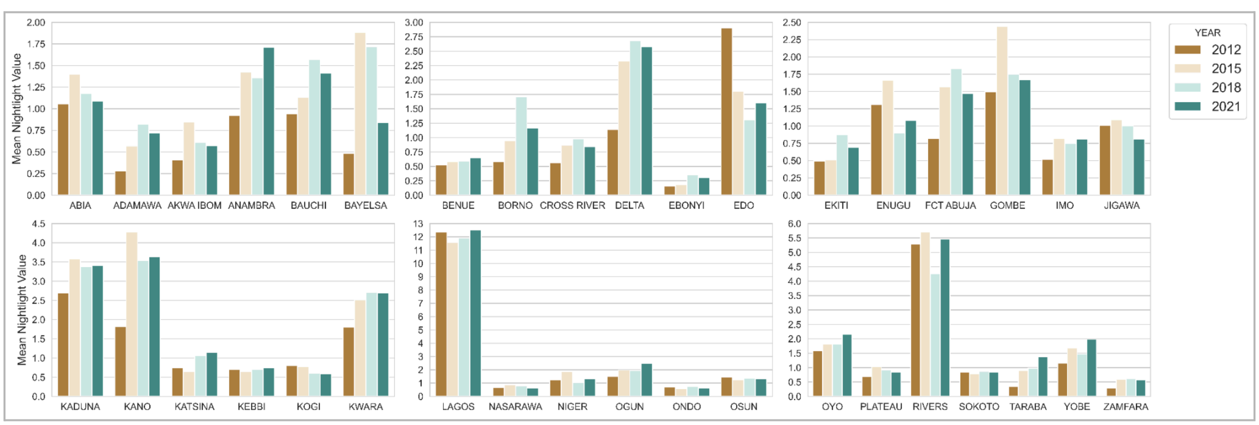


Fig 5. Mean nightlight value across Nigeria’s 36 states and FCT in 2012, 2015, 2018, and 2021.

Figure 5 presents the electricity usage of clusters across the Nigerian States for the years under consideration. Based on the clusters sampled, 33 of the 37 Nigerian States (including the Federal Capital Territory) have experienced growth in electricity usage. Only four States (Edo, Enugu, Jigawa, and Kogi) saw a decline in electricity usage (***Figure 5***). The steepest decrease occurred in Edo state, where the nightlight value fell from 2.9 in 2012 to 1.6 in 2021. Conversely, the most significant increase in nightlight value occurred in Kano state, which rose twofold from 1.8 to 3.6 between 2012 and 2021 (***Figure 5***). Across all States, Lagos demonstrated the highest nightlight value between 2012 and 2021 (***Figure 5***). Lagos is the most populous Nigerian State and the nation's commercial capital. These socioeconomic factors explain its high electricity usage compared with other states. Nightlight value in Lagos State remained relatively stable across the four years, with an average of around 12. Like Lagos State, Rivers State also demonstrated high nightlight values, beginning at 5.3 in 2012 and increasing to 5.7 in 2015. By 2018, this figure fell to 4.2 but rose to 5.5 in 2021 (***Figure 5***).

4.3 Correlation of Nightlight Values (Electricity Usage) to Wealth

To assess how electricity usage can serve as a proxy for wealth in Nigeria, I assessed the correlation between the Cluster Mean Wealth Index and the nightlight values across each year which is shown below in **Figure 6**.

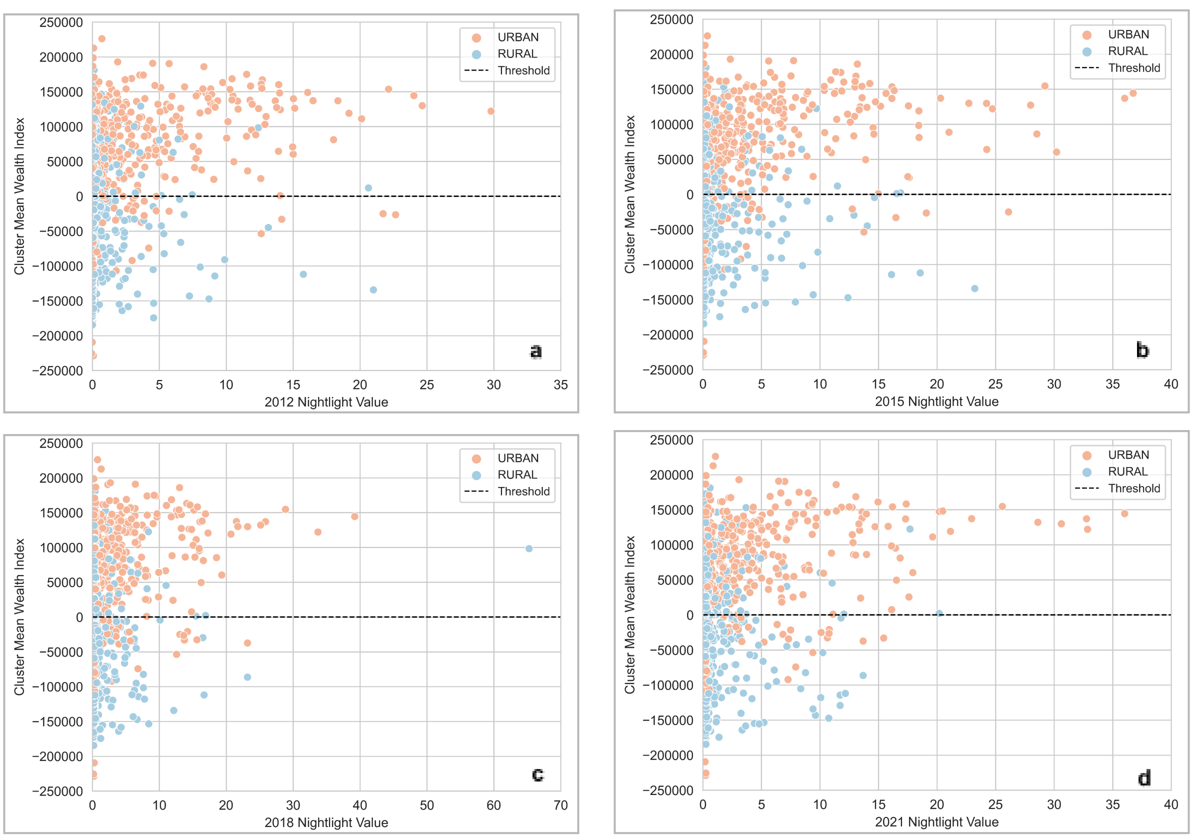


Fig 6. Cluster Mean Wealth Index (CMWI) as a function of nightlight value in **a.** 2012, **b.** 2015, **c.** 2018, and **d.** 2021.

Figure 6 illustrates some trends across the four years. Firstly, the nightlight value of the majority of clusters falls between 0 and 20. Secondly, as pixel values increase, the number of rural clusters (i.e., blue dots in **Figure 6**) decreases. However, despite the majority of clusters with nightlight values higher than

20 being urban clusters (i.e., red dots in **Figure 6**), the wealth index of these clusters doesn't increase. In other words, the wealth index doesn't increase proportionally to the nightlight value. Finally, most clusters that fall below the threshold[4] (black dashed lines in **Figure 6**) and have a negative CMWI are predominantly rural clusters. Although these clusters falling below the threshold have similar pixel values to urban clusters, the CMWI of these clusters is still lower.

Given these trends, an important question arises: Why do most rural clusters fall below the threshold despite similar nightlight values to some urban clusters? I believe the methodology for computing the CMWI answers this question. The mean wealth index is computed based on various independent variables (i.e., asset ownership) such as bicycles, televisions, refrigerators, access to water, sanitation facilities and electricity. Employing the CMWI as a dependent variable and using only one independent variable (electricity access) as a proxy presents an inherent mismatch. Nevertheless, **Figure 6** fails to present a noticeable correlation between the CMWI and nightlight value. Rather, it illustrates that urban clusters generally have higher CMWI than rural areas. Given the methodology for computing the CMWI, it is logical urban areas show higher wealth levels. Access and affordability to these assets would be higher in urban than rural areas as income levels tend to be higher.

4.4 Assessing the frequency of rural clusters at defined CMWI and Nightlight Pixel Values

Figure 4 illustrated the mean nightlight pixel value within urban and rural clusters for the four years under consideration. It showed that across the four years, 2012 accounted for the lowest mean nightlight pixel in rural clusters at 0.7, while 2015, 2018, and 2021 had relatively similar nightlight pixel values at 1. Given this rise in nightlight value, I tested the concept of how electricity access enables economic activity to generate income. Ideally, the number of rural clusters within a defined wealth bracket should increase between 2012 and the remaining three years, given the rise in nightlight pixel value (i.e., electricity access). This hypothesis was tested against rural clusters only considering their lower wealth levels and nightlight pixel values as **Figures 4 & 6** show. **Figure 7** presents the number of rural clusters given defined values for the CMWI and nightlight pixel values across the four years.

Fig 7. Defined Cluster Mean Wealth Index (CMWI) and Nightlight Pixel Value at **a.** ≥5,000 and ≥5; **b.** ≥10,000 and ≥10.

[4] I consider this threshold to be the poverty line. Identifying an established poverty line for the DHS wealth index has proven elusive and as such this poverty line was self-defined.

In 2012, the number of rural clusters with a CMWI of ≥5,000 and nightlight pixel value of ≥5 was 5 (**Figure 7a**). Over the next three years, this figure increased two-fold to 10 rural clusters. This year (2015) accounted for the highest number of rural clusters within the defined CMWI bracket (≥5,000) and nightlight pixel value (≥5). By 2018, the number of rural clusters fell to 9, further declining in 2021 and reaching 7 (**Figure 7a**). Most important, however, is the overall trend across the years. 2012, which had the lowest mean nightlight pixel value, accounted for the fewest number of rural clusters (5) within the defined CMWI bracket and nightlight pixel value. 2015 (10), 2018 (9), and 2021 (7), with higher mean nightlight pixel values than 2012, had more rural clusters (**Figure 7a**). Therefore, this validates the concept of electricity access improving wealth levels.

With a higher CMWI bracket and nightlight pixel value, however, differences become less evident. **Figure 7b** shows the number of rural clusters at a defined CMWI of ≥10,000 and a nightlight pixel value of ≥10. In the first year, 3 clusters met these criteria (**Figure 7b**). In the following years (2015 and 2018), this figure dropped to 2. Nevertheless, by 2021, rural clusters with a CMWI of ≥10,000 and a nightlight pixel value of ≥10 increased to 4. Overall, the difference between the number of rural clusters in these years is less significant than the previous criteria (CMWI of ≥5,000 and a nightlight pixel value of ≥5).

5. Conclusion

This study sought to assess how electricity usage could function as an indicator of wealth in Nigeria. Employing data from the DHS program and VIIRS satellite, it explored the correlation between these variables. The findings revealed urban clusters generally have higher nightlight values than rural clusters, given their function as commercial hubs. Urban clusters also demonstrated higher wealth levels than their rural counterparts. Nevertheless, the study failed to find a significant correlation between the nightlight pixel values and the Cluster Mean Wealth Index (CMWI). This is attributable to how the wealth index is computed and its use of varied indicators. Also, it found the concept of electricity access improving wealth levels to be true. To explore how the analyses in this study were conducted, I refer readers to the jupyter notebook in my GitHub (idrisaderinto/Electricity-and-Wealth-Project.git).