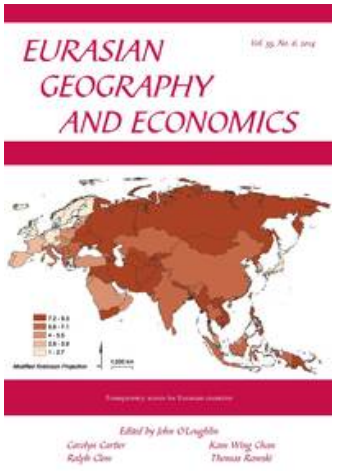

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A nighttime light imagery estimation of ethnic disparity in economic well-being in mainland China and Taiwan (2001-2013)

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A nighttime light imagery estimation of ethnic disparity in economic well-being in mainland China and Taiwan (2001–2013)

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Ethnic disparity in economic well-being in China is drawing more and more attention from researchers. Past efforts for estimating ethnic disparities relied only on survey data in yearbooks or other statistical data obtained at the province or county level, which is usually limited by specific administrative boundaries that may not reflect ethnic differences. The details of ethnic disparities in economic well-being across all ethnic groups still remain unknown. In this study, we analyzed ethnic disparity in economic well-being in China over a 13-year period using nighttime light imagery and obtained a detailed and relatively accurate understanding of these disparities. This study presents and discusses the ranking of ethnic groups in China in terms of economic well-being and human development level, as well as their development patterns. We also make a comparison between the non-Han Chinese and the Han Chinese and find that non-Han ethnic groups as a whole have higher economic levels of well-being than do the Han Chinese. Although the human development level of the non-Han Chinese is lower than that of the Han Chinese, the human development level of non-Han Chinese is increasing all the time, and the disparity between them fell from 2001 to 2013, except in 2011. This study introduces a simple, convenient, and cost-effective way to measure ethnic disparities in economic well-being across ethnic groups and provides a detailed approximation of these disparities in China over a 13-year period, which will help inform policy makers in their future decision-making regarding ethnic-related issues.

Keywords: ethnic disparity; Han Chinese; non-Han Chinese; economic well-being; nighttime light imagery; China

1. Introduction

Ethnicity remains a highly sensitive and concerning word or concept worldwide today, even several decades after the great anti-racial inequality campaign of the 1960s, which aroused a worldwide fight against ethnic inequality, evidenced as much in the civil rights struggles in the US as in the liberation of African countries from colonial rule. Our world has become vulnerable to ethnic segregation, especially in some regions riven with religious hatred, like the Middle East, and reminds us that our world is still confronted with racism and there are still people suffering from ethnic inequality, either directly or indirectly.

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Because of the significance of ethnicity, various institutions and researchers have focused their attention on race-related issues, particularly on ethnic disparities between different ethnic groups. In its World Development Report 2009, the World Bank pointed out that ethnic disparities between ethnic majorities and some ethnic minorities (who usually reside in many lagging areas) deepen political divisions, fuel tensions, and civil conflict, and cause greater divergence in living standards – even reverse development (World Bank Group 2009). Rebecca M. Blank (2001), the former Acting and Deputy United States Secretary of Commerce, has indicated that ethnic disparities are a salient predictor of well-being in many aspects of American society, such as education attainment, health status, employment, and housing quality, reflecting a country's progress and development on race-related issues. In her publication, which discusses the trend of ethnic disparity in social and economic well-being in America, Blank restates that to understand the status and future of America, one must understand the role of ethnicity. The truth of this assertion is not confined to the United States, but applies to any country with ethnic divisions.

China has a large number of ethnic groups. According to the official statistics from the National Bureau of Statistics of China (2002), in addition to the Han majority there are 55 ethnic minority groups within Chinese territory, which constitute roughly 8 percent of the total population of China and take up 64 percent of Chinese territory. China is also faced with race-related conflicts. The recent series of incidents in northwestern China have caused casualties and great economic loss, resulting in heightened tension and threats to local stability. It is widely suspected that ethnic disparity in economic well-being plays a vital role in causing these conflicts (Cao 2010). Therefore, a detailed investigation into ethnic disparity in economic well-being is urgently needed.

The matter of ethnic disparity issues in economic well-being in China has drawn more and more attention in recent years (Gustafsson and Li 2003; Li and Gustafsson 2002; Sullivan 2011). But to our surprise, so far little literature in English discussing this issue has been found, and most of the existing literature is from Chinese journals. We attribute this to a lack of solid data. Even among the handful of empirical studies on the matter, scholars have not yet reached agreement about whether or not such disparities exist. Some researchers argue that substantial ethnic disparities existed in education and occupation in certain regions – like the Xinjiang province from 1982 to 1990 (Hannum 2002; Hannum and Xie 1998) – and that ethnic disparities between minorities and Han Chinese grew between 1978 and 2008 (Zhang and Dong 2009). Still other researchers concluded that the income of minorities had been brought up to and even above the level of the Han majority in Guizhou and Yunnan provinces from 1988 to 1995, based on two surveys of rural China (Gustafsson and Li 2003; Li and Gustafsson 2002). Apparently, researchers have quite divergent opinions on what ethnic disparities may exist in China.

A major problem in existing studies is inaccurate measurement due to data limitations. Existing studies were conducted at a provincial or county level using survey data or statistical data from yearbooks (Li and Gustafsson 2002; Zhang and Dong 2009). However, in most cases, survey data and statistical data are limited by administrative boundaries, which mean that data on ethnic groups is usually collected in a specific administrative region, such as by province and/or county. But the areas that ethnic groups inhabit do not always match the administrative boundaries. In fact, in China, except in a small number of autonomous regions such as Sanjiang Dong Autonomous County in Guangxi province and Zhangjiachuan Hui Autonomous County in Gansu province, most ethnic groups do not live in one specific administrative region. Thus, the

results obtained by previous studies on ethnic disparity in economic well-being are probably inaccurate, and the details of these disparities across all ethnic groups in the overall country remain unknown.

With the adoption of nighttime imagery, this study presents a detailed approximation of economic disparities between ethnic groups in China regardless of administrative boundaries. A simple trend analysis was conducted to reveal the history of such disparities over a 13-year period. The study introduces a useful and handy tool to measure these disparities, and our results have significant implications for regional development and ethnic-related policy formulation.

2. Relevant concepts and assumptions

Ethnic disparity is a type of social inequality (Jasso and Kotz 2008), which is defined as inequality or disproportionate differences between ethnic groups in key areas that shape a person's or group's opportunities in social functioning and opinions and behaviors toward each other (Blank 2001). One of these differences can be inequality in economic well-being (O'Connell 2012; Semyonov and Lewin-Epstein 2011; van de Walle and Gunewardena 2001; Wojtkiewicz 1993). Specifically, it can refer to inequality in employment (Hannum and Xie 1998; Zang 2008), education (Hannum 2002; Kirdar 2009), home ownership (Flippen 2001; Lewin-Epstein, Elmelech, and Semyonov 1997), health (Nazroo 2003), and access to other social resources and capital (Yaish 2001; Zang 2012, 2013). Since these aspects of inequality are closely linked with and affected by economic well-being, either directly or indirectly (Blank 2001; Nazroo 2003), it suggests that ethnic disparity in economic well-being plays a fundamental role in various aspects of inequalities between ethnic groups.

Economic well-being is a broad concept. Traditionally, economic well-being is defined as income or per capita GDP (Blank 2001), but there is more to economic well-being than merely income or per capita GDP. According to Osberg and Sharpe (2005), economic well-being not only means economic status as measured by GDP, but also includes job security, life expectancy, leisure, etc. In this regard, economic well-being is closer to a part of the human development index and cannot simply be represented using income or per capita GDP. For this reason, this study employs two indicators of economic well-being to measure ethnic disparity, the details of which are elaborated in the following section of this study.

In order to measure economic well-being more comprehensively, we made an assumption that economic well-being can be represented by luminosity. The rationale behind this assumption is that nocturnal lighting is a proxy for economic activity and is closely correlated with economic development level, which has been well demonstrated in the literature (Chen and Nordhaus 2011; Doll 2003; Doll, Muller, and Elvidge 2000; Elvidge et al. 1997; Ghosh et al. 2009, 2010; Lo 2002; Sutton, Elvidge, and Ghosh 2007). These studies have developed fine correlations between economic activity levels and various measures of light, such as the sum of values of lit pixels (Sutton and Costanza 2002) and the lit area (Doll, Muller, and Elvidge 2000; Elvidge et al. 1997). Economic researchers have also demonstrated in a very convincing way that light data is a good supplementary measurement to the conventional measures of GDP, and that increases in luminosity approximate true income growth (Henderson, Storeygard, and Weil 2009, 2011). These successful applications of nighttime light data to the estimation of economic activity make this study possible.

3. Methods and materials

3.1. Measurement of ethnic disparity

This study adopts two instruments to measure disparity in economic well-being between ethnic groups. Average luminosity per capita is one indicator, which functions like per capita GDP and is used to proxy the average economic activity level of each ethnic group. It can be defined as follows:

$$\overline{L}_i = \mathrm{DN}_i / P_i \tag{1}$$

where $\overline{L}_i$ represents the average luminosity per capita of ith cell, DN_i is the digital value of ith cell, and P_i is the population of ith cell.

Luminosity per capita only measures a statistical average of economic well-being, ignoring other aspects of economic well-being, which is probably unrepresentative. Therefore, we utilize the Night Light Development Index (NLDI) developed by Elvidge et al. (2012) to measure the human development level of ethnic groups. The basic idea of this index resembles the formulation of the Gini coefficient, which combines the nighttime light data with gridded population data to measure the co-distribution of nocturnal lights and people.

As shown in Figure 1, a curve is drawn as the cumulative nocturnal light in an area is plotted against cumulative population, arranged from the lowest value of light data to the highest value of light data. The diagonal line at 45° represents an even distribution of light; i.e., perfect equality of light. If A represents the area that lies between the curve and the diagonal line at 45° and B represents the total area above the diagonal line, the NLDI can be defined as follows:

$$\mathrm{NLDI} = A/B \tag{2}$$

NLDI varies between 0 and 1. Note that NDLI is not a measure of income inequality like Gini coefficient, but is closer to the human development index that measures "standard of living," life expectancy, and education level in a region (UNDP 2010). The higher the NLDI, the lower the human development it indicates.

3.2. Geo-referencing of ethnic groups

The distribution map of ethnic groups in China was obtained from "Geo-referencing of Ethnic Groups" (GREG), developed by Weidmann, Rød, and Cederman (2010). The

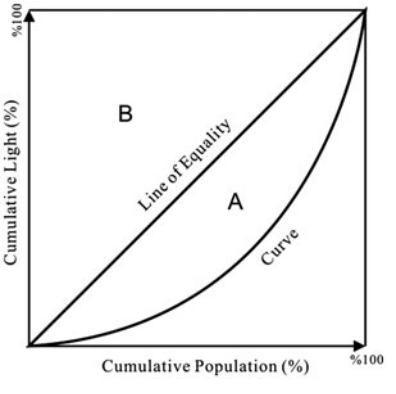

Figure 1. A graphical representation of calculation of NLDI.

data are produced in the GREG data project by the International Conflict Research Group of ETH Zurich. The original data and maps in the GREG data-set are drawn from the Soviet Atlas Narodov Mira (Bruk and Apenchenko 1964), which is derived from a worldwide mapping project of ethnic groups carried out by Soviet ethnographers in the 1960s.

Forty-nine ethnic groups are recorded in this GREG data-set, including *Gaoshan* in Taiwan (Table 1). Seven ethnic groups are not recorded in this data-set; namely the Russian, Uzbek, Gin, Monba, Pumi, Jino, and the Tatars. Given the fact that all of these seven ethnic groups have a sparsely dispersed distribution and small population, as is revealed in the China Population Statistics Yearbook 2002 (National Bureau of Statistics 2002, 78–106), we did not modify the GREG data to include all of the 56 officially recognized ethnic groups in China.

A possible problem with the GREG data-set that could probably raise doubt is that there may be some differences between the map derived from the GREG data-set and the true distribution map that illustrates the exact living areas of ethnic groups in China. The atlas produced in the 1960s from which the data-set was derived is one of the reasons for this problem, as it is possible that there has been relocation in the living areas of ethnic groups. Another potential issue is the within-group mobility of ethnic groups. Migration is not a rare phenomenon in China. Every year millions of people from different ethnic groups move into urban areas to make a living or move to another city due to job transfers or marriages. This makes the nighttime light-based measurement of ethnic disparity less desirable and satisfactory. However, the two problems may not be very severe, as many studies report that minority ethnic groups usually stay in their traditional homelands due to attachment to native land and being unaware of the greater economic opportunities available with migration (Poston, Micklin, and Shu 1998; Yang 2007), and most of them tend to reside in border areas highly segregated residentially from the Han Chinese (Poston, Chang, and Dan 2006; Poston, Micklin, and Shu 1998). Even for those who migrate, they tend to prefer places within their traditional regions of residence; areas with similar languages, religions, and ethnic traditions (Yang 2007).

Table 1. The 49 ethnic groups in China (including Taiwan) recorded in GREG.

Name	Cont'd	Cont'd
Achang	Lhoba	Salar
Qiang	Manchu	Yugur
Han	Maonan	She
Zhuang	Miao	Sui
Daur	Mongol	Xibe
Ewenki	Mulao	Dai
Hani	Naxi	Tibetan
Hui	Hezhen	Tujia
Jingpo	Nu	Tu
Gaoshan	Oroqen	Derung
Kazak	Bai	Dong
Gelao	Deang	Dongxiang
Kirgiz	Tajik	Uyghur
Korean	Bonan	Va
Lahu	Blang	Yao
Li	Buyei	Yi
Lisu		

To determine the reliability of the data, we conducted an accuracy assessment of the GREG data-set based on the following assumption: If the 1960s GREG data for ethnic population distribution is still accurate, meaning that each polygon in GREG data is homogeneous and just for that specific ethnic group, then for each administrative region such as a county, the estimated population for each ethnic group using GREG and LandScan (described below) within that administrative region should be consistent with the ethnic population census data within that administrative region. Drawing on this idea, we overlay the GREG data with the national county administrative map and LandScan 2000 to get the estimated ethnic population for each county in the year 2000. We then compare this data array with the 2000 population census data at the county level and compute the correlation coefficient Pearson's *r*. As long as GREG data is more accurate to the true distribution of each ethnic group, Pearson's *r* should be closer to 1.

The results show that 2484 counties (86.9 percent of the 2860 counties within mainland China) have a high Pearson's *r* of more than 0.9. The average Pearson's *r* for all 2860 counties is 0.9303. This may serve as a strong evidence that GREG data is reliable and accurate, although it cannot prove the data accuracy fully.

3.3. LandScan 2001–2013

We use the 2001–2013 LandScan population grids produced by Oak Ridge National Laboratory (ORNL) to estimate the population of each ethnic group. It provides a fine global population distribution referenced by latitude/longitude (WGS 1984) coordinates with an approximately 30-arc-second resolution. This data-set is created using a population distribution model that proportionally allocates population to each cell according to a likelihood coefficient calculated based on land cover, roads, slope, urban areas, and other information.

In order to facilitate data extraction, LandScan datasets are also used to shift the nighttime light data specified in next section to obtain the best possible match with LandScan datasets.

One thing worth noting is that the first two LandScan products, namely LandScan 1998 and LandScan 2000, adopted nighttime lights as an input for the calculation of population count (Dobson et al. 2000), while subsequent versions of LandScan products dropped this input data source (Bhaduri et al. 2002). To avoid co-variation and duplication in data, this study only employed the LandScan products of years following 2000.

3.4. DMSP/OLS nighttime light imagery

The nighttime light data time series were made using US Air Force Defense Meteorological Satellite Programs (DMSP) Operational Linescan System (OLS) night images. These data sets include three image types: cloud-free composites, raw average visible coverage, and stable lights coverage. For this study, we used the annual stable light product, from which background noise has been removed.

Because of the absence of an onboard calibration system and gain setting of the sensors, the digital number (DN) values in the data stream are not directly comparable from one year to the next. As Figure 2 shows, the sum of values of lit pixels for different nighttime light images of China from different satellites jumps at certain years, indicating an inconsistent increase in the sum of values of lit pixels. Therefore, an intercalibration procedure is required before a direct comparison of DN values across the time series can be made.

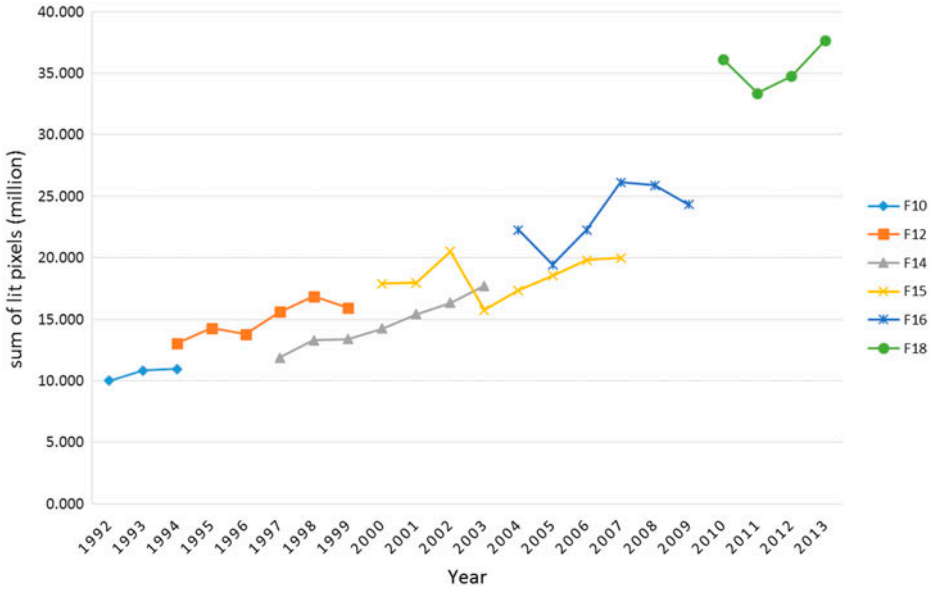

Figure 2. Variation of sum of lit pixels in nighttime light data from different satellites before intercalibration.

In this study, we followed a quadratic regression model introduced by Elvidge et al. (2009) to perform the intercalibration. The nighttime light data of 2007 captured from DMSP satellite F16 was selected as the reference image due to its high sum of lit pixels (Figure 2) and its middle position, which connects both sides across the time series. We then identified several areas with invariable or little change of light across the time series. Two rules were formulated to select the invariant areas. One was that the variation of DN values of the selected area across the time series had to be small; the other was that the DN values of selected areas must cover as much as possible of the full range of nighttime light images, i.e., 0–63. We examined several cities in East Asia and found that Hong Kong and Okinawa from Japan had the two features specified above. Hence, the two areas were selected as the invariable area to compute the coefficients of the quadratic regression model (Equation (3)). With the selected invariable areas of the reference image as the dependent variable, and the same areas of to-be-calibrated images as the independent variable, the model parameters a, b, and c were calculated using least squares regression for each nighttime light data (Table 2).

$$\mathrm{DN}_{\mathrm{calibrated}} = a \times \mathrm{DN}^2 + b \times \mathrm{DN} + c \tag{3}$$

where $\mathrm{DN}_{\mathrm{calibrated}}$ is the DN value after intercalibration, DN is the original DN value, and a, b, c are the model parameters.

The coefficients of the quadratic regression models were then applied to calibrate the nighttime light data of each year from each satellite, respectively. During the intercalibration, we excluded the DN value of zero from the DN adjustment because zero indicates a complete lack of light and those DN values of zero should be maintained as their original values. Finally, the nighttime light data of the same year but from different satellites were averaged. Figure 3 shows the nighttime light data time series after

Table 2. Coefficients of quadratic regression models for intercalibration of the nighttime light data (1992–2010).

Satellite	Year	a	b	c	R^2
F10	1992	0.0032	0.7693	−0.0209	0.9364
	1993	−0.0020	1.1854	−1.7283	0.9457
	1994	−0.0016	1.1087	0.1192	0.9544
F12	1994	0.0086	0.3782	3.1977	0.9358
	1995	0.0045	0.6949	1.5422	0.9516
	1996	0.0034	0.7734	1.0277	0.9530
	1997	0.0057	0.5709	2.2024	0.9561
	1998	0.0040	0.7493	0.6193	0.9699
	1999	0.0057	0.6184	1.4913	0.9751
F14	1997	−0.0008	1.0041	1.1296	0.9505
	1998	−0.0046	1.3036	−0.6836	0.9773
	1999	−0.0017	1.1035	0.4699	0.9773
	2000	−0.0020	1.1108	0.4923	0.9724
	2001	0.0003	0.9352	1.2116	0.9760
	2002	0.0008	0.9031	1.2613	0.9688
	2003	−0.0002	0.9629	1.0007	0.9835
F15	2000	0.0051	0.6343	1.3419	0.9756
	2001	0.0039	0.7308	0.8986	0.9815
	2002	0.0061	0.5705	1.6292	0.9801
	2003	−0.0051	1.2987	0.1306	0.9829
	2004	−0.0045	1.2618	0.1157	0.9869
	2005	−0.0056	1.3603	−0.2435	0.9830
	2006	−0.0041	1.2455	0.0828	0.9913
	2007	−0.0068	1.4422	−0.6341	0.9880
F16	2004	−0.0009	1.0214	0.0603	0.9748
	2005	−0.0082	1.5256	−0.958	0.9896
	2006	−0.0041	1.2855	−1.3198	0.9894
	2007	0.0000	1.0000	0.0000	1.0000
	2008	−0.0029	1.1728	−0.6556	0.9931
	2009	−0.0041	1.2440	−0.1295	0.9508
F18	2010	0.0055	0.6023	1.5134	0.9470
	2011	0.0044	0.6175	3.0061	0.9073
	2012	0.0002	0.9729	−0.2182	0.9859
	2013	0.0013	0.8912	0.0865	0.9873

intercalibration, which indicates a consistent and gradual increase in the sum of values of lit pixels across the time series, demonstrating that the intercalibration process for the DMSP/OLS nighttime light time series is effective and valid.

4. Results and verification

With GREG datasets, LandScan population grid datasets, nighttime light data, and the two measurement instruments of ethnic disparity, we computed the light per capita and NLDI for 49 ethnic groups in China. Table 3 shows the light per capita for 49 ethnic groups in China from 2001 to 2013. In the table, we note that several ethnic groups have a light per capita of zero, which could raise doubts about the results, because a zero light per capita indicates a complete lack of light in the living areas of these ethnic groups – a suggestion which strains credulity. However, acknowledging that the DMSP/OLS nighttime light datasets have a very limited capacity for capturing low levels of light, it is understandable that they might report that the living areas of some ethnic

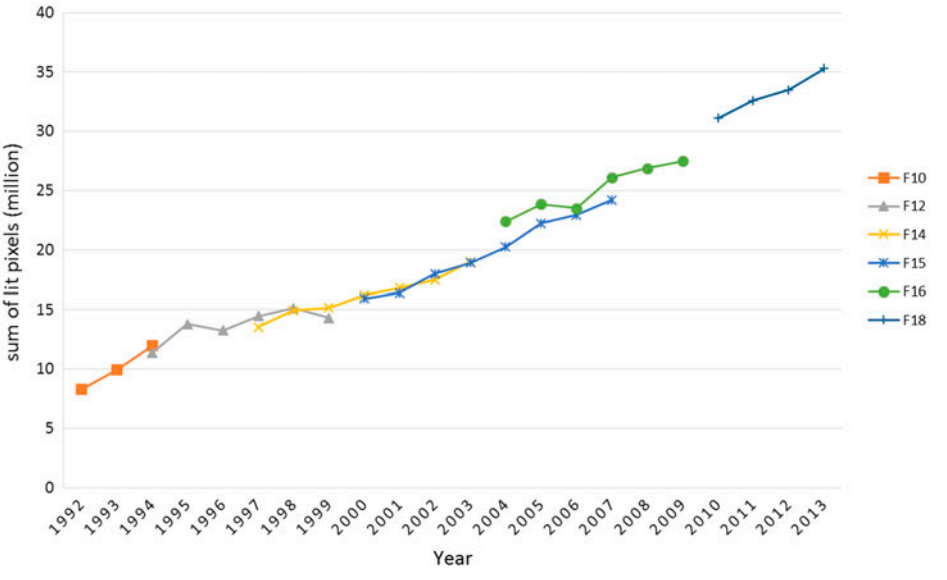

Figure 3. Variation of sum of lit pixels in nighttime light data time series after intercalibration.

Table 3. Result of correlation analysis between light per capita and GDP per capita.

Pearson correlation	0.926*
Sig. (2-tailed)	0.000
N	49

*Correlation is significant at the 0.01 level (2-tailed).

groups far from urban areas have a zero light per capita. In this study, we therefore understand a light per capita of zero as an indication of low but not inexistent light per capita.

The result in Table A1 in the Appendix roughly matches the development of regions where different ethnic groups live. In the year 2010, among the 49 ethnic groups, the Gaoshan of Taiwan have the highest light per capita, followed by the Hezhen, Kazak, Manchu, and Mongol, while the Tujia, Maonan, Nu, Tajik, and Derung have the lowest light per capita. Taiwan, where the Gaoshan ethnic group live, is one of the most developed areas in China; northeast China, where the Hezhen and Manchu live, is also a well-developed area, while the southwest of China, home to the Maonan, Nu, and Derung, has the largest number of designated national poverty-stricken counties in the country.

The results of the NLDI of 49 ethnic groups from 2001 to 2013 are shown in Appendix Table A2. For those ethnic homelands where population is present but no lights were detected, the NLDI is set to 1, indicating a minimal level of human development.

In order to verify the results obtained from light data, we conducted a correlation analysis between light per capita in the year of 2001 and GDP per capita in 2000 for each ethnic group based on the data availability.

The data we use to calculate GDP per capita for each ethnic group include GDP statistics in 2000 and China's 2000 population census data produced by China Data Center of the University of Michigan. Before calculating the GDP share of each ethnic group in each prefectural city, we assume that each ethnic group contributes to GDP proportionally to the population share of each ethnic group within the city. Then, the GDP share of each ethnic group in each prefectural city is aggregated to obtain GDP share of each ethnic group in the whole country. By dividing the total population of each ethnic group in the whole country, we have GDP per capita for each ethnic group. The above computing process can be represented by the following equation:

$$\text{GDP per capita}_j = \sum_{i=1}^{n}\left(\text{GDP}_i \times \text{Population}_{ij}/\text{Total population}_i\right)/\sum_{i=1}^{n}\text{Population}_{ij} \quad (4)$$

where GDP per capita$_j$ is GDP per capita for the jth ethnic group, GDP$_i$ is the GDP of the ith prefectural city, Total population$_i$ is the total population of the ith prefectural city, and Population$_{ij}$ is the population of the jth ethnic group in the ith prefectural city.

Appendix Table A3 shows the result of GDP per capita for each ethnic group in China in 2000. For convenience of comparison, we also attached the result of light per capita for each ethnic group in 2001 to Appendix Table A3. We believe that light per capita of each ethnic group should be highly linearly correlated with GDP per capita of each ethnic group, which could provide strong evidences that the novel method in this study based on nighttime light satellite images is a valid and effective way to estimate ethnic disparity in economic well-being.

Thus, a correlation analysis is done to reveal the strength of linear association between light per capita and GDP per capita for each ethnic group. The result is presented in Table 3. It shows that the coefficient of correlation between light per capita and GDP per capita is 0.926, and we can easily compute the coefficient of determination, Pearson's r^2, of 0.86. Clearly, light per capita is a very useful aggregate measure of GDP per capita for each ethnic group and thus is a workable and valid way to estimate ethnic disparity in economic well-being.

5. Discussion

A ranking of light per capita is made including the first ten and last ten ethnic groups from 2001 to 2013 in China, as shown in Appendix Table A4. The result suggests that in the last five years of this study (from 2009 to 2013), the Gaoshan, Hezhen, Kazak, Manchu, Mongol, Xibe, Uyghur, and Oroqen were the most wealthy ethnic groups in China, while the Sui, Blang, Gelao, Tujia, Derung, Maonan, Nu, and Tajik were the least economically developed. (We include a graphic representation of light per capita for all ethnic groups in 2013 in Figure 4.) The results indicate that in the last five years of the study, the Manchu, Korean, Oroqen, Han, Xibe, Achang, and Gaoshan are those ethnic groups with relatively high human development level, while the Tujia, Yugur, Tajik, Nu, Maonan, Derung, Sui, and Tibetan display a low level of human development.

These observations and results are supported and explained by many studies. According to Poston, Chang, and Dan (2006), Shu (1989), and Poston and Shu (1987), Manchu and Korean are among the most advanced of all the Chinese minorities in terms of education, occupation, and socioeconomic status, which is consistent with the results of the ranking of NLDI in this study. Goodman's (2004) analysis accords with our conclusions too. His results showed that Xinjiang Uyghur Autonomous Regions

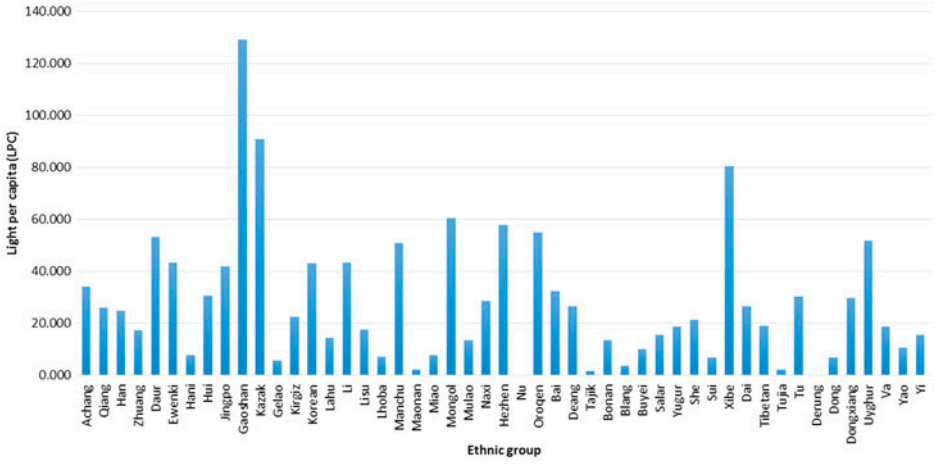

Figure 4. Light per capita for all ethnic groups at the year of 2013.

exhibited high economic development – even higher than the Jilin provinces, which are regarded as well-developed areas – while in the Tibet Autonomous Region and Qinghai provinces, Tibetan lives are substantially worse in terms of economic growth as well as in terms of provision of welfare including health and education. According to the analysis by Wang and Fan (2004), southwest China, where the Sui, Blang, Gelao, Tujia, Derung, Maonan, and Nu reside, has a lower economic development level than the rest of China before the famous "open door" policy was initiated. Since the inception of the "open door" policy in the 1980s, coastal eastern China as well as northeast China, where most of the Han Chinese, Hezhen, Manchu, Xibe, and Oroqen live, has grown faster. This growth was due to the preferential policies it received, its better industrial foundation including ports and road infrastructures, more skilled workers, more capital investment, and geographic location benefits (Démurger et al. 2002; Wang and Fan 2004), which has left southwest China far behind.

Since the Han Chinese is the largest ethnic group in China and the possible disparities between the Han Chinese and non-Han Chinese are of great interest and significance to people, we made a comparison between the two. As Appendix Table A1 shows, the Han Chinese are not among the wealthiest ethnicities in China in terms of light per capita. In fact, the position of the Han in terms of light per capita is in the middle of all ethnic groups. However, the result of NLDI (Appendix Table A2) shows that the Han have a higher human development level than most other groups. Further, we calculated the light per capita and NLDI from 2001 to 2013 for non-Han ethnic groups as a whole and the Han, respectively, as shown in Figures 5 and 6. The results show that in 2001 and 2002, the Han light per capita was slightly higher than that of non-Han, but in the next few years the light per capita of non-Han ethnic groups overtook the Han's and the gap between the two groups continued to grow, except in 2013. In terms of NLDI, it is obvious that the Han exhibited higher human development levels than non-Han ethnic groups (Figure 6). But the interesting thing is that from 2001 to 2013, the Han NLDI was fluctuating, while the non-Han's was decreasing, showing that despite a lower human development level, the human development level of non-Han ethnic groups was increasing, and the discrepancy between the Han and non-Han

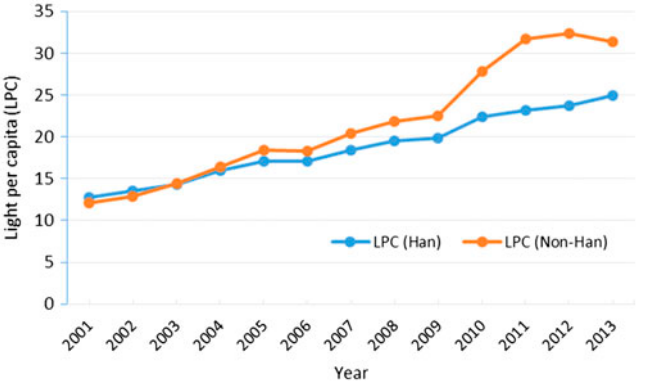

Figure 5. The comparison between the non-Han and the Han in terms of light per capita.

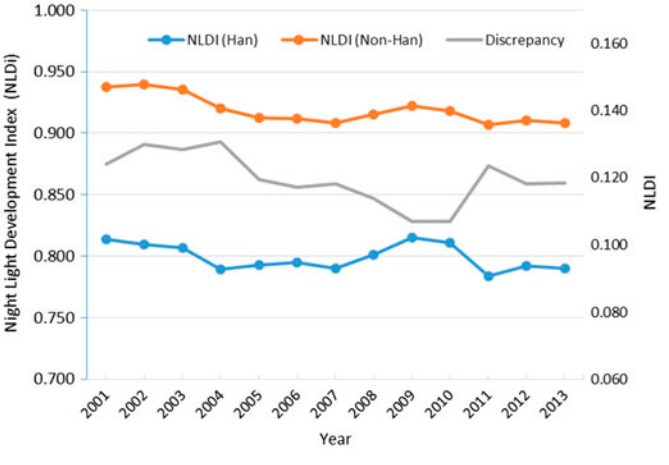

Figure 6. The comparison between the non-Han and the Han in terms of NLDI.

narrowed throughout the study time period, except for 2011, due to a sudden decrease of NLDI for the Han group.

In the late 1990s, the China central government announced that the enormous gap between the west and eastern regions should be narrowed, and it launched the national "Open Up the West" campaign, which aimed to encourage economic growth and ensure social and political stability in non-Han areas (Goodman 2004). Hundreds of national key projects have been initiated since the inception of the "Open up the West" campaign. These projects mainly involve the infrastructure, including airports, railways, roads, water facilities, etc. (Wang and Wei 2003). It is also reported that the "Make Electricity Available to the Countryside" project initiated in 2002 had covered all the rural areas of western China by 2012 (NDRC 2012). The national investment in infrastructure construction including the Qinghai–Tibet railway, the west-east electricity transfer project, and the "Make Electricity Available to the Countryside" project have boosted light production in western China, thus substantially increasing the light per capita in those non-Han areas. As for the human development level, an analysis from

the annual report on economic development in western region of China (2011) showed that the living standard in western China has improved greatly since the beginning of "Open up the West" campaign, indicating a growing human development level throughout the years (Yao and Ren 2011).

If we look into the variations of light per capita for each ethnic group across the time series, different trends can be seen. In order to classify these trends, we subtract the mean from each trend, then divide each demeaned trend by the standard deviation of each trend. In this way, the trends for all ethnic groups retain their basic features and can be compared directly. We then classify all these trends into several patterns based on the slope variations. As Figure 7 shows, two patterns are formed and named as increasing pattern and fluctuating pattern, respectively. Thirty-seven ethnic groups including the Han, Uyghur, Mongol, Tibetan, Manchu, etc. have increasing trends in terms of light per capita (Figure 7(A)), indicating a growing economic well-being. Twelve ethnic groups including the Deang, Derung, Hani, Mulao, Tujia, etc. exhibit fluctuating trends (Figure 7(B)), which suggest a tough economic development pattern.

It is easy to understand that those ethnic groups in Figure 7(A) show rises in economic well-being since the majority of these groups are residing in wealthy eastern China with an increasing GDP. But for other type of pattern, the trends appear to be confusing. In Figure 7(B) for example, the trend for the Deang has a striking rise in 2010, which appears unusual. The reason why the Deang trend fluctuated greatly is that the region has been troubled by a series of earthquakes since 2008. The first series of earthquakes in late August 2008, named the 2008 Yingjiang earthquakes, damaged more than 80,000 houses and resulted in an evacuation of more than 125,000 people (Xinhuanet 2008). The second series of earthquakes occurred on 10 March 2011 and caused more than 127,000 people to be evacuated to nearby areas (Xinhuanet 2011). There have been more earthquakes, with the latest one on 24 May 2014. These catastrophes resulted in a light per capita value for Deang in 2009 of zero. The rising of light per capita in 2010 is due to a well-rebuilt homes with good lighting systems. People moved out again because of a later series of earthquakes, which corresponds to decreasing lights in 2011 and 2012.

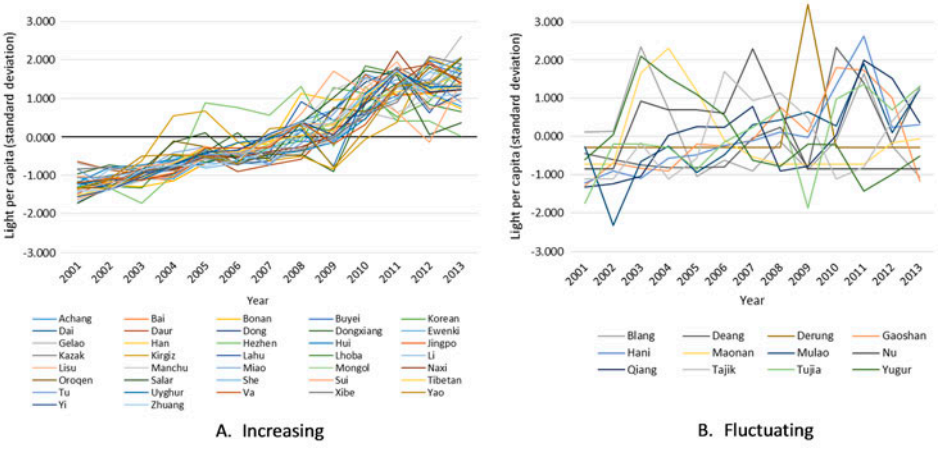

Figure 7. Patterns of the trajectories of each ethnic group in terms of light per capita across time series.

While our study provides a detailed and relatively accurate understanding of ethnic disparities in economic well-being in China, it does have limitations that may undermine the accuracy of our results. The outdated nature of GREG data-set and the mixed living of ethnic groups could affect the validity of the conclusion for some ethnic groups, although we provided strong evidence previously here to show that the data-set is accurate and reliable. For caution's sake, we recommend that more specific analysis be conducted in the future to reveal more accurate results for ethnic groups which have a high within mobility.

The well-known saturation of nighttime light data might undermine the accuracy of the result in this study. Due to the limited radiometric range of the DMSP/OLS satellite, which can only store 6-bit data, the maximum DN it can denote is 63. As a result, the DNs in urban core area where there are many lights are usually saturated pixels of 63 (Elvidge et al. 2007), which reduce the accuracy and limit the utilization of nighttime light data. In this study, however, we calculated the statistics of saturated pixels in China (Table 4). We found that the number of saturated pixels for all images from all

Table 4. The percentage of number of saturated pixels in total number of lit pixels.

Satellite	Year	Number of saturated pixels/total number of lit pixels (%)
F10	1992	0.29
	1993	0.05
	1994	0.12
F12	1994	0.41
	1995	0.22
	1996	0.15
	1997	0.22
	1998	0.21
	1999	0.30
F14	1997	0.19
	1998	0.16
	1999	0.18
	2000	0.11
	2001	0.25
	2002	0.29
	2003	0.31
F15	2000	0.21
	2001	0.21
	2002	0.25
	2003	0.16
	2004	0.19
	2005	0.21
	2006	0.22
	2007	0.06
F16	2004	0.37
	2005	0.19
	2006	0.36
	2007	0.25
	2008	0.42
	2009	0.39
F18	2010	0.82
	2011	0.77
	2012	0.70
	2013	1.11

satellites is below 1 percent of the total number of lit pixels. The results show that the saturation of the DMSP/OLS nighttime images is acceptable and has a minor effect on our results.

Additionally, it appears that the economic disparity within each ethnic group might be a problem too. For example, Hong Kong, a city with high level of economic activities and luminosity, of which the majority ethnic group is Han Chinese, has tremendous economic disparities across different social classes in Han Chinese population. There are a lot of impoverished Han Chinese people and millionaires living in the same city. However, since we do not have the economic well-being information of every single person for each ethnic group, the average of equivalent measure (e.g. light per capita in this study) will be the suitable and best estimator to measure the aggregated economic well-being of each ethnic group.

Disparities between different ethnic groups can be dangerous when it comes with regional division and political tension. The violence in Kenya in early 2008 and ethnic conflicts between Uyghur and Han in western China in July 2009 are recent examples of this fact. Policy makers and other stakeholders should acquire an in-depth understanding of ethnic disparities in economic well-being. Our study used nighttime light data, LandScan population data, and GREG ethnic map data and calculated light per capita and NLDI to measure this disparity in China. The methodology is simple and effective, and the results are intuitive and handy. It can be anticipated that further improvements can be made using finer datasets. One possible data source to eliminate the saturation problem of nighttime light data is the Day/Night Bands data collected by the onboard Visible Infrared Imaging Radiometer Suite (VIIRS) in the newly launched Suomi National Polar-orbiting Partnership Project satellite. The VIIRS sensor can acquire better and finer global nighttime light data free of saturation using its onboard calibration facilities, which offers new opportunities and shows great potential for improving the measurement of ethnic disparity.

6. Conclusion

Ethnic disparity in economic well-being in China is an important issue that has drawn much attention. Previous research usually analyzed it using survey data collected according to administrative regions such as province and county, which do not necessarily match geographic divisions between the living spaces of ethnic groups. This research analyzed ethnic disparities in economic well-being in China using nighttime light data – LandScan and GREG datasets – and obtained a detailed and relatively accurate understanding of these disparities over the past 13 years. We found that in terms of light per capita, the Gaoshan, Hezhen, Kazak, Manchu, Mongol, Xibe, Uyghur, and Oroqen are economically well-developed ethnic groups in China, while the Sui, Blang, Gelao, Tujia, Derung, Maonan, Nu, and Tajik are the poorest ethnic groups. We also found that the Manchu, Korean, Oroqen, Han, Xibe, Achang, and Gaoshan have relatively high levels of human development, while the Tujia, Yugur, Tajik, Nu, Maonan, Derung, Sui, and Tibetan show low levels of human development. The comparison between Han and non-Han ethnic groups shows that non-Han ethnic groups as a whole have higher economic levels of well-being than do the Han. Although the human development level of the non-Han is lower than that of the Han, the human development level of non-Han Chinese is increasing all the time, and these disparities between the two narrowed from 2001 to 2013, except in 2011 due to a sudden decrease of NLDI for Han group. Additionally, we concluded that from 2001 to 2013, 37 ethnic groups, including the

Han, Uyghur, Mongol, Tibetan, Manchu, etc., increasingly developed. Twelve other groups including the Deang, Derung, Hani, Mulao, Tujia, etc. show fluctuated economic development. While our study has certain weaknesses, such as saturation of nighttime light data, which can be improved with finer datasets in the future, it proposes a possible way of estimation of the ethnic disparities and provides a detailed understanding of current ethnic disparities in China that will help inform policy makers in their future decision-making regarding ethnic-related issues.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1

This supporting information consists of tables that are not essential but supplementary to the study:

Table A1. Light per capita for each ethnic group in China from 2001 to 2013.

Ethnic group	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Achang	12.673	9.97	12.017	12.321	18.127	17.277	22.042	29.507	32.919	43.670	40.244	38.003	33.974
Bai	8.047	7.706	8.1	7.024	11.498	14.031	17.179	18.592	19.165	29.688	35.851	29.311	32.240
Blang	5.727	5.75	9.506	6.744	3.762	4.488	4.015	5.329	4.076	5.375	8.327	5.104	3.735
Bonan	1.997	2.295	2.037	2.913	5.534	8.562	8.228	15.811	14.887	15.069	15.718	15.765	13.596
Buyei	4.249	4.25	5.141	5.296	6.129	5.644	6.865	6.524	6.636	8.117	8.884	10.488	9.971
Korean	16.83	17.796	18.474	21.735	25.073	21.564	25.501	26.775	38.35	37.059	31.937	35.368	43.080
Dai	9.554	11.059	11.088	11.982	14.965	15.989	17.966	20.177	17.338	24.129	28.683	26.064	26.437
Daur	19.916	16.388	14.57	22.522	23.105	15.652	18.455	21.04	34.405	38.143	58.788	61.647	53.253
Deang	4.633	2.709	0.994	0	0	0.368	9.682	13.177	0	39.404	27.762	7.816	26.595
Derung	0	0	0	0	0	0	0	0	2.877	0.000	0.000	0.000	0.000
Dong	1.277	1.604	2.422	2.929	3.289	2.752	2.914	4.626	5.824	7.431	8.194	5.859	6.775
Dongxiang	5.728	7.631	6.81	6.715	10.271	14.296	8.963	9.922	6.33	20.355	24.493	24.268	29.644
Ewenki	10.904	13.959	14.603	19.078	17.395	20.75	16.629	24.361	23.043	36.417	40.107	37.040	43.292
Gaoshan	126.089	140.577	136.999	135.455	152.173	151.165	154.964	175.547	159.813	200.283	198.645	181.615	129.153
Gelao	1.38	1.15	1.266	1.274	1.49	1.767	1.537	1.697	2.225	3.155	2.867	4.262	5.756
Han	12.76	13.563	14.359	15.955	17.117	17.129	18.425	19.467	19.835	22.382	23.187	23.721	24.936
Hani	4.113	4.851	4.39	5.598	5.834	6.378	6.655	7.186	6.863	9.988	12.934	7.475	7.626
Hezhen	24.539	24.557	14.726	33.08	79.161	76.175	71.437	89.631	51.302	89.764	67.681	67.658	57.857
Hui	13.496	15.821	16.144	17.031	17.517	16.517	17.669	18.317	19.7	23.246	28.131	32.028	30.743
Jingpo	12.311	16.459	16.982	17.232	23.13	23.309	28.486	32.155	32.174	46.313	40.285	41.243	41.995
Kazak	26.959	28.558	33.028	35.39	46.405	44.983	51.086	49.463	64.424	83.921	104.785	93.872	90.869
Kirgiz	6.429	7.364	10.278	16.425	17.062	12.876	10.283	10.914	9.178	13.233	15.578	24.366	22.433
Lahu	5.145	4.823	6.037	6.331	6.814	7.647	7.711	12.023	10.457	10.964	14.488	11.065	14.491
Lhoba	4.122	3.921	3.831	5.325	4.98	5.259	6.086	6.627	6.377	9.272	8.937	7.541	7.222
Li	16.778	22.12	22.196	23.973	23.48	23.452	23.313	31.817	32.729	38.950	38.557	44.465	43.318
Lisu	3.836	4.822	5.533	6.343	8.557	9.5	11.397	13.68	13.623	18.998	23.005	15.969	17.457
Manchu	25.387	25.659	28.019	32.9	36.668	32.137	37.607	42.938	52.137	55.088	46.088	49.785	50.991

(*Continued*)

Table A1. (*Continued*).

Ethnic group	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Maonan	0	0	8.386	10.667	6.728	2.21	0.662	0	0	0.000	0.000	1.996	2.366
Miao	2.48	2.963	3.69	4.361	4.587	4.269	4.894	5.478	4.804	5.862	6.885	6.809	7.812
Mongol	17.704	17.596	21.052	28.355	33.185	31.657	36.105	38.995	45.94	50.852	61.217	69.556	60.444
Mulao	11.155	7.899	10.53	11.168	10.073	10.821	12.053	12.244	12.588	11.992	14.591	11.726	13.526
Naxi	1.543	1.771	4.105	3.915	8.374	7.884	9.537	11.058	14.688	24.712	40.533	27.667	28.478
Nu	0	0	6.536	5.713	5.705	5.418	11.622	5.743	0	0.000	0.000	0.000	0.000
Oroqen	26.382	26.313	29.815	38.606	37.146	32.439	35.24	34.803	47.376	46.332	49.597	57.818	54.796
Qiang	15.888	16.4	17.593	24.134	25.513	25.42	28.725	18.457	19.148	24.133	36.107	33.189	26.123
Salar	7.562	9.244	10.873	13.747	14.686	11.915	12.155	15.663	18.198	20.944	20.487	14.478	15.675
She	8.533	8.592	9.386	10.536	9.626	10.137	11.65	13.477	12.954	15.275	17.034	19.874	21.392
Sui	1.931	2.344	3.306	3.421	4.134	3.77	4.176	5.501	7.295	6.452	5.570	4.315	6.854
Tajik	0	0	0.625	0	0.354	1.851	1.351	1.476	1.053	0.000	0.208	0.990	1.559
Tibetan	5.651	6.773	7.722	9.622	11.544	10.985	12.289	13.008	13.63	17.790	20.587	18.542	18.925
Tu	20.757	17.986	19.408	21.062	22.854	23.085	21.519	24.453	28.721	33.924	33.001	33.643	30.344
Tujia	0.994	1.633	1.629	1.598	1.359	1.653	1.812	2	0.943	2.115	2.279	1.998	2.251
Uyghur	26.874	27.938	27.984	31.691	34.488	37.34	38.348	40.794	31.335	49.958	55.713	51.678	51.801
Va	5.08	5.646	5.458	6.37	9.878	9.859	9.967	13.439	10.445	13.077	18.589	21.637	18.776
Xibe	17.923	19.031	16.557	18.497	24.928	20.322	27.669	29.157	36.959	50.325	57.879	84.895	80.325
Yao	3.917	4.381	5.526	5.609	5.543	5.164	6.912	7.051	4.965	6.847	9.038	9.237	10.499
Yi	7.148	7.699	8.686	9.625	10.577	10.725	11.966	12.952	11.881	14.311	16.857	15.234	15.429
Yugur	18.065	23.61	40.924	36.112	32.414	27.83	17.893	16.609	21.562	21.309	11.162	14.782	18.848
Zhuang	7.129	7.248	9.389	9.899	9.791	10.451	13.036	14.377	14.615	17.153	19.696	16.892	17.363

Table A2. NLDI for each ethnic group in China from 2001 to 2013.

Ethnic group	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Achang	0.789	0.806	0.814	0.834	0.806	0.800	0.802	0.812	0.827	0.836	0.806	0.818	0.797
Bai	0.926	0.932	0.930	0.939	0.919	0.914	0.908	0.913	0.917	0.913	0.895	0.900	0.887
Blang	0.984	0.968	0.966	0.968	0.973	0.972	0.979	0.947	0.968	0.967	0.931	0.973	0.974
Bonan	0.950	0.929	0.941	0.898	0.881	0.857	0.893	0.889	0.864	0.861	0.797	0.847	0.877
Buyei	0.934	0.936	0.931	0.924	0.916	0.923	0.915	0.928	0.938	0.932	0.913	0.910	0.916
Korean	0.799	0.800	0.793	0.750	0.756	0.757	0.763	0.767	0.783	0.786	0.786	0.794	0.794
Dai	0.907	0.899	0.903	0.903	0.897	0.891	0.885	0.890	0.898	0.887	0.875	0.879	0.878
Daur	0.934	0.940	0.946	0.897	0.894	0.897	0.897	0.905	0.899	0.906	0.898	0.896	0.908
Deang	0.942	0.917	0.997	1.000	1.000	0.998	0.872	0.895	1.000	0.901	0.896	0.943	0.911
Derung	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000
Dong	0.982	0.983	0.981	0.975	0.973	0.972	0.970	0.969	0.974	0.960	0.955	0.962	0.966
Dongxiang	0.907	0.858	0.865	0.879	0.828	0.778	0.846	0.888	0.925	0.824	0.778	0.789	0.712
Ewenki	0.925	0.940	0.941	0.921	0.909	0.911	0.935	0.923	0.946	0.930	0.924	0.920	0.877
Gaoshan	0.835	0.861	0.856	0.858	0.838	0.839	0.840	0.841	0.839	0.844	0.850	0.841	0.724
Gelao	0.972	0.977	0.969	0.965	0.950	0.946	0.950	0.953	0.946	0.918	0.910	0.894	0.883
Han	0.814	0.809	0.807	0.790	0.793	0.796	0.790	0.801	0.816	0.811	0.784	0.792	0.790
Hani	0.964	0.959	0.960	0.947	0.950	0.941	0.942	0.946	0.955	0.947	0.928	0.952	0.945
Hezhen	0.965	0.911	0.962	0.939	0.902	0.907	0.911	0.890	0.942	0.922	0.914	0.925	0.939
Hui	0.927	0.918	0.918	0.897	0.880	0.884	0.882	0.892	0.909	0.907	0.886	0.893	0.884
Jingpo	0.897	0.901	0.905	0.907	0.901	0.893	0.885	0.886	0.892	0.885	0.878	0.874	0.875
Kazak	0.964	0.964	0.961	0.946	0.917	0.920	0.919	0.923	0.932	0.917	0.910	0.917	0.913
Kirgiz	0.995	0.992	0.991	0.982	0.965	0.964	0.966	0.963	0.971	0.954	0.946	0.920	0.949
Lahu	0.946	0.942	0.942	0.944	0.945	0.935	0.933	0.931	0.943	0.937	0.933	0.932	0.928
Lhoba	0.986	0.991	0.989	0.973	0.972	0.973	0.971	0.972	0.958	0.955	0.951	0.952	0.954
Li	0.866	0.841	0.844	0.825	0.849	0.842	0.861	0.844	0.862	0.857	0.852	0.850	0.846
Lisu	0.980	0.981	0.978	0.975	0.968	0.962	0.961	0.967	0.970	0.958	0.954	0.965	0.955
Manchu	0.749	0.749	0.766	0.719	0.739	0.749	0.755	0.747	0.778	0.773	0.790	0.769	0.774
Maonan	1.000	1.000	0.986	0.986	0.985	0.994	0.997	1.000	1.000	1.000	1.000	0.990	0.991
Miao	0.964	0.960	0.956	0.949	0.947	0.946	0.944	0.946	0.956	0.953	0.943	0.940	0.945

(*Continued*)

Table A2. (*Continued*).

Ethnic group	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Mongol	0.945	0.953	0.949	0.915	0.915	0.922	0.917	0.931	0.936	0.940	0.923	0.921	0.929
Mulao	0.850	0.867	0.874	0.861	0.861	0.872	0.868	0.890	0.884	0.894	0.878	0.892	0.900
Naxi	0.990	0.989	0.984	0.990	0.980	0.980	0.980	0.988	0.985	0.976	0.956	0.965	0.960
Nu	1.000	1.000	0.969	0.974	0.956	0.968	0.958	0.975	1.000	1.000	1.000	1.000	1.000
Oroqen	0.901	0.892	0.892	0.769	0.772	0.772	0.771	0.780	0.791	0.806	0.788	0.782	0.795
Qiang	0.942	0.951	0.945	0.926	0.926	0.922	0.911	0.946	0.944	0.962	0.921	0.930	0.949
Salar	0.917	0.894	0.891	0.880	0.884	0.886	0.899	0.914	0.893	0.896	0.879	0.939	0.927
She	0.874	0.862	0.860	0.848	0.850	0.855	0.849	0.861	0.868	0.867	0.841	0.834	0.831
Sui	0.994	0.993	0.990	0.988	0.986	0.982	0.983	0.982	0.980	0.982	0.979	0.983	0.990
Tajik	1.000	1.000	0.999	1.000	0.999	0.999	0.999	0.999	0.999	1.000	0.999	0.999	0.999
Tibetan	0.984	0.984	0.981	0.972	0.972	0.972	0.971	0.973	0.972	0.970	0.968	0.970	0.969
Tu	0.857	0.880	0.867	0.861	0.866	0.865	0.859	0.862	0.857	0.862	0.864	0.858	0.851
Tujia	0.991	0.983	0.984	0.987	0.985	0.984	0.980	0.984	0.992	0.985	0.982	0.986	0.987
Uyghur	0.952	0.952	0.951	0.935	0.898	0.895	0.887	0.888	0.899	0.882	0.870	0.869	0.871
Va	0.934	0.933	0.942	0.939	0.928	0.923	0.929	0.928	0.936	0.928	0.918	0.919	0.923
Xibe	0.828	0.815	0.833	0.793	0.767	0.791	0.777	0.786	0.807	0.768	0.768	0.782	0.796
Yao	0.949	0.949	0.949	0.936	0.940	0.942	0.929	0.933	0.956	0.943	0.931	0.938	0.931
Yi	0.940	0.938	0.934	0.924	0.926	0.931	0.924	0.930	0.934	0.931	0.913	0.914	0.908
Yugur	0.993	0.996	0.996	0.993	0.989	0.993	0.992	0.993	0.980	0.989	0.987	0.978	0.980
Zhuang	0.889	0.895	0.888	0.881	0.889	0.880	0.875	0.892	0.891	0.885	0.867	0.879	0.879

Table A3. Light per capita and GDP per capita for each ethnic group at the year of 2000.

Ethnic group	Light per capita	GDP per capita (1000 RMB)	Ethnic group	Light per capita	GDP per capita (1000 RMB)
Achang	12.673	3.554	Lisu	3.836	3.165
Bai	8.047	4.073	Manchu	25.387	8.706
Blang	5.727	3.740	Maonan	0	4.103
Bonan	1.997	4.634	Miao	2.48	3.542
Bouyei	4.249	3.155	Mongol	17.704	6.158
Dai	9.554	4.257	Mulao	11.155	4.783
Daur	19.916	6.451	Naxi	1.543	3.147
Deang	4.633	3.254	Nu	0	2.559
Derung	0	3.566	Oroqen	26.382	6.958
Dong	1.277	3.500	Qiang	15.888	5.224
Dongxiang	5.728	2.204	Salar	7.562	3.717
Ewenki	10.904	6.228	She	8.533	8.597
Gaoshan	126.089	115.394	Sui	1.931	3.062
Gelao	1.38	3.474	Tajik	0	2.390
Han	12.76	11.401	Tibetan	5.651	3.883
Hani	4.113	3.802	Tu	20.757	4.538
Hezhen	24.539	7.333	Tujia	0.994	4.414
Hui	13.496	6.452	Uyghur	26.874	3.973
Jingpo	12.311	3.511	Va	5.08	2.908
Kazak	26.959	6.190	Xibe	17.923	10.191
Kirgiz	6.429	2.325	Yao	3.917	5.117
Korean	16.83	8.187	Yi	7.148	4.435
Lahu	5.145	3.263	Yugur	18.065	5.904
Lhoba	4.122	6.843	Zhuang	7.129	5.128
Li	16.778	5.769			

Table A4. Ranking of light per capita for ethnic groups (the first ten and last ten) in China from 2001 to 2013.

Ranking	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan	Gaoshan
2	Kazak	Kazak	Yugur	Oroqen	Hezhen	Hezhen	Hezhen	Hezhen	Kazak	Hezhen	Kazak	Kazak	Kazak
3	Uyghur	Uyghur	Kazak	Yugur	Kazak	Kazak	Kazak	Kazak	Manchu	Kazak	Hezhen	Xibe	Xibe
4	Oroqen	Oroqen	Oroqen	Kazak	Oroqen	Uyghur	Uyghur	Manchu	Hezhen	Manchu	Mongol	Mongol	Mongol
5	Manchu	Manchu	Manchu	Hezhen	Manchu	Oroqen	Manchu	Uyghur	Oroqen	Mongol	Daur	Hezhen	Hezhen
6	Hezhen	Hezhen	Uyghur	Manchu	Uyghur	Manchu	Mongol	Mongol	Mongol	Xibe	Xibe	Daur	Oroqen
7	Tu	Yugur	Li	Uyghur	Mongol	Mongol	Oroqen	Oroqen	Korean	Uyghur	Uyghur	Oroqen	Daur
8	Daur	Li	Mongol	Mongol	Yugur	Yugur	Qiang	Jingpo	Xibe	Oroqen	Oroqen	Uyghur	Uyghur
9	Yugur	Xibe	Tu	Qiang	Qiang	Qiang	Jingpo	Li	Daur	Jingpo	Manchu	Manchu	Manchu
10	Xibe	Tu	Korean	Li	Korean	Li	Xibe	Achang	Achang	Achang	Naxi	Li	Li
40	Bonan	Sui	Lhoba	Miao	Lhoba	Blang	Lhoba	Nu	Yao	Yao	Blang	Miao	Lhoba
41	Sui	Bonan	Miao	Naxi	Miao	Miao	Miao	Sui	Miao	Sui	Dong	Dong	Sui
42	Naxi	Naxi	Sui	Sui	Sui	Sui	Sui	Miao	Blang	Miao	Miao	Blang	Dong
43	Gelao	Tujia	Dong	Dong	Blang	Dong	Blang	Blang	Derung	Blang	Sui	Sui	Gelao
44	Dong	Dong	Bonan	Bonan	Dong	Maonan	Dong	Dong	Gelao	Gelao	Gelao	Gelao	Blang
45	Tujia	Gelao	Tujia	Tujia	Gelao	Tajik	Tujia	Tujia	Tajik	Tujia	Tujia	Tujia	Maonan
46	Maonan	Maonan	Gelao	Gelao	Tujia	Gelao	Gelao	Gelao	Tujia	Derung	Tajik	Maonan	Tujia
47	Nu	Nu	Deang	Tajik	Tajik	Tujia	Tajik	Tajik	Deang	Maonan	Derung	Tajik	Tajik
48	Tajik	Tajik	Tajik	Deang	Deang	Deang	Maonan	Derung	Maonan	Nu	Maonan	Derung	Derung
49	Derung	Derung	Derung	Derung	Derung	Derung	Derung	Maonan	Nu	Tajik	Nu	Nu	Nu