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# NIGHTTIME LIGHTS OR HAPPINESS: WHICH ONE WOULD A SOCIETY CHOOSE?

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## ABSTRACT

This study discovers evidence of a bidirectional causation between nighttime lights and happiness using the panel Granger non-causality tests of a short (balanced) panel data of 132 countries, within the period from 2008 to 2012. There are different findings throughout the six geographical regions. A bidirectional causation is observed for Latin America and the Caribbean, while a unidirectional causality is from happiness to nighttime lights for East Asia and Pacific, Europe and Central Asia, and the Middle East and North Africa. In Sub-Saharan Africa is found, the situation is from nighttime lights to happiness. These findings are complemented by the impulse response function, various decomposition analysis, and their estimates of panel random (or fixed) effect models. This study offers an insight that nighttime lights are required for a happy society.

***Keywords*:** Causality, happiness, nighttime lights, panel data.

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## 1. INTRODUCTION

There will always be times when unpleasant situations overwhelm a person, but as the saying goes, "*Every cloud has a silver lining*"- there is always something good that happens after a bad situation has occurred. For a long time, the study of happiness has been a theoretical focus of academic research including those to define, measure, and assess happiness in various contexts and disciplines from neuroscience and psychology to philosophy and economics. Before the COVID-19 epidemic, the United States economy, stock market, and job levels were all robust, but such robustness did not make the Americans feel happy as many underprivileged and middle-class Americans had feelings of hopelessness, worry, and tension (Graham & Pinto, 2019). Since 2013, the United Nations has celebrated the International Day of Happiness as a way to recognise the importance of happiness in the lives of people around the world, which supports the notion that happiness is a universal human right. Indeed, the happiness and life satisfaction of people is still

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not improving even after one year of the COVID-19 pandemic (Dwidienawati et al., 2021). According to the World Happiness Report 2023, six key ingredients are outlined for national happiness, namely, income, healthy life expectancy, social support, freedom, trust, and generosity.[1] In general, there are two forms of happiness, viz. relative happiness and absolute happiness (Ikeda, 2015). Accordingly, relative happiness is dependent on external things such as recognition, wealth, and other materialistic desires, while absolute happiness comes from the internal of an individual and is also known as the unrivalled and indestructible life condition. Studies have found that happiness and health are intertwined, with happiness affecting health and *vice versa* (Graham, 2008). Individuals who experience chronic unhappiness may lead to a more serious condition i.e., depression.[2]

Human beings have always behaved in a way to seek happiness (Abounoori & Asgarizadeh, 2013, p.5). The pursuit of happiness has been included by economists and philosophers from Aristotle to John Stuart Mill and Adam Smith. As economics grew more scientific and quantitative, less lofty concepts of happiness gained hold, happiness was considered to be purely determined by income as mediated by personal preferences or choices. Since happiness has been determined by employment and income statistics in the earlier work of economists, "the Economics of Happiness" (Graham, 2005), has been utilised in this modern day, which is a method to assess people's welfare based on surveys of reported happiness from hundreds of thousands of people across nations. Easterlin (1974; 2010) reveals that being wealthier than their ancestor, the succeeding generations are not happy with their lives. The so-called "*Easterlin paradox*" advocates that there is no relationship between a society's level of economic growth and its citizens' overall happiness.[3] In fact, wealthier countries are happier than poor ones as happiness seems to rise with income up to a point, but not beyond it. Yet even among the less happy, poorer countries, there is no clear relationship between average income and average happiness levels, suggesting that many other factors, including cultural traits, are at play (Graham, 2005, p. 45). The United States recorded significant economic growth between 1946 and 1970, but there was only a little rise in happiness especially during the postwar boom. It also relies on broader concepts of happiness than traditional economics, stressing the impact of non-income factors that influence happiness. However, the economics of happiness does not purport to replace income-based measures of welfare, but instead to complement them with a broader measure of well-being.

*"Happiness can be found even in the darkest of times if one only remembers to turn on the light."*
~ Albus Dumbledore, Harry Potter and the Prisoner of Azkaban (2004)

Nighttime lights data have always been used to proxy economic activity (Donaldson & Storeygard, 2016; Addison & Stewart, 2015; Pagaduan, 2023). Broadly speaking, nightlights are typically

[1] World Happiness Report 2023, Retrieved from worldhappiness.report/
[2] According to World Health Organization (2021), depression affects approximately 3.8% of the global population, including 5.0% of adults and 5.7% of persons over the age of 60. People who suffer from depression are reported they have lost the capacity to picture a bright future or cherish a happy past.
[3] The Easterlin paradox incorporates both micro and macro concepts. The micro-proposition is concerned with the impact of individual income on subjective well-being, while the macro-proposition is that national economic growth does not always boost population happiness.

installed to create a sense of security and to alleviate fears of the dark, especially for children.[4] By the same token, statisticians have utilised the available satellite images of Earth's night lights to measure social and economic activity.[5] A study by Robert et al. (2020) evaluates the changes in nighttime lights in 50 cities spanning over 18 economies. Such data (i.e., the sum of lights) calculated from the meteorological satellite recording are available from the United States National Oceanic and Atmospheric Administration (NOAA). Meanwhile, social scientists utilise the satellite images from nighttime lights to develop proxy measurements of various official statistics. The assumption is that most social and economic activities at night require light; hence, the intensity and area covered by nighttime lights should correspond with socioeconomic indicators and economic progress.

Since the early 2000s, studies have considered nighttime lights to proxy economic activity, especially Gross Domestic Product (GDP) when official GDP data are unavailable (Henderson et al., 2012; Mellander, et al., 2015; Donaldson & Storeygard, 2016; John, et al., 2020; Pagaduan, 2023). They are based on remotely sensed nighttime light observations and have opened up a new pathway for understanding how the Earth is changing by applying these insights to effective decision-making, driving policy, delivering services, and improving governance in near real-time. Addison and Stewart (2015) use nighttime lights to capture constant price gross domestic product, non-agricultural gross domestic product, manufacturing value-added, capital stocks, electricity consumption, total population, and urban population, especially where data are weak or unavailable. However, they find that economists should use nighttime lights data as a proxy only for electricity use. Nighttime lights' data have also been used to proxy carbon dioxide emissions throughout cities (Zhao et al., 2018), for economic and social development across administrative boundaries (Doll et al., 2006) and at subnational levels (Michalopoulos & Papaioannou, 2018) to control pollution (Koen et al., 2018), and so on.

A group of studies has looked at the association between GDP per capita (or economic growth) and happiness (Veenhoven, 1991; Veenhoven & Hagerty, 2006; Liu et al., 2013; Easterlin et al., 2010; Ghosh, et al., 2010).[6] They find that the society in richer countries is happier than in poorer countries, however, increasing national prosperity is not necessarily accompanied by increasing happiness. Indeed, for the last 15 years, economists have demonstrated their interest in the economics of happiness between Scitovsky (1976) and Abounoori and Asgarizadeh (2013). Asgarizadeh (2013) examines the economic factors affecting happiness using the panel data of 58 countries (2003-2011), and finds that while the effect on inflation and unemployment is negative, it is positive for economic growth and government expenditure.[7] Lastly, Lim and Tang (2024) find

[4] Nightlights. Retrieved from www.nachi.org/nightlights.htm#:~:text=Nightlights%20are%20typically%20installed%20to,the%20dark%2C%20especially%20for%20children.

[5] Night light data: an innovative way to track development. Retrieved from development.asia/insight/night-light-data-innovative-way-track-development

[6] Other studies relate happiness to unemployment (Lindbeck et al., 1999; Di Tella et al., 2001; Petri & Ilmakunnas, 2006; Clark, 2006), corruption (Rothstein & Stolle, 2003; Welsch, 2008; Li & An, 2020), beauty (Feingold, 1992; Diener et al., 1995a,b; Aharon et al.,2001; Deaton, 2008; Deaton & Arora, 2009; Kahneman & Deaton, 2010; Hosada et al., 2006; Hamermesh & Abrevaya, 2013), and religion (Koenig et al.,2012; Mak et al., 2011; Stavrova et al., 2013; Vishkin et al., 2014; Graham & Crown, 2014; Rizvi & Hossain, 2017), and between age and marital duration (Clark & Oswald, 1994; Collins & Coltrane, 1995; Gelles, 1995; Cherlin, 2021; Huston & Houts, 1998; Gerdtham & Johannesson, 2001; Vanlaningham et al., 2001; Frey & Stutzer, 2002a, b).

[7] Wu et al. (2013) consider night light as a type of consumer goods and propose a model for factors affecting the relationship between night lights and GDP. It is then decomposed into agricultural and non-agricultural productions. Further, the model is

a [Granger] causality from income to happiness, and to sugar consumption from a panel data of 129 countries between 2016 and 2020. Similar finding occurs for the developing economies, but income causes happiness for the developed economies. For the economies in transition, the causality is from happiness to income and to sugar consumption.

On the literature search, the study on the happiness and nighttime lights nexus remain exploratory. Inspired by Matthias et al. (2021), the study aims to examine the direction of causation [association] between happiness and nighttime lights. It considers a balanced panel data of 132 countries between 2008 and 2012 with six geographical regions, namely, East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, the Middle East and North Africa, South Asia, and Sub-Saharan Africa. North America is excluded since there are only two countries (Canada, and the United States) with ten observations. The findings are further complemented by impulse response function, various decomposition analyses, as well as estimates of panel random (or fixed) effect models. This study does not consider the determination of happiness because it is complex in nature.

The structure of this study is organised as follows: the next section is about hypothesis development, data, and testing methods, Section 3 reports and discusses the empirical results, and Section 4 concludes the study.

## 2. HYPOTHESIS DEVELOPMENT, DATA, AND TESTING METHODS

### *2.1 Hypothesis Development*

The economics of happiness is an approach to assessing welfare which combines the techniques that are typically used by economists with those that are more commonly used by psychologists (Graham, 2005, p. 41). Psychologists have spent decades delving deeply into the factors that influence human happiness. Light is fundamental to life and light therapy products can help to create happiness in life. Indeed, light is bestowed in many religions upon the holy- radiating from religious iconography. New Age philosophy throws another perspective into the mix, elaborating on fields of light that surround human bodies known as auras.[8] As a society approaches any festival such as Chinese New Year, National Day, or New Year's Eve, the sky will be filled with bursting art. When witnessing hundreds of fireworks in the shape of beautiful umbrellas of glittering light, people feel happy and satisfied to see these light-up shows over and over again. For example, Randy Simonson, a professor of psychology from the College of Southern Idaho says that Christmas lights can increase dopamine levels in the brain, and dopamine is a neurotransmitter that can make someone feel pleasure or satisfaction[9]- studies generally show that adequate lighting is important in everyday life because it can boost people's happy hormones and energy level, similar

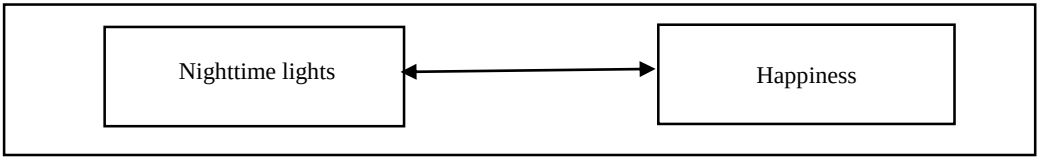
modified to determine how the factors affect residents' propensity to consume lights. Models are tested with time-fixed regression on a set of 15-year panel data of 169 countries globally and regionally. They find that light consumption propensity is affected by GDP per capita, latitude, spatial distribution of human activities and gross saving rate, and that light consumption per capita has an U-inverted relationship with GDP per capita.

[8] Using Light Therapy to Create Happiness and Health, Retrieved from theinspiredhome.com/articles/using-light-to-create-happiness-and-health/

[9] Can Christmas lights make you happy? Retrieved from: www.kmvt.com/2020/12/29/can-christmas-lights-make-you-happy/

to the fireworks mentioned above. Lighting helps people to feel more energetic and lifts people's mood because lighting has a direct impact on the human brain and hormone balance through the retina in the eyes. The happiness neurotransmitter serotonin is not released to the same extent if it does not receive enough light. An easy way to address the lack of light is to increase lighting levels- numerous studies have shown that effective lighting increases well-being and concentration. Alison and Aparna (2014) suggest that turning on the light when making a decision might trigger our emotional system due to the perception of heat. Therefore, lighting is recommended by physicians, psychologists and interior architects.[10] It is inevitable that light is symbolic of an eternal quest for happiness.[11] These factors allow this study to hypothesise that in a Granger sense, nighttime lights cause happiness. In layman's terms, it is about 'Chicken or egg: which came first?' The reverse is true that happy people like to turn the nighttime lights on, which further hypothesises that happiness causes nighttime lights. Both hypotheses are illustrated in Figure 1.

**Figure 1:** Conceptual Framework of Nighttime Lights and Happiness Nexus




### *2.2 Variables and Data*

This study uses a balanced short panel data of 132 countries with annual observations spanning between 2008 and 2012 given their data availability. The Happiness data is available for the period from 2008 to 2018, while the nighttime lights data are collected for the period from 1992 to 2012. Only 132 countries have their data available for the period of 2008 to 2012. The 132 countries are from the seven geographical regions, namely, East Asia and the Pacific (14 countries), Europe and Central Asia (43 countries), Latin America and the Caribbean (19 countries), the Middle East and North Africa (18 countries), South Asia (6 countries), Sub-Saharan Africa (30 countries), and North America (2 countries) (see Appendix A for the countries). Table 1 describes the two underlying variables, viz. nighttime lights and happiness.

[10] Light up your mood, Retrieved from www.schlueter-systems.com/en/liprotec/light-creates-happiness.aspx
[11] Light, Joy, Zest: A Window to Hope and Happiness, Retrieved from klovestudio.com/2021/05/06/light-hope-happiness-and-harmony/

**Table 1:** Variables Definition and Sources

| Variables | Definition | Data Sources |
|---|---|---|
| **Nighttime lights** | The sum of light, commonly known as nighttime lights, is estimated from weather satellite recordings and made accessible as a yearly time series by the United States National Oceanic and Atmospheric Administration (NOAA). The variable is transformed into natural logarithm, *ln*. | National Centers for Environmental Information, National Oceanic and Atmospheric Administration. Available at https://ngdc.noaa.gov/eog/download.html<br><br>Since 1994, NOAA's Earth Observation Group (EOG) has been collecting and analyzing nighttime lights data from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS). |
| **Happiness** | The World Happiness Report's happiness scores are based on the Gallup World Poll surveys, a series of nationally representative polls conducted in more than 160 nations and 140 languages. From 2005 to 2008, the distribution of answers to the Cantril ladder question asked respondents to value their lives today on a 0 to 10 scale, with the worst possible life as a 0 and the best possible life as a 10. This helps to compare happiness levels and inequality in different parts of the world. | World Happiness Report 2019. Available at https://worldhappiness.report/ed/2019/#appendices-and-data<br><br>Psychologists believe that happiness may be evaluated by asking people how they feel, and one method of determining happiness is through a survey. The World Happiness Report is a publication of the Sustainable Development Solutions Network, and it is based on data from Gallup World Poll surveys and the Lloyd's Register Foundation, who provided access to the World Risk Poll. |

**Table 2:** Summary Statistics

| ***All countries*** | **Mean** | **Median** | **Max.** | **Min.** | **S.D.** | **J.B.** | ***p*-value** | **n** |
|---|---|---|---|---|---|---|---|---|
| **Happiness** | 5.417 | 5.243 | 7.971 | 2.997 | 1.105 | 28.813 | (0.000) | 660 |
| **Nighttime lights** | 12.396 | 12.313 | 17.546 | 5.601 | 1.997 | 2.293 | (0.318) | 660 |
| ***East Asia and Pacific*** | | | | | | | | |
| **Happiness** | 5.645 | 5.478 | 7.450 | 3.899 | 0.957 | 3.523 | (0.172) | 70 |
| **Nighttime lights** | 13.123 | 13.716 | 16.772 | 9.714 | 1.938 | 2.873 | (0.238) | 70 |
| ***Europe and Central Asia*** | | | | | | | | |
| **Happiness** | 5.825 | 5.717 | 7.971 | 3.801 | 1.013 | 8.104 | (0.017) | 215 |
| **Nighttime lights** | 13.156 | 13.211 | 16.281 | 10.523 | 1.394 | 5.860 | (0.053) | 215 |
| ***Latin America and the Caribbean*** | | | | | | | | |
| **Happiness** | 6.066 | 6.062 | 7.615 | 3.766 | 0.844 | 4.785 | (0.091) | 95 |
| **Nighttime lights** | 12.624 | 12.115 | 15.943 | 9.012 | 1.508 | 1.508 | (0.470) | 95 |
| ***Middle East and North Africa*** | | | | | | | | |
| **Happiness** | 5.477 | 5.131 | 7.433 | 3.164 | 0.984 | 4.110 | (0.128) | 90 |
| **Nighttime lights** | 12.595 | 12.837 | 15.180 | 7.980 | 1.755 | 11.668 | (0.003) | 90 |
| ***South Asia*** | | | | | | | | |
| **Happiness** | 4.593 | 4.578 | 5.786 | 3.724 | 0.512 | 0.454 | (0.797) | 30 |
| **Nighttime lights** | 12.798 | 12.413 | 16.291 | 10.248 | 2.016 | 2.533 | (0.282) | 30 |
| ***Sub-Saharan Africa*** | | | | | | | | |
| **Happiness** | 4.316 | 4.275 | 5.608 | 2.997 | 0.538 | 1.349 | (0.510) | 150 |
| **Nighttime lights** | 10.344 | 10.435 | 14.337 | 5.601 | 1.547 | 7.298 | (0.026) | 150 |
| ***#North America*** | | | | | | | | |
| **Happiness** | 7.321 | 7.348 | 7.650 | 7.026 | 0.202 | 0.560 | (0.741) | 10 |
| **Nighttime lights** | 16.589 | 16.585 | 17.546 | 15.577 | 0.967 | 1.645 | (0.439) | 10 |

***Notes***: Max. stands for Maximum, Min. is Minimum, S.D. is Standard deviation, and J.B. is Jargue-bera.
#This region consists of two countries namely the U.S. and Canada with 10 observations which is not feasible to be included for regional analysis.

Table 2 illustrates the summary of descriptive statistics of the two variables and also by the seven geographical regions. The average world happiness (as measured by median) is 5.243 between 0 and 10 on the scale (including North America). Among the six geographical regions (ignoring North America), the highest happiness score is 6.062 for Latin America and the Caribbean. This is followed by Europe and Central Asia (5.717), and East Asia and the Pacific (5.478). On the contrary, Sub-Saharan Africa had the lowest happiness score of 4.275. The average world nighttime lights are 12.313. East Asia and the Pacific is the highest among the six geographical regions, that is 13.716. Europe and Central Asia come in second, followed by the Middle East and North Africa. Sub-Saharan Africa had the lowest nighttime lights usages.

Table 3 reports the results of panel Phillips-Perron (1988) unit root tests. Their respective test statistics reject the null hypothesis of a unit root at 1% significance level that both variables, namely, happiness, and nighttime lights are stationary at levels, or $I(0)$ regardless of their geographical regions. However, it is not the case for East Asia and the Pacific in which the nighttime lights data

is non-stationary, or *I*(1). Nevertheless, for convenience (simplicity), this variable is assumed to be stationary, *I*(0) when entering the 'short' panel data (i.e., 5 years) analysis since a first-differencing transformation of *I*(1) may cause information loss.

**Table 3:** Phillips-Perron (panel) unit root tests

| ***All countries*** | **Fisher Chi-square statistics** | **Inference, *I*(0) or *I*(1)** |
|---|---|---|
| **Happiness** | 648.982*** | Stationary, *I*(0) |
| **Nighttime lights** | 598.307*** | Stationary, *I*(0) |
| ***East Asia and Pacific*** | | |
| **Happiness** | 66.522*** | Stationary, *I*(0) |
| **Nighttime lights** | 29.535 | Has a unit root, *I*(1) |
| ***Europe and Central Asia*** | | |
| **Happiness** | 243.991*** | Stationary, *I*(0) |
| **Nighttime lights** | 150.176*** | Stationary, *I*(0) |
| ***Latin America and the Caribbean*** | | |
| **Happiness** | 98.294*** | Stationary, *I*(0) |
| **Nighttime lights** | 132.528*** | Stationary, *I*(0) |
| ***Middle East and North Africa*** | | |
| **Happiness** | 73.691*** | Stationary, *I*(0) |
| **Nighttime lights** | 67.346*** | Stationary, *I*(0) |
| ***South Asia*** | | |
| **Happiness** | 27.198*** | Stationary, *I*(0) |
| **Nighttime lights** | 70.863*** | Stationary, *I*(0) |
| ***Sub-Saharan Africa*** | | |
| **Happiness** | 134.341*** | Stationary, *I*(0) |
| **Nighttime lights** | 142.924*** | Stationary, *I*(0) |

***Notes***: ***$p$-value < 0.01 rejecting the null hypothesis of a unit root (individual unit root process). The underlying assumptions of the tests for the exogenous variables are individual effects, individual linear trends; and Newey-West automatic bandwidth selection and Bartlett kernel apply.

### *2.3 Testing Method*

Instead of the baseline understanding of the correlation between nighttime lights and happiness, this study mainly employs the so-called Granger non-causality tests in order to predict the possible direction of the causal relationship between nighttime lights and happiness as illustrated in Figure 1. Based on the vector autoregressive (VAR) model, this test examines whether the lagged values of nighttime lights help in predicting happiness, and *vice versa*. Nighttime lights variable is said to Granger-cause happiness if nighttime lights is 'helpful' for predicting the happiness; the lagged nighttime lights variables that are added in the model can improve the explanation power of happiness.

$$Happiness_{i,t} = \alpha_0 + \alpha_1 Happiness_{i,t-1} + \ldots + \alpha_3 Happiness_{i,t-3} + \beta_1 Nighttime\ lights_{i,t-1} + \ldots + \beta_3 Nighttime\ lights_{i,t-3} + \varepsilon_{i,t} \quad (1)$$

$$Nighttime\ lights_{i,t} = \alpha'_0 + + \alpha'_1 Nighttime\ lights_{i,t-1} + \ldots + \alpha'_3 Nighttime\ lights_{i,t-3} + \beta'_1 Happiness_{i,t-1} + \ldots + \beta'_3 Happiness_{i,t-3} + \varepsilon_{i,t} \quad (2)$$

More technically, the estimated coefficients of lagged nighttime lights variables are jointly and statistically significant at least 10%. Of panel data regression (1), the computed *F*-statistic (or Wald test), is to reject the null hypothesis of $\beta_1 = \ldots = \beta_3 = 0$, that is the nighttime light does not Granger-cause the happiness at least 10% level. The coefficients of the respective variables are estimated by the OLS (ordinary least squares) estimator. It also captures the effect of the variable(s) to another. For regression (2), the null hypothesis is expressed statistically as $\beta'_1 = \ldots = \beta'_3 = 0$, that is to express "Happiness does not Granger-cause the nighttime lights". As illustrated in Figure 1, it is to expect a bidirectional (two-way) causality between nighttime lights and happiness. However, the data may suggest a different story, that is unidirectional causality from nighttime lights on happiness, or otherwise. There is also a possibility that there is no causality between nighttime lights and happiness.

Further analysis complements the Granger non-causality tests that are the impulse response function and various decomposition. The lag order of VAR is chosen by a set of conventional selection criteria i.e., sequential modified likelihood-ratio, final prediction error, Akaike information criterion, Schwarz information criterion, and Honnan-Quinn information criterion at a 5% level. Of the results, three (3) lags are selected for all countries, East Asia and Pacific, Latin America and the Caribbean, and South Asia, two (2) lags for Europe and Central Asia, and the Middle East and North Africa, and a one (1) lag for Sub-Saharan Africa. For the impulse response function, a 90% confident interval (CI) is constructed using the Monte Carlo standard error with 100 replications.

It is to note that causality does not depict the magnitude (i.e., positive, negative or none) and the effect (size) of the underlying right-hand side variable(s). It is also the cases of imposed response functions, and various decomposition analyses. Hence, this study estimates the (current) effect between these two variables by the OLS estimator. Their simple linear equation regressions can be written as $Happiness_{i,t} = \alpha_0 + \beta_1 Nighttime\ lights_{i,t} + \varepsilon_{i,t}$, and $Nighttime\ lights_{i,t} = \alpha'_0 + \beta'_1 Happiness_{i,t} + \varepsilon'_{i,t}$ that the Hausman tests suggest random effect (RE) model, except for Europe and Central Asia in which, the fixed effect (FE) model is used for happiness equation (see, Appendix B). The OLS (ordinary least squares) estimates are based on the cross-section seemingly unrelated regression (SUR) panel-corrected standard errors (PCSE). The above methods are not discussed here since they are conventional and available upon search.

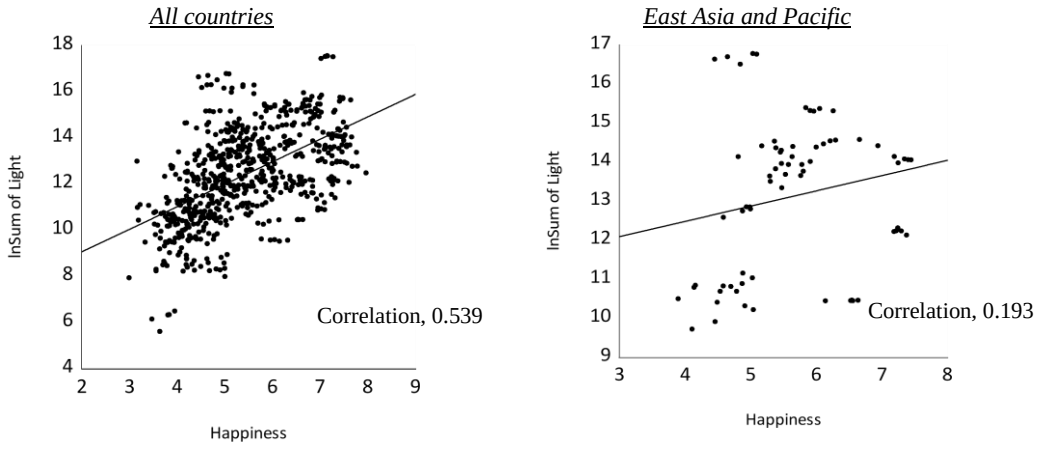
## 3. EMPIRICAL RESULTS

This section reports and discusses the empirical results. For ground information, the scatter plots in Figure 2 first show the correlation coefficients between nighttime observes lights and happiness for all countries' panels, and for each region including North America. For all countries, it is observed that there is a moderately positive correlation between the two variables (0.539). The higher the estimated correlation coefficient between nighttime lights and happiness, the stronger they correlated. Regional-wise results show that Latin America and the Caribbean, and South Asia, have a moderate positive correlation of 0.593 and 0.503, respectively. East Asia and the Pacific

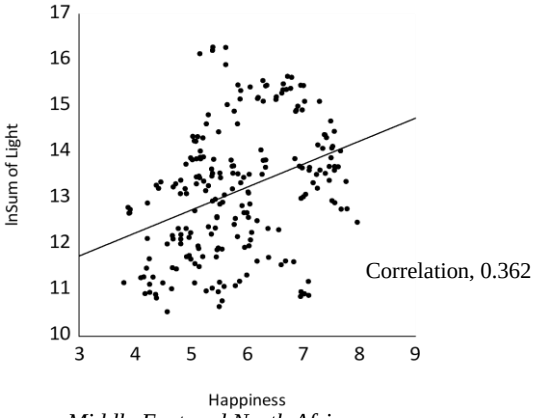
have a low correlation of 0.193 implying a minimal correlation between nighttime lights and happiness. Surprisingly, there is no correlation (approaching a zero-correlation coefficient) between the nighttime lights and happiness in the Middle East and North Africa (0.008). Remarkably, North America has a strong negative correlation between nighttime lights and happiness, with a value of -0.896. Such a strong negative correlation coefficient implies that both nighttime lights and happiness are inconsistent with the common fashion (i.e., a positive correlation). However, North America is not included in further tests since there are only two countries with ten observations.

Indeed, correlation does not imply any direction of causation, as well as their association (effect). Table 4 reports the results of the panel data Granger non-causality tests with their computed *F*-statistics and their *p*-values for a maximum lag length of three for regression (1) and (2). The empirical results indicate the existence of bidirectional causality between nighttime lights and happiness, in general (i.e., all countries' panel data). Both the null hypotheses "Nighttime lights do not Granger-cause happiness", and "Happiness does not Granger-cause nighttime lights" can be rejected with at least a 10% level of significance among the three different lags. That is both variables have predictive content for each other, or to say, they are *interdependent*- a happy person turns on the lights at nighttime, while nighttime lights make a person happy. This finding supports the early hypothesis that has been developed that a bidirectional causality occurs between nighttime lights and happiness (see Figure 1).

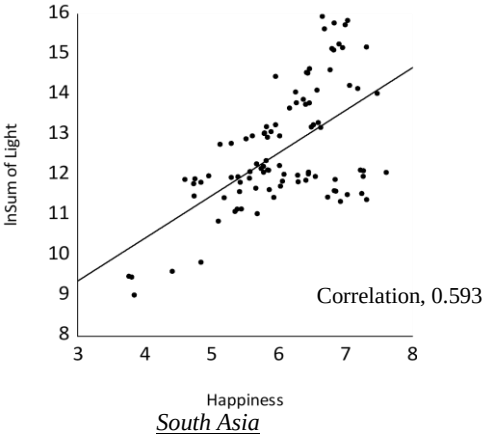
**Figure 2:** Scatter Plots of Nighttime Lights and Happiness



*Europe and Central Asia*




*Latin America and the Caribbean*




*Middle East and North Africa*


*South Asia*


*Sub-Saharan Africa*


*North America*

**Table 4:** Granger Non-Causality Tests

| **Null Hypothesis:** *All countries* | **Lag structure** | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| Nighttime lights =/=> Happiness | 6.257 (0.013)** | 3.167 (0.043)** | 1.420 (0.237) |
| Happiness =/=> Nighttime lights | 1.885 (0.170) | 2.714 (0.068)* | 10.518 (0.000)*** |
| *East Asia and Pacific* | | | |
| Nighttime lights =/=> Happiness | 1.698 (0.198) | 1.106 (0.341) | 0.653 (0.590) |
| Happiness =/=> Nighttime lights | 2.903 (0.094)* | 3.541 (0.039)** | 1.526 (0.237) |
| *Europe and Central Asia* | | | |
| Nighttime lights =/=> Happiness | 0.215 (0.643) | 0.429 (0.652) | 1.098 (0.355) |
| Happiness =/=> Nighttime lights | 0.194 (0.661) | 2.861 (0.061)* | 14.065 (0.000)*** |
| *Latin America and the Caribbean* | | | |
| Nighttime lights =/=> Happiness | 4.790 (0.032)** | 2.478 (0.094)* | 1.765 (0.174) |
| Happiness =/=> Nighttime lights | 3.941 (0.051)* | 6.639 (0.003)*** | 1.205 (0.324) |
| *Middle East and North Africa* | | | |
| Nighttime lights =/=> Happiness | 0.022 (0.883) | 1.218 (0.305) | 0.436 (0.729) |
| Happiness =/=> Nighttime lights | 1.317 (0.255) | 3.729 (0.031)** | 1.775 (0.174) |
| *South Asia* | | | |
| Nighttime lights =/=> Happiness | 1.790 (0.195) | 2.608 (0.112) | 1.015 (0.459) |
| Happiness =/=> Nighttime lights | 0.669 (0.423) | 0.336 (0.721) | 0.507 (0.694) |
| *Sub-Saharan Africa* | | | |
| Nighttime lights =/=> Happiness | 8.435 (0.004)*** | 2.883 (0.061)* | 2.604 (0.061)* |
| Happiness =/=> Nighttime lights | 1.732 (0.191) | 1.007 (0.370) | 1.066 (0.371) |

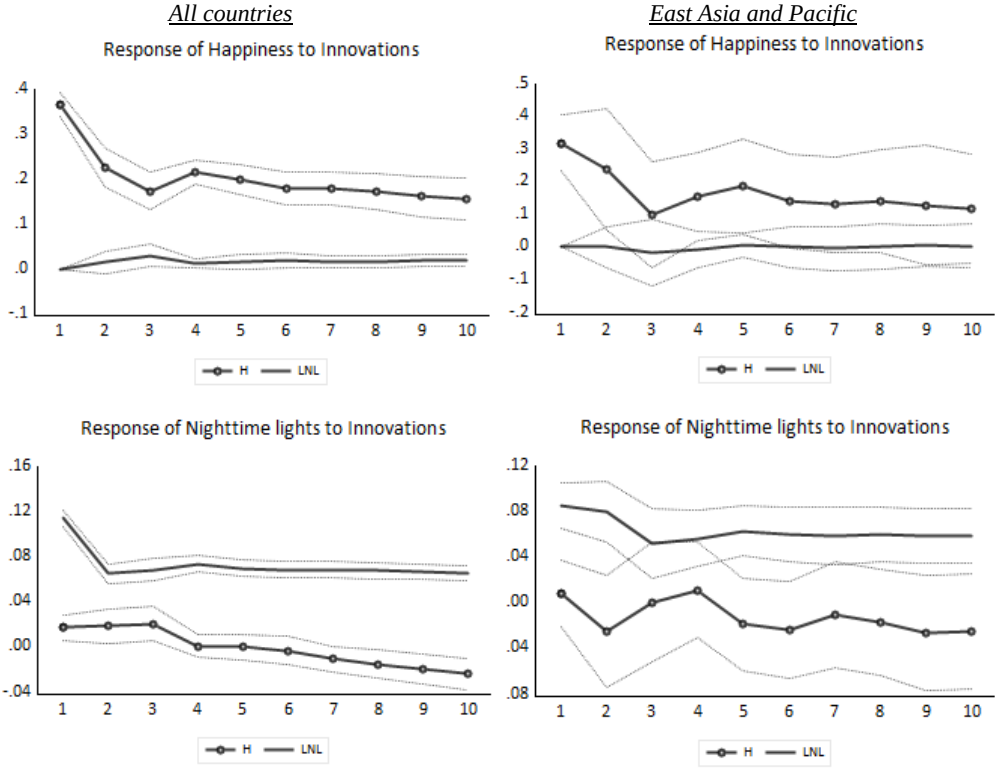
***Notes:*** The reported value in (.) is *p*-value. ***$p$-value < 0.01; **$p$-value < 0.05; *$p$-value < 0.1. The symbol, "=/=>" stand for "does not Granger cause".

For region-wise results, they are consistent with the generalised finding- that there is a bidirectional causality between nighttime light and happiness for Latin America and the Caribbean only; that is nighttime lights do Granger-cause happiness and *vice versa*, and have at least a 10% level of significance up to two lags in length. For East Asia and the Pacific, a unidirectional causality is observed from happiness in response to nighttime lights with at least a 5% level of significance (up to two lags). The null hypothesis of nighttime lights does not Granger-cause happiness and cannot be rejected even at a 10% level of significance; that is happiness helps to predict nighttime lights but not *vice versa*. This reflects that the societies in this region are always happy with what they have, and turning on the nighttime lights is a sign of happiness. A similar finding occurred for Europe and Central Asia (with at least a 10% level for two- and three lags), and the Middle East and North Africa (with only two lags at a 5% level). In Sub-Saharan Africa, there is also a unidirectional causality but its direction is from nighttime lights to happiness. The null hypothesis that nighttime lights do not Granger-cause happiness is rejected over all the three lag lengths for at least a 10% level. It reveals that nighttime light is a good indicator to predict happiness. This implies that turning on the nighttime lights can bring happiness to the societies of Sub-Saharan Africa. Surprisingly, it is found that there is no causation between nighttime lights and happiness in South Asia. Both null hypotheses cannot be rejected at a 10% significance level where both

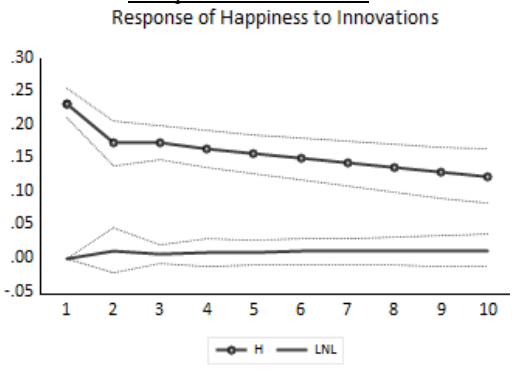
variables are said to be *independent*- both variables have no information on each other. Other causes such as income, health and so on do matter for the societies' happiness in this region.

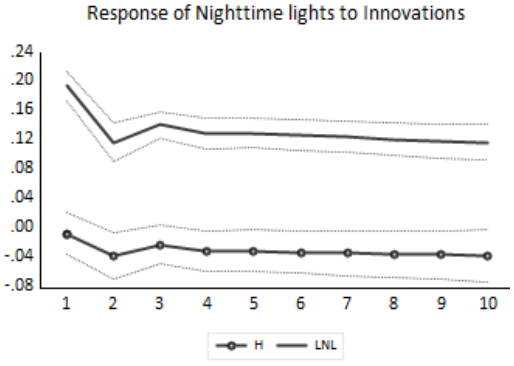
Turning to Figure 3, the impulse response function analysis shows that the overall (i.e., all countries' results) happiness slightly increases until period 3 in response to an initial shock of the nighttime lights, but happiness decreases in response to its own shock. The nighttime light responds positively to a shock in happiness until period 3 before decreasing. It responds negatively to its own shock until period 2 then increases for periods 2 and 4. Similar responses (but slightly smaller) are observed for both East Asia and the Pacific, and Europe and Central Asia. For Latin America and the Caribbean, an initial shock of nighttime lights impacts happiness gradually over the 10 periods, even while happiness responds to its own shock. Indeed, in this region, the nighttime lights respond to own shock, but not to happiness (i.e., constant after period 2). Happiness decreases in response to its own initial shock until period 2 then increases for the Middle East and North Africa, but it [happiness] is slightly impacted by nighttime lights. The nighttime lights increase due to both happiness and their own shock. It has been noted that in all of them (including all countries) the impact on no converge goes back to zero after period 10. However, for South Asia, both happiness and nighttime lights have not responded to one another, including to their own shock; there is no impact and have always been at the converging level (i.e., zero). For Sub-Saharan Africa, happiness decreases in response to its own initial shock, but there has been a slight increase to nighttime lights after period 2, converging back to zero at period 6. The nighttime lights increase to an initial shock in happiness until period 2, and there is no response thereafter. A similar finding for the response to its own shock i.e., the nighttime lights reduce until period 2 and then remain constant. Both have no tendency to converge back to zero.

**Figure 3:** Plots of Impulse Response Function Analysis

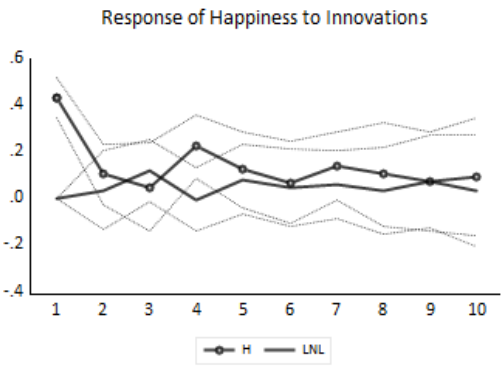


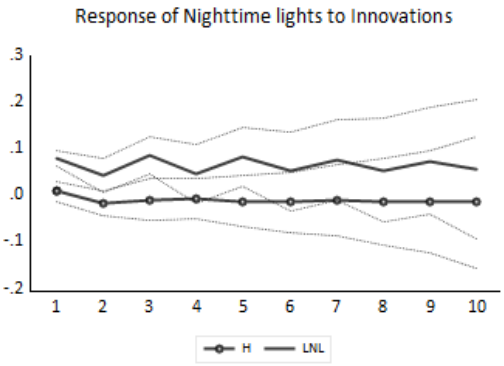
*Europe and Central Asia*



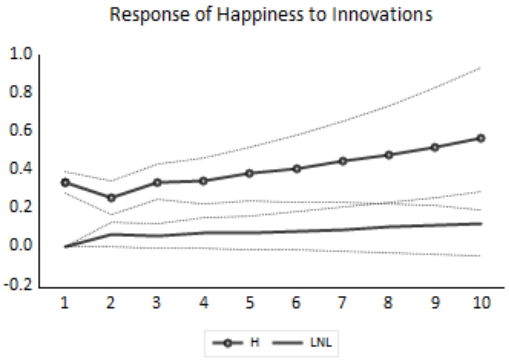



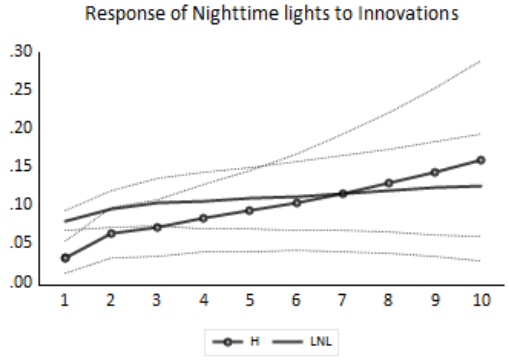

*Latin America and the Caribbean*



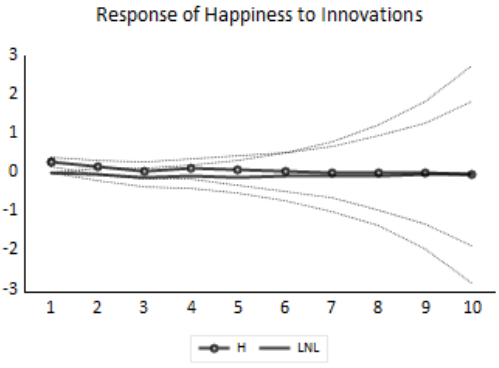



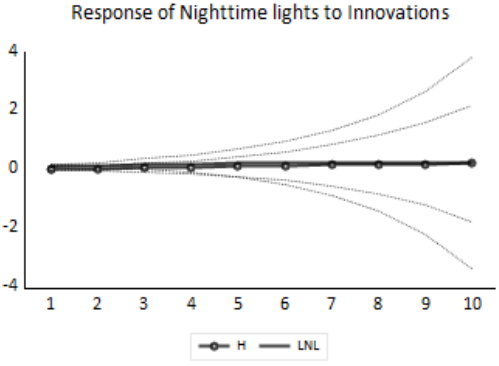
*Middle East and North Africa*




*South Asia*



*Sub-Saharan Africa*

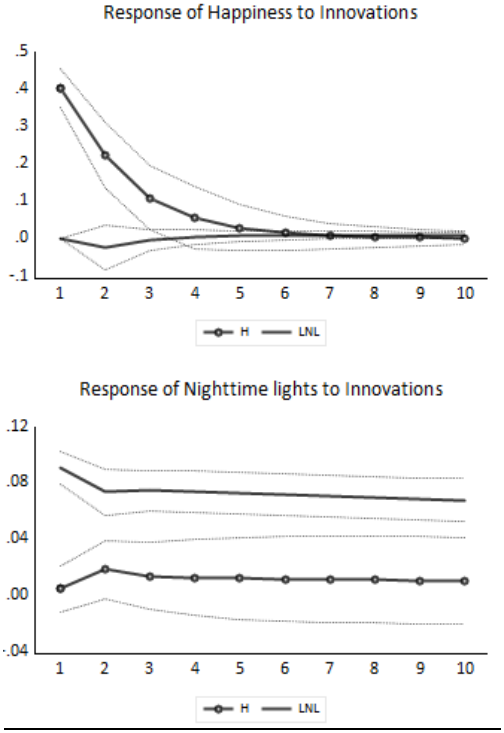


**Table 5:** Various Decomposition Analysis Results

| Variance Decomposition of | Happiness (H) | | Nighttime lights (N) | | | Happiness (H) | | Nighttime lights (N) | |
|---|---|---|---|---|---|---|---|---|---|
| **Period** | **H** | **N** | **H** | **N** | **Period** | **H** | **N** | **H** | **N** |
| **All countries** | | | | | **East Asia and Pacific** | | | | |
| **1** | 100 | 0 | 2.249 | 97.751 | **1** | 100 | 0 | 0.881 | 99.119 |
| **2** | 99.899 | 0.101 | 3.608 | 96.392 | **2** | 100 | 0 | 5.071 | 94.929 |
| **3** | 99.499 | 0.501 | 4.683 | 95.317 | **3** | 99.816 | 0.184 | 4.273 | 95.727 |
| **4** | 99.547 | 0.453 | 3.782 | 96.218 | **4** | 99.796 | 0.204 | 4.187 | 95.813 |
| **5** | 99.531 | 0.469 | 3.229 | 96.771 | **5** | 99.812 | 0.188 | 4.922 | 95.078 |
| **6** | 99.460 | 0.540 | 2.853 | 97.147 | **6** | 99.827 | 0.173 | 6.085 | 93.915 |
| **7** | 99.435 | 0.565 | 2.807 | 97.193 | **7** | 99.831 | 0.169 | 5.773 | 94.227 |
| **8** | 99.409 | 0.591 | 3.014 | 96.986 | **8** | 99.842 | 0.158 | 5.969 | 94.031 |
| **9** | 99.372 | 0.628 | 3.440 | 96.560 | **9** | 99.843 | 0.157 | 7.065 | 92.935 |
| **10** | 99.341 | 0.659 | 4.151 | 95.849 | **10** | 99.847 | 0.153 | 7.872 | 92.128 |
| **Europe and Central Asia** | | | | | **Latin America and the Caribbean** | | | | |
| **1** | 100 | 0 | 0.184 | 99.816 | **1** | 100 | 0 | 1.495 | 98.505 |
| **2** | 99.829 | 0.171 | 2.885 | 97.115 | **2** | 99.304 | 0.696 | 4.207 | 95.793 |
| **3** | 99.840 | 0.160 | 2.825 | 97.175 | **3** | 92.665 | 7.335 | 2.619 | 97.381 |
| **4** | 99.803 | 0.197 | 3.447 | 96.553 | **4** | 94.048 | 5.952 | 2.520 | 97.480 |
| **5** | 99.781 | 0.219 | 3.788 | 96.212 | **5** | 92.108 | 7.892 | 2.321 | 97.679 |
| **6** | 99.751 | 0.249 | 4.195 | 95.805 | **6** | 91.548 | 8.452 | 2.749 | 97.251 |
| **7** | 99.720 | 0.280 | 4.569 | 95.431 | **7** | 90.955 | 9.045 | 2.509 | 97.491 |
| **8** | 99.688 | 0.312 | 4.946 | 95.054 | **8** | 90.937 | 9.063 | 2.838 | 97.162 |
| **9** | 99.654 | 0.346 | 5.316 | 94.684 | **9** | 89.706 | 10.294 | 2.876 | 97.124 |
| **10** | 99.618 | 0.382 | 5.684 | 94.316 | **10** | 89.662 | 10.338 | 3.095 | 96.905 |
| **Middle East and North Africa** | | | | | **South Asia** | | | | |
| **1** | 100 | 0 | 14.392 | 85.608 | **1** | 100 | 0 | 4.822 | 95.178 |
| **2** | 97.748 | 2.252 | 25.193 | 74.807 | **2** | 98.387 | 1.613 | 2.883 | 97.117 |
| **3** | 97.531 | 2.469 | 28.112 | 71.888 | **3** | 88.264 | 11.736 | 3.662 | 96.338 |
| **4** | 96.994 | 3.006 | 31.428 | 68.572 | **4** | 84.770 | 15.230 | 5.911 | 94.089 |
| **5** | 96.772 | 3.228 | 34.232 | 65.768 | **5** | 79.253 | 20.747 | 8.599 | 91.401 |
| **6** | 96.548 | 3.452 | 37.079 | 62.921 | **6** | 74.808 | 25.192 | 11.764 | 88.236 |
| **7** | 96.391 | 3.609 | 39.867 | 60.133 | **7** | 71.374 | 28.626 | 15.442 | 84.558 |
| **8** | 96.251 | 3.749 | 42.659 | 57.341 | **8** | 69.621 | 30.379 | 19.329 | 80.671 |
| **9** | 96.134 | 3.866 | 45.432 | 54.568 | **9** | 68.573 | 31.427 | 23.248 | 76.752 |
| **10** | 96.029 | 3.971 | 48.182 | 51.818 | **10** | 68.344 | 31.656 | 27.153 | 72.847 |
| Sub-Saharan Africa | | | | | | | | | |
| 1 | 100 | 0 | 0.248 | 99.752 | | | | | |
| 2 | 99.753 | 0.247 | 2.641 | 97.359 | | | | | |
| 3 | 99.764 | 0.236 | 2.835 | 97.165 | | | | | |
| 4 | 99.760 | 0.240 | 2.847 | 97.153 | | | | | |
| 5 | 99.736 | 0.264 | 2.809 | 97.191 | | | | | |
| 6 | 99.699 | 0.301 | 2.764 | 97.236 | | | | | |
| 7 | 99.655 | 0.345 | 2.723 | 97.277 | | | | | |
| 8 | 99.609 | 0.391 | 2.689 | 97.311 | | | | | |
| 9 | 99.561 | 0.439 | 2.660 | 97.340 | | | | | |
| 10 | 99.514 | 0.486 | 2.637 | 97.363 | | | | | |

***Note***: The reported values are in percentage (%).

As the figures in Table 5 indicate, overall (i.e., all countries), in the initial period, approximately 100% (98%) of the variation in happiness (nighttime lights) is from the shocks to itself. The system

is stable for the 10 periods. This is the same for other regions i.e., East Asia and Pacific, Europe and Central Asia, and Sub-Saharan Africa. For East Asia and the Pacific, similar findings in all countries, except for most of the remaining 7% of nighttime lights are from happiness over the periods 9-10. The contribution of nighttime lights to variations in happiness rises more slowly, at roughly 10% approaching period 10 for Latin America and the Caribbean. It is even larger for South Asia, which is about 32% at period 10 from 12% (period 3), and its nighttime lights are explained increasingly by happiness from 5% to 27% over the 10 periods. The largest contribution of happiness to the variation of nighttime lights is from the Middle East and North Africa, which is increasing substantially from its initial period of 14% to 48% at period 10.

As conventional wisdom in econometrics, Granger's non-causality tests, impose response functions, and various decompositions do not capture the 'effect'. Table 6 provides the estimated random effect (RE) models of simple linear regressions for both variables, for example, nighttime lights on happiness, and *vice versa*. The estimated happiness equation for Europe and Central Asia is a fixed effect (FE) model. Panel A is for the regression, the estimated coefficient of nighttime light, $\beta_1$ is statistically significant, at least 1% level for all countries, and the regions of Latin America, the Caribbean, and Sub-Saharan Africa. All estimates have an expected sign that is positive, ranging between 0.17 (Sub-Saharan Africa) and 0.374 (Latin America and the Caribbean). This signals that nighttime lights increase happiness- *if you are turning on the lights at night, you feel happy!* This is not the case for other regions. As reported in Panel B, the estimated coefficient of happiness is statistically significant at the 5% level in all countries, including two regional results, namely, East Asia and the Pacific, and Latin America and the Caribbean. Their estimated coefficient is between 0.076 (all) and 0.196 (East Asia and the Pacific). This implies that happiness has a positive implication on nighttime lights globally and in the two respective regions. Happiness increases nighttime lights- *if you are happy, just turn the lights on at night!* Compared to the pure OLS estimates as reported in Appendix C, the effect of nighttime lights on happiness is eventually consistent in both sign and size, where the South Asia region is statistically significant. However, the estimated coefficient (size) of happiness on nighttime lights is much larger, and three regions (Europe and Central Asia, South Asia, and Sub-Saharan Africa) are statistically significant. East Asia and the Pacific are statistically insignificant. A low (or zero) $R^2$ and a negative adjusted $R^2$ are expected for the cases in which their *sole* explanatory variable is statistically insignificant (at 10%). Higher explanatory power, $R^2$ can be generated if more explanatory variables are incorporated, but this is infeasible in this study with short-balanced panel data. The core concern of this study is the direction of casualty between happiness and nighttime lights.

**Table 6:** The Estimates of Random Effects (RE) Models

| | All countries | East Asia and Pacific | Europe and Central Asia | Latin America and the Caribbean | Middle East and North Africa | South Asia | Sub-Saharan Africa |
|---|---|---|---|---|---|---|---|
| ***Panel A*** **- Dependent Variable: Happiness** | | | | | | | |
| **Constant** | 2.036*** [4.196] | 3.244** [2.292] | 5.699*** [3.662] | 1.349** [2.252] | 4.909*** [3.49] | 3.047** [2.985] | 2.562*** [8.843] |
| **Nighttime lights** | 0.273*** [8.138] | 0.183 [1.428] | 0.009 [0.081] | 0.374*** [8.219] | 0.045 [0.478] | 0.121 [1.664] | 0.170*** [6.108] |
| **$R^2$** | 0.084 | 0.042 | 0.961 | 0.150 | 0.002 | 0.086 | 0.115 |
| **Adjusted $R^2$** | 0.082 | 0.028 | 0.951 | 0.141 | -0.01 | 0.053 | 0.109 |
| **Standard error** | 0.313 | 0.267 | 0.224 | 0.370 | 0.341 | 0.35 | 0.375 |
| ***F*-statistic** | 60.092 | 2.954 | 97.542# | 16.444 | 0.132 | 2.623 | 19.176 |
| ***Panel B*** **- Dependent Variable: Nighttime lights** | | | | | | | |
| **Constant** | 11.985*** [11.443] | 12.018*** [9.062] | 2.869*** [14.412] | 11.901*** [12.46] | 12.389*** [10.518] | 12.926*** [9.081] | 10.216*** [10.323] |
| **Happiness** | 0.076** [2.469] | 0.196** [2.252] | 0.049 [0.649] | 0.119** [2.1] | 0.038 [0.752] | -0.028 [-0.276] | 0.030 [0.444] |
| **$R^2$** | 0.015 | 0.056 | 0.003 | 0.086 | 0.01 | 0.003 | 0.003 |
| **Adjusted $R^2$** | 0.014 | 0.042 | -0.001 | 0.077 | -0.001 | -0.033 | -0.004 |
| **Standard error** | 0.176 | 0.202 | 0.182 | 0.135 | 0.117 | 0.171 | 0.199 |
| ***F*-statistic** | 10.036 | 4.018 | 0.691 | 8.805 | 0.882 | 0.078 | 0.378 |
| **Cross-sections** | 132 | 14 | 43 | 19 | 18 | 6 | 30 |

***Notes:*** #Fixed effect (FE) model is preferred. ***$p$-value < 0.01, and **$p$-value < 0.05. The reported value in [.] is $t$-statistic. All OLS estimates are based on the Cross-section Seemingly Unrelated Regression (SUR) Panel-Corrected Standard Errors (PCSE).

## 4. CONCLUSION

Viewing nighttime lights provides a unique perspective of the Earth. Nighttime light imagery as an unusual remote sensing data source offers capabilities to represent human activities on the Earth's surface through the observation of artificial lighting at night (e.g., building and transport). This study explores the causal relationship (association) between nighttime lights and happiness using a short-balanced panel data of 132 countries spanning a period between 2008 to 2012. This study discovers a bidirectional causality between nighttime lights and happiness for all countries data (including the North American region) and for the region of Latin America and the Caribbean.

While, a unidirectional causality is from happiness to nighttime lights for the regions of East Asia and Pacific, Europe and Central Asia Middle East and North Africa. For Sub-Saharan Africa, the direction of causality is from nighttime lights to happiness. Both nighttime lights and happiness are independent (i.e., no causality) for the region of South Asia. Furthermore, the impulse response function, various decomposition analyses, and the estimated OLS equation regressions are feasible and have a supportive insight into the above core findings, in general and region-wise.

This study highlights some relevant implications especially, in order to promote a happy society. Nighttime lights are more than just aesthetics; they can be used by researchers to obtain data that is beneficial to establish socioeconomic indicators when no other accurate information is available. This shows that nighttime lights can have an effect on happiness. Turning on more lights may help in brightening the satellite imagery, and can enhance the observation of nighttime lights. For example, when the United Arab Emirates became an international business hub in the Middle East, the nighttime lights in the country have increased due to the rapid expansion of the road system and the manufacturing unit, and according to the World Happiness Report in 2020, the United Arab Emirates retained its first place among the Arab countries for a few years. Hence, it is the way how nighttime lights might affect the happiness of this country. For regions where the nighttime lights have no effect on happiness, viz. East Asia and Pacific, Europe and Central Asia, Middle East and North Africa, and South Asia, instead of focusing on the nighttime lights, the governments of these regions might explore and implement alternative policies. For example, governments can focus on the economic development of their countries, as well as the welfare of the people by improving educational funding and spending more on the healthcare system. As a result, strategies that are centred on happiness can have the potential to enhance both happiness and health outcomes. Appropriate macroeconomic policies can be pursued in order to increase happiness, such as by reducing the cost of living (i.e., inflation), and unemployment while promoting income (i.e., growth of GDP per capita), and government expenditure.

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## APPENDIXES

**Appendix A:** Selected Sample Countries by Regions - 132 Countries

| | |
|---|---|
| **East Asia and Pacific (14 countries)** | Australia, Cambodia, China. Indonesia, Japan, South Korea, Laos, Malaysia, Mongolia, New Zealand, Philippines, Singapore, Thailand, Vietnam |
| **Europe and Central Asia (43 countries)** | Albania, Armenia, Austria, Azerbajian, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Moldova, Netherlands, Poland, Portugal, Romania, Russia, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sweden, Tajikistan, Turkey, Turkmenistan, Ukraine, the United Kingdom, Ubekistan |
| **Latin America and the Caribbean (19 countries)** | Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela |
| **Middle East and North Africa (18 countries)** | Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Malta, Morocco, Qatar, Saudi Arabia, Syria, Tunisia, the United Arab Emirates, Yemen |
| **South Asia (6 countries)** | Afghanistan, Bangladesh, India, Nepal, Pakistan, Sri Lanka |
| **Sub-Saharan Africa (30 countries)** | Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Chad, Comoros, Congo, Gabon, Ghana, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia, Zimbabwe |
| **North America (2 countries)** | Canada, the United States |

**Appendix B:** Hausman Tests

| Dependent variable: | Happiness | Nighttime lights |
|---|---|---|
| **All countries** | 1.383 (RE) | 0 (RE) |
| **Region: East Asia and Pacific** | 0 (RE) | 0 (RE) |
| **Europe and Central Asia** | 2.856* (FE) | 1(RE) |
| **Latin America and the Carribbear** | 1.985 (RE) | 0.235 (RE) |
| **Middle East and North Africa** | 0.343 (RE) | 0 (RE) |
| **South Asia** | 0.477 (RE) | 0 (RE) |
| **Sub-Saharan Africa** | 0.175 (RE) | 0.432 (RE) |

***Notes:*** **p*-value < 0.10 rejecting the null hypothesis of random effects (RE), the fixed effects model (FE) is preferred. The reported statistics are Chi-Square statistic. The cross-section test is invalid with Hausman statistic set to zero.

**Appendix C:** Ordinary Least Squares (OLS) Estimates

| | **All countries** | **East Asia and Pacific** | **Europe and Central Asia** | **Latin America and the Caribbean** | **Middle East and North Africa** | **South Asia** | **Sub-Saharan Africa** |
|---|---|---|---|---|---|---|---|
| ***Panel A* - Dependent Variable: Happiness** | | | | | | | |
| **Constant** | 1.720 | 4.395 | 2.363*** | 1.880 | 5.419 | 2.958 | 2.520 |
| | [7.536] | [5.640] | [3.851] | [3.164] | [7.133] | [5.507] | [9.718] |
| **Nighttime lights** | 0.298*** | 0.095 | 0.263 | 0.332*** | 0.005 | 0.127*** | 0.174*** |
| | [16.412] | [1.621] | [5.675] | [7.097] | [0.078] | [3.079] | [7.007] |
| **$R^2$** | 0.290 | 0.037 | 0.131 | 0.351 | 0.000 | 0.253 | 0.249 |
| **Adjusted $R^2$** | 0.289 | 0.231 | 0.127 | 0.344 | -0.011 | 0.226 | 0.244 |
| **Standard error** | 0.9316 | 0.945 | 0.946 | 0.683 | 0.989 | 0.450 | 0.468 |
| ***F*-statistic** | 269.360 | 2.630 | 32.206 | 50.366 | 0.006 | 9.485 | 49.105 |
| ***Panel B* - Dependent Variable: Nighttime lights** | | | | | | | |
| **Constant** | 7.121 | 10.917 | 10.248 | 6.198 | 12.514 | 3.700 | 4.154 |
| | [21.708] | [7.913] | [19.712] | [6.780] | [11.826] | [1.245] | [4.666] |
| **Happiness** | 0.974*** | 0.391 | 0.499*** | 1.059*** | 0.015 | 1.981*** | 1.434*** |
| | [16.412] | [1.622] | [5.675] | [7.097] | [0.078] | [3.080] | [7.007] |
| **$R^2$** | 0.290 | 0.037 | 0.131 | 0.351 | 0.000 | 0.253 | 0.249 |
| **Adjusted $R^2$** | 0.289 | 0.023 | 0.127 | 0.344 | -0.011 | 0.226 | 0.244 |
| **Standard error** | 1.683 | 1.915 | 1.303 | 1.221 | 1.765 | 1.773 | 1.345 |
| ***F*-statistic** | 269.360 | 2.630 | 32.206 | 50.366 | 0.006 | 9.485 | 49.105 |
| **Cross-sections** | 132 | 14 | 43 | 19 | 18 | 6 | 30 |

***Notes:*** $^{***}p$-value < 0.01. The reported value in [.] is *t*-statistic. The time period is between 2008 and 2012.