Exploration of Potential Association between Car Ownership and Nighttime Light Data

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Abstract: Remotely sensed nighttime light (NTL) data can measure nocturnal artificial lighting on Earth's surface and be used to monitor urbanization dynamics. As car ownership at the city level is closely associated with urbanization, NTL data and car ownership time series are likely to be connected. This study is to set out to explore potential association between car ownership and NTL data. Based on data of prefecture-level cities in Jiangsu province, this study empirically examines how and to what extent car ownership associates with nighttime light brightness. The results show that the number of lit pixels with large digital number in NTL imagery is closely connected with prefecture-level car ownership.

1. Introduction

Car ownership is a key issue for urban and transportation planning. Growth in car ownership contributes to concerns about air pollution, traffic congestion and energy consumption [1-3]. Numerous studies have focused on modeling car ownership as well as its relationship with various factors. However, there have been few empirical investigations into the relationship between nighttime light brightness and car ownership.

Remotely sensed nighttime light (NTL) data, which can measure nocturnal artificial lighting on Earth's surface, offers a new perspective for studying urbanization dynamics [4-8]. The utility of NTL data for monitoring urban change has been widely verified in previous studies through statistical correlations between nighttime light brightness and demographic and economic variables (such as population density, economic activity, energy use, and carbon emissions) [9,10]. Growth of car ownership is also associated with urbanization as urban areas can concentrate people, economic activity, and the built environment [11]. As a result, nighttime light data has the potential for car ownership estimation. Verifying association between NTL and car ownership can provide basis for car ownership estimation using NTL data, thereby providing a new perspective for studying car ownership.

The primary objective of this study is to explore potential association between nighttime light data and car ownership time series. To achieve this, this study empirically investigates the relationship based on prefecture-level car ownership data and nighttime light data of Jiangsu, China. This study contributes to the literature by demonstrating the potential relationship between car ownership and nighttime light data, thus providing insights into how and to what extent car ownership associates with nighttime light. The findings of this study can be of great interest for urban and transportation planning.

The reminder of this paper is organized as follows. Section 2 describes the data and methodology used in this study. Section 3 presents the results based on data of Jiangsu, China. Finally, the conclusions are presented.

2. Data and method

2.1 Data

Car ownership data and nighttime light data of prefecture-level cities in Jiangsu, China are collected. Prefecture-level car ownership data from 2004 to 2013 are obtained from the Jiangsu Provincial Bureau of Statistics. Global nighttime light data during the same period in the Defense Meteorological Satellite Program's Operational Linescan System (DMSP/OLS) are used to extract corresponding nighttime light data according to administrative boundaries of these prefecture-level cities. Values of digital number for all lit pixels are real numbers between 0 to 63. The obtained nighttime light imagery is projected using Asia Lambert Conformal Conic projection and resampled to a pixel size of 1 km to facilitate calculation.

2.2 Methodology

The following methodology is employed to explore association between car ownership and nighttime light brightness. For a prefecture-level city in a given year, lit pixels of its NTL imagery are categorized according to its digital number (DN) value. As shown in Table.1, a total of 13 DN intervals are used in this study. The number of lit pixels lie within every DN interval is obtained based on annual prefecture-level NTL imagery. Characteristics of the NTL imagery are then captured using the 13-dimensional feature vector. Each dimension represents the number of lit pixels lie within corresponding DN interval. Correlation analysis and random forest model are employed to investigate association between car ownership and feature vector of NTL imagery. Correlation coefficients between car ownership and each DN interval is calculated for each prefecture-level city. In addition, importance of each DN interval on car ownership estimation is measured by a random forest model trained with all data.

3. Results

The results of correlation analysis and random forest are set out in Table.1, Figure 1 and Figure 2. Table 1 provides correlation coefficient between each DN interval and car ownership and importance measure of each DN interval on car ownership estimation. Figure 1 shows the boxplot of correlation coefficient between car ownership and each DN interval across all prefecture-level cities in Jiangsu, while Figure 2 presents importance measure of each DN interval based on the random forest model trained with all data. The following conclusions can be drawn.

Table.1. Association of each DN interval and car ownership based on correlation analysis and random forest

Interval	Range of digital number	Correlation coefficient				Importance measure
		Mean	Standard deviation	Maximum	Minimum	
1	[0, 5)	-0.294	0.737	0.911	-0.911	2197.12
2	[5, 10)	0.006	0.704	0.949	-0.798	7619.37
3	[10, 15)	0.272	0.736	0.942	-0.977	5220.85
4	[15, 20)	0.448	0.722	0.971	-0.911	1651.94
5	[20, 25)	0.549	0.617	0.978	-0.872	1757.88
6	[25, 30)	0.590	0.611	0.974	-0.754	3617.60
7	[30, 35)	0.637	0.506	0.948	-0.557	5446.40
8	[35, 40)	0.733	0.359	0.968	-0.305	12130.56
9	[40, 45)	0.769	0.227	0.955	0.209	12437.54
10	[45, 50)	0.826	0.125	0.964	0.494	26750.74
11	[50, 55)	0.800	0.110	0.945	0.595	25479.83
12	[55, 60)	0.821	0.059	0.915	0.674	28592.75
13	[60, 63]	0.733	0.057	0.848	0.632	28859.69

According to the results of correlation analysis, a clear growth trend in mean correlation coefficient exists from Interval 1 to Interval 10. The maximum value is obtained in Interval 10, which is 0.826. While mean correlation coefficients of Interval 10, Interval 11 and Interval 12 are around 0.8, mean correlation coefficient decreases to 0.733 in Interval 13. In general, Interval 8 to Interval 13 have a mean correlation coefficient larger than 0.7, indicating that the numbers of lit pixels lie within corresponding intervals are closely related to prefecture-level car ownership. In addition, there is a general decrease in standard deviation of correlation coefficient as DN values increases.

Based on the results of random forest model, Interval 10 to Interval 13 shows relatively larger importance in car ownership estimation, indicating that the numbers of lit pixels lie within these DN intervals play an important role in estimating car ownership accurately.

In sum, these findings provide evidence on association between car ownership and nighttime light imagery. With respect to estimating car ownership based on nighttime light data, the number of lit pixels with large digital number can be of great value.

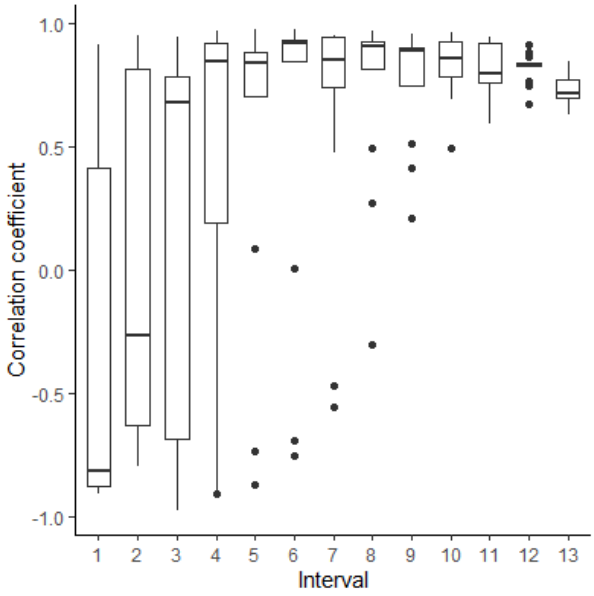

Figure 1. Association of each DN interval and car ownership based on correlation analysis

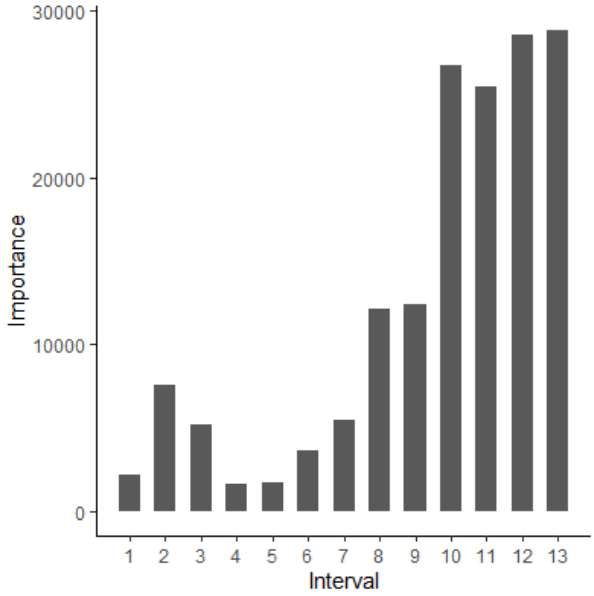

Figure 2. Association of each DN interval and car ownership based on random forest

4. Conclusions

The purpose of this study is to examine the potential relationship between nighttime light data and car ownership. Based on nighttime light data and car ownership data of prefecture-level cities in Jiangsu province from 2004 to 2013, this study conducts correlation analysis and random forest to explored how and to what extent car ownership associates with nighttime light. The findings of this study verify the association between nighttime light data and car ownership data, indicating that nighttime light data has the potential to be used to evaluate prefecture-level car ownership. It is found that closely correlation exists between car ownership and the number of lit pixels with large digital number value in nighttime light imagery. Further investigation into relationship between nighttime light and car ownership with more data is strongly recommended.

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