# Nightlights as a Proxy Measure in an Economy.

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**Abstract.** *The night-time economy is increasingly being recognized as a driver of economic growth, but for it to succeed a broad range of professionals need to improve it. Whether you work in planning, health, economics, transport, the arts or property – the night-time economy can no longer be an afterthought. Leading research has suggested that night-time light can be used as a proxy for several variables, including urbanization, density, and economic growth. Scientists have been using satellite images of Earth at night—often referred to as "night lights" — to study human activity and natural events. In the past decade, economists have followed suit, clearing that night lights can help gauge economic growth, map poverty, analyze inequality, and tackle numerous questions otherwise impossible to answer, especially in places where data are lacking. If aliens were ever to approach Earth from its dark side, they would already know some basics about the global economy long before reaching our atmosphere.*

The night-time economy is a growing part of the UK economy. Nationally, it is the UK's fifth-biggest industry, accounting for at least 8% of the UK's employment and annual revenues of £66bn [18]. According to Boyce's paper, the uses of light at night continues to increase [4]. Simply put, this is because, without light, we are deprived of our premier sense. By enabling view, the use of light at night delivers several benefits to people. Such gains include more excellent safety for pedestrians and drivers, reduced fear of crime, more use of outdoor facilities after dark, enhanced economic growth and the creation of built and natural environments that are a source of beauty and entertainment. This suggests that the use of light at night is linked to some fundamental human motivations, which in turn means that people value such benefits and will not willingly abandon them. Fortunately, careful lighting design, soundly-based outdoor lighting standards and new lighting and sensor technology offers the possibility of providing the benefits of light at night while decreasing the impact on the environment.

Before moving onto discussing the possibility that assemblage thought and atmosphere might offer for understanding the urban night, it is worth exploring current. This phrase refers to the mixture of social science studies of alcohol and social science studies of the night-time leisure industry that has come to dominate how we understand night-time cities. I want to argue that under an assemblage urbanism[3] approach, this area of research can be understood as closing down the assemblages, which make up the night-time city. By making the object of study the night-time economy, the town at night is reduced, first, to just the bars and clubs which make up city centres city centre, and second, to the "economic" ways of relating between these. Even studies within this area which offer a more diverse empirical perspective or which have integrated new theoretical approaches into night-time economy studies [14].

Andrew Barr's *"Drink: A Social History"* provides another way of thinking about these changing patterns of late-night activity. Barr's account is less about the expansion of work into the night, but more a reminder that our use of time is not ahistorical or universal [2]. As an example, he recounts how breakfast, dinner and the eighteenth-century fashion for lunch occurred at different points in the day for different people. Parisian customs of the nineteenth century, for example, saw different social classes sitting to dine at progressively later times, with the artisan dining at 2 p.m. and *"rich bachelors"* not before 6 p.m. [22]. Echoing Amin and Thrift's argument about the ever-changing rhythms of urban life, these examples demonstrate that night and day are not entirely stable concepts [1]. Activities and conduct considered appropriate for one time can just as quickly shift, whether that be due to economic and cultural changes, or the whims of fashion. The late-night city is irrefutably different from the city during the day, and as this book attests, there are significant variations around leisure, access, exclusion and economic rationale. Nonetheless, while these current patterns of usage may seem thoroughly natural, the 'right' time to work, eat or socialize is historically and geographically contingent, and likely to change.

According to Jayne's and et al.; paper considers how geographies of alcohol, drinking and drunkenness have been found within and beyond the discipline of geography [14]. They argue that while there has been a large amount of relevant, detailed and vibrant research considering *"geographical"* issues, alcohol studies have tended to under-theorized the role of space and place. While geographers, on the other hand, have been relatively slow to engage with the alcohol, drinking and drunkenness, they show that geography has much to offer future research agendas. Despite recent progress, however, a failing of geographers' engagement with alcohol, drinking and drunkenness has been an inability to transcend disciplinary boundaries. They conclude by arguing that geographical research into alcohol, drinking and drunkenness must continue to pursue theoretical and empirical advances, but also offer policy-relevant *"public geographies"* that speak to non-academic audiences.

The brightest areas of the Earth are the most urbanized, but not necessarily the most populated. (Compare western Europe with China and India.) Cities tend to grow along coastlines and transportation networks. Even without the underlying map, the

[3] Assemblage theory is an ontological framework developed by Gilles Deleuze and Félix Guattari, originally presented in their book *A Thousand Plateaus (1980)*. Assemblage theory provides a bottom-up framework for analyzing social complexity by emphasizing fluidity, exchangeability, and multiple functionalities. Assemblage theory asserts that, within a body, the relationships of component parts are not stable and fixed; rather, they can be displaced and replaced within and among other bodies, thus approaching systems through relations of exteriority [7].

outlines of many continents would still be visible. The United States interstate highway system appears as a lattice connecting the brighter dots of city centres. In Russia, the Trans-Siberian railroad is a thin line stretching from Moscow through the centre of Asia to Vladivostok. The Nile River, from the Aswan Dam to the Mediterranean Sea, is another bright thread through an otherwise dark region. Even more than 100 years after the invention of the electric light, some regions remain thinly populated and unlit. Antarctica is entirely dark. The interior jungles of Africa and South America are mostly dark, but lights are beginning to appear there. Deserts in Africa, Arabia, Australia, Mongolia, and the United States are poorly lit as well (except along the coast), along with the boreal forests of Canada and Russia, and the magnificent mountains of the Himalaya.

The night-time economy can have significant impacts on the health and well-being of individuals. Embedding a strategy to promote culture in Local Plans and Town Centre Strategies can also make a difference to the success of an area's night economy. These plans, while implemented and written by planners, require political vision and leadership to be successful. The recently released draft London Plan contains, for the first time, a chapter for culture and heritage in addition to City Hall's existing Supplementary Planning Guidance on culture and the night-time economy. Culture and leisure are vitality essential to peoples' quality of life and it is vital that a city of Plymouth's size offers a level of cultural and leisure facilities that meet the needs of its growing population, and the broader needs of the sub-region. A strong cultural / leisure sector comprises a holistic mix of:

- Individual experiences and the opportunity to enhance and develop these,
- A range of accessible, affordable and high-quality culture and leisure facilities where people can promote their skills and interests,
- An active private sector involvement,
- A strong and pro-active voluntary and community (not for profit) sector,
- A public and rightful sector that provides support and resources, where required, for sustainable cultural development.

These are key to the creation of a thriving, vibrant city and helps to create a place where people want to live, work and visit. The 1980s saw the gradual recognition of this changing role of culture in the city (and elsewhere). Local government, arts organizations, business people, both companies and umbrella groups such as the Chamber of Commerce, community groups, training organizations and, of course, local artists began to create, often informal coalitions around the elaboration of (formal and informal) cultural strategies aimed at the regeneration of the city centre and (hopefully) the city as a whole. This role of culture in 'regeneration' has been defined in terms of its input into the built environment, in terms of the economic benefits of the arts and cultural industries sector, and in terms of the re-imaging of the city on the national and international stage. It is right that all these should be included. Still, it is increasingly recognized that, just as the deep resources of a city lie within the skills and creativity of its people (to which cultural strategies must be central), the cultural vibrancy of a town lies in the involvement and the identification of the people within its orbit. It is not only the raised horizons as to what it is possible to do that are essential but also the decision to do it here [16].

In what could be a new way to measure economic growth, economists at the Brown University in the US have come up with a framework for estimating a country's gross domestic product (GDP) by using satellite images of the area's night-time lights. In

their research paper, economists J Vernon Henderson, Adam Storeygard, and David N Weil say they don't envision the lights density data as a replacement for official numbers. Still, when added to existing data from agencies like the World Bank, the lights density can provide a better indicator of how these economies are performing [13].

According to J Vernon Henderson, Adam Storeygard, and David N Weil's article *"Measuring Economic Growth from Outer Spac"*, where they are developing a statistical framework to use satellite data on night lights to augment official income growth measures. For countries with weak national income accounts, the optimal estimate of growth is a composite with roughly equal weights on conventionally measured growth and growth predicted from lights. The views differ from official data by up to three percentage points annually. Using lights, empirical analyses of growth need no longer use countries as the unit of analysis; paper can measure growth for sub- and supranational regions. For example, coastal areas in sub-Saharan Africa are growing slower than the hinterland. The luminosity studies so far aim to examine the underlying relationship between nightlights and economic variables such as GDP growth, development and population. Sometimes, nightlights are used to create an index of development, a density ratio of human settlements, etc. Neural Networks, on the other hand, is an alternative estimation method in the econometrics used for complex systems. These are the black box models which do not need giving an economic meaning to the estimated relationship.

Henderson et al., first review the literature of nightlights as a proxy measure in an economy, and second briefly mention concerning areas of *Neural Networks*[4] in econometrics. William Nordhaus of Yale University states that about 3,000 studies have used nightlights as a proxy of economic activities since 2000. Chen and Nordhaus (2010) statistically examine how well nightlights can help researchers to measure the commercial activities of the countries [6]. They find that satellite images are beneficial in assessing economic activities of cities and regions. They also note that traditional data sources are often far less reliable. The studies show that nightlights can be used as a proxy for many variables such as urbanization, city dynamics, population movements, economic growth, development indicator and so on. Mellander et al, examine the correlation between population density and nightlights by using geo-coded residential and industrial microdata of Sweden and both radiance and saturated lights emissions [19]. They find a strong relationship to make nightlights a relatively good proxy for economics activities.

Doll et al. (2006), based on the data of 11 European Union Countries and the United States, maps regional economic activity from nightlights satellite images [8]. They find that there is a strong positive relationship between the nightlight series and GDP across a range of spatial scale. Also, authors of World Bank, Bundervoet et al. (2015), estimated GDP growth rates and levels for 47 counties in Kenya and 30 districts in Rwanda by using satellite imagery [5]. Forbes (2005) examines whether there is a statistical correlation between GDP and nightlights data at Metropolitan

[4] A neural network is a network or circuit of neurons, or in a modern sense, an artificial neural network, composed of artificial neurons or nodes. Thus a neural network is either a biological neural network, made up of real biological neurons or an artificial neural network, for solving artificial intelligence problems. The connections of the biological neuron are modelled as weights. A positive influence reflects an excitatory connection, while negative values mean inhibitory connections. All inputs are modified by a weight and summed. This activity is referred to as a linear combination. Finally, an activation function controls the amplitude of the output.

Statistical Era (MSA) of Florida [11]. Forbes not only finds strong relationship, but he also detects specific industries within each MSA, contributing to the variance of nightlights at the greatest amount. Ghosh et al., use the radiance-calibrated nightlights as a proxy measure of human well-being at both the national and sub-national level [12]. One way that they review is regressing sum of lights intensity values for countries against their official GDP plus informal economy. They create 36 overlapping groups of administrative units at different levels of economic development with ratios of the sum of light intensity to official GDP and GSP (Gross Sub-National Product) plus informal economy.

The regression model calibrates the sum of lights intensity to the official GDP values or GSP plus informal economy for all 36 groups. They obtained R2 more significant than 0.9 for all groups. Sutton et al. (2007) estimate GDP at the sub-national level for the countries, China, India, Turkey, and the United States [24]. The study stays limited to estimate sub-national GDP as a time series although it provides beneficial instruments in the starting point. Briefly, they use two different methods; first one is summation of light intensity values; and second one is a spatial analytic approach using areal extent of the lit area and non-linear relationship between nightlights and population [3],[9],[12].

After disaggregating the DMSP OLS according to sub-national administrative units, sub-national level lights integrations (first and second) are regressed against to sub-national level GDP values of corresponding countries including Turkey [3]. The residuals from the regression models, which are divided into five quintiles, are used to create regional parameters. To predict sub-national GDP in 2000, they apply geographical parameters derived from errors in 1992-1993 data to the 2000 data. However, Sutton, Elvidge, Ghosh, et al. (2007) argue that aka summation of light intensity suffers from the saturation of nightlights in urban core centres. For example, R2 of first simple model is 0.58 for Turkey [24]. However, R2 increases dramatically to 0.95 in second approach. They suppose that the reason of improvement is because İstanbul is a single giant city composing a significant fraction of GDP of its nation. Therefore, this simple model relatively fails to estimate without correcting DMSP OLS regarding areal lit. One of the most pronounced studies is conducted by Vernon Henderson, Adam Storeygard and David Weil from Brown University in 2009 [13],[3]. In their study, the intensity of outer space lights, i.e. nightlights, emitted from the countries as an outcome of electricity consumption is used for the measurement of real GDP of 188 countries over 17 years. Also, they provide a long-term picture of differences in income of South and North Korea. For the first time, Henderson et al. (2009) use nightlights as a tool, more than a proxy, to correct GDP series of 188 countries.

Moreover, Pinkovskiy and Sala-i Martin (2014) use nightlights as a referee variable to compare national accounts GDP per capita to survey means in measuring real GDP of India and Angola [20]. The spirit of their study is very close to Henderson et al.. In both studies, the measurement errors of official GDP are assumed to be uncorrelated with the errors resulting from physical conditions affecting luminosity record quality. This is the necessary assumption for our study, as well. Both Henderson, and Pinkovskiy and Sala-i Martin (2016) benefit nightlights to correct miscalculated official GDP of some countries [21]. However, we use a different method to benefit nightlights as a tool to estimate national and sub-national level GDP due to the reasons mentioned earlier. The technique we exploit is Neural Networks analysis. Kuan and White (1994) are the first ones giving the definitive introduction of Neural Network to the econometric literature [15]. Their theoretical approaches are applied by Maasoumi et al. (1994), who show that fourteen macroeconomic series would be well-modelled with Neural

Networks [17]. Tkacz, Hu, et al. (1999) examine whether forecasting performance of financial and monetary variables for output growth can be improved using *Neural Networks* [25]. They find that neural network predicts GDP growth with less errors compared to its linear counterparts such as ARIMA. Feng and Zhang (2014) show the application of artificial neural network in forecasting economic growth [10]. They obtain a map of stimuli effect of various known and unknown variables over GDP growth via combination of non-linear functions. Also, Sokolov-Mladenovic et al. (2016) predict the economic growth based on trade indicators with two different neural network algorithms [23]. Considering both the implementation of neural network in macroeconomic analysis and using nightlights as an indicator for economic activities, there are novel kinds of literature. Among many approaches, the combination of these two seems to create an accurate solution for the question and conditions specific to data in hand.

## References

1. Amin, A., Thrift, N.: Cities: reimagining the urban. Polity Press (2002)
2. Barr, A.: Drink: a social history. Pimlico (1998)
3. Basihos, S.: Nightlights as a development indicator: The estimation of gross provincial product (gpp) in turkey. Available at SSRN 2885518 (2016)
4. Boyce, P.R.: The benefits of light at night. Building and Environment **151**, 356–367 (2019)
5. Bundervoet, T., Maiyo, L., Sanghi, A.: Bright lights, big cities: measuring national and subnational economic growth in Africa from outer space, with an application to Kenya and Rwanda. The World Bank (2015)
6. Chen, X., Nordhaus, W.D.: The value of luminosity data as a proxy for economic statistics. Tech. rep., National Bureau of Economic Research (2010)
7. Deleuze, G., Guattari, F.: A thousand plateaus. 1980. Trans. Brian Massumi. Minneapolis: University of Minnesota Press **105** (1987)
8. Doll, C.N., Muller, J.P., Morley, J.G.: Mapping regional economic activity from night-time light satellite imagery. Ecological Economics **57**(1), 75–92 (2006)
9. Ebener, S., Murray, C., Tandon, A., Elvidge, C.C.: From wealth to health: modelling the distribution of income per capita at the sub-national level using night-time light imagery. international Journal of health geographics **4**(1), 5 (2005)
10. Feng, L., Zhang, J.: Application of artificial neural networks in tendency forecasting of economic growth. Economic Modelling **40**, 76–80 (2014)
11. Forbes, D.J.: Statistical correlation between economic activity and. Urban Systems **29**, 179–95 (2005)
12. Ghosh, T., Anderson, S., Elvidge, C., Sutton, P.: Using nighttime satellite imagery as a proxy measure of human well-being. Sustainability **5**(12), 4988–5019 (2013)
13. Henderson, J.V., Storeygard, A., Weil, D.N.: Measuring economic growth from outer space. American economic review **102**(2), 994–1028 (2012)
14. Jayne, M., Valentine, G., Holloway, S.L.: The place of drink: Geographical contributions to alcohol studies (2008)
15. Kuan, C.M., White, H.: Artificial neural networks: An econometric perspective. Econometric reviews **13**(1), 1–91 (1994)
16. Lovatt, A., O'Connor, J.: Cities and the night-time economy. Planning Practice & Research **10**(2), 127–134 (1995)
17. Maasoumi, E., Khotanzed, A., Abaye, A.: Artificial neural networks for some macroeconomic series: a first report. Econometric Reviews **13**(1), 105–122 (1994)

18. Masud, F.: The growing importance of the night-time economy. Business reporter, BBC World Service (2019)
19. Mellander, C., Lobo, J., Stolarick, K., Matheson, Z.: Night-time light data: A good proxy measure for economic activity? PloS one **10**(10), e0139779 (2015)
20. Pinkovskiy, M., Sala-i Martin, X.: Lights, camera,... income!: Estimating poverty using national accounts, survey means, and lights. Tech. rep., National Bureau of Economic Research (2014)
21. Pinkovskiy, M., Sala-i Martin, X.: Lights, camera... income! illuminating the national accounts-household surveys debate. The Quarterly Journal of Economics **131**(2), 579–631 (2016)
22. Schivelbusch, W.: Disenchanted night: The industrialization of light in the nineteenth century, trans. Angela Davies (Berkeley: University of California Press, 1988) **57** (1988)
23. Sokolov-Mladenović, S., Cvetanović, S., Mladenović, I.: R&d expenditure and economic growth: Eu28 evidence for the period 2002–2012. Economic research-Ekonomska istraživanja **29**(1), 1005–1020 (2016)
24. Sutton, P.C., Elvidge, C.D., Ghosh, T., et al.: Estimation of gross domestic product at sub-national scales using nighttime satellite imagery. International Journal of Ecological Economics & Statistics **8**(S07), 5–21 (2007)
25. Tkacz, G., Hu, S., et al.: Forecasting GDP growth using artificial neural networks. Citeseer (1999)