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Poverty in China as Seen from Outer Space

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Poverty in China as seen from outer Space*

Ingvild Almås   Åshild Auglænd Johnsen   Andreas Kotsadam

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Abstract

Estimates of poverty are highly sensitive to price and income measures across time and space. This paper offers a complementary approach to traditional poverty measurement that ensures comparability: we use nighttime light as a proxy for poverty measurement. We measure the percentage of populated areas in China with no nighttime light, and the percentage of the population living in these areas. Between 1992 and 2005, both measures reveal a steady decrease in poverty in China. From 2005 to 2010, however, we find no evidence of a significant poverty reduction.

Keywords: China, Poverty, Nighttime light.

JEL classification: I30, I32, O10.

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1 Introduction

Whether the world will attain the first millennium goal of halving world poverty before 2015 depends heavily on poverty reduction in China. China has experienced remarkable growth, and the World Bank (WB) reports that the country has achieved tremendous poverty reduction in the decades following reforms. However, the reported numbers are sensitive to the data and the methods used for comparison. Figure 1 displays different poverty estimates for China, all published by the World Bank.[1] These all show evidence of substantial decreases in poverty, but they also indicate very different *levels* of poverty for the different years. As such, they illustrate how sensitive poverty estimates are to the choice of the income and price data used for comparison.

[Figure 1 about here.]

In this paper, we create a proxy for poverty in China by measuring the prevalence of zero nighttime light. We suggest a spatial measure that provides the percentage of areas with no nighttime light. We also suggest a headcount measure that reports the percentage of the total population living in areas with no nighttime light.[2] As our measures depend on neither income nor price data, and as the definition of no nighttime light is constant over time and space, our measures ensure comparability. It is clear that nighttime light prevalence correlates with consumer welfare and that no nighttime light indicates that an area is relatively poor. Several recent studies have provided empirical evidence showing that nighttime light corresponds well to economic activity and wellbeing (see e.g., Alder et al. (2013), Alesina et al. 2012, Chen and Nordhaus 2011, Doll et al. 2006, Ghosh et al. 2010, Henderson et al. 2012, Michalopoulos and Papaioannou 2013, and Sutton et al. 2007).

However, it is also clear that nighttime light does not measure wellbeing without noise. For example, it is possible that a person living in an area with nighttime light is still hungry and thus would be defined as poor according to some poverty definitions based

[1]The differences result from using various purchasing power parity measures to transfer Chinese incomes into USD, various poverty lines (such as the one or two dollars a day line), and adjusting for cost of living differences *within* China. For other studies of poverty in China, see e.g., Meng et al. (2005) who study urban poverty from 1986 to 2000 and Montalvo and Ravallion (2010) who examine patterns of poverty in both urban and rural areas and variations across rural and urban provinces.

[2]A headcount measure counts the number of people below a certain threshold, which in our case is set at exposure to some nighttime light. Our measure is thus an absolute poverty measure as the poverty line is not defined relative to the distribution of outcomes in the population, i.e., the distribution of nighttime light across the Chinese population.

on hunger. Therefore, our headcount measure does not capture all aspects relevant to human poverty. Hence, we consider our nighttime light measures as complements to existing measures in that they provide a good measure for spatial comparisons — and avoid some of the pitfalls of traditional measures — because they secure comparability across time and space.

We measure nighttime light using images of the Earth taken by satellites in outer space. Since the 1970s, the United States Air Force Defense Meteorological Satellite Program (DMSP) has had satellites circling the Earth 14 times per day, recording the intensity of Earth-based light. From 1992 and onwards, these data were digitalized and made publicly available.

Our results point to two main conclusions. First, there has been a steady decrease in both the percentage of poor areas and headcount poverty from 1992 to 2005. Second, we are unable to identify any comparable significant decrease from 2005 to 2010.

Why is it necessary to suggest and use this complementary approach? In brief, the poverty figures from existing methods are subject to uncertainty relating to the methods used for comparison as well as the lack of data. First, micro data on individual or household income and consumption in China are scarce. Second, there is an ongoing debate about the reliability of the national accounts data often used when survey data are not available.[3] Third, we have reason to be concerned that spatial price differences are not fully accounted for in existing comparisons, and this creates concerns that the within-country distribution of income in China is not well measured (see e.g., Almås and Johnsen 2012, and Gong and Meng 2008).

The fourth reason for using this complementary approach, is that there is no consensus as to how to transform the US dollar into Chinese yuan. To illustrate, the World Bank recently adjusted their cost-of-living calculations, resulting in a significant downward adjustment in Chinese GDP (in international dollars) by some 40 percent (World Bank 2008). This in turn triggered a whole new debate on international comparisons and China's role (see Feenstra et al. 2012, and Hill and Syed 2010). Fifth, somewhat arbitrarily set poverty lines defined by a specific income or expenditure level determine poverty estimates. The main motivation behind these lines was to make international

[3] See Ravallion (2003) for a comparison of the national accounts and survey data and Li and Gibson (2013) for a discussion on the coverage and quality of official Chinese data.

comparisons possible (Chen and Ravallion 2013).[4]

Our approach escapes the difficulties related to the comparability of prices and income over time. Moreover, we have complete data coverage, and our approach anchors the poverty line to a clear definition related to basic needs and wellbeing. One caveat, however, is that our approach relies on population data from China. There is some uncertainty related to these data, as they do not capture population variation within counties and ignore unofficial migration. While this is a challenge faced by all studies using Chinese population data, we should keep it in mind when interpreting the results.

The paper is organized as follows. Section 2 explains our approach and the data used in the analysis. Section 3 discusses the findings. Section 4 concludes.

2 Data and methodology

Our measure of nighttime light is from satellite images from the US Air Force DMSP and its Operational Linescan System. The satellites circle the Earth 14 times each day and record Earth-based lights with their Operational Linescan System for grid cells of 30 arc-seconds (corresponding to approximately 1 km^2). The entire planet between latitudes 65 degrees N and 65 degrees S is covered. This means that, for China, we have information on yearly nighttime light for 13,854,436 areas for the period 1992 to 2010. From 1992 and onwards, these data were digitalized and made publicly available. In order to measure human-generated light, the light data is filtered by purging away observations with forest fires, auroral activity, cloud cover, and those from months when the sun sets late.

We then average the valid data points for each grid cell for each year, and the final measure is a yearly nighttime light measure ranging from zero (no light) to 63. We censor a small number of areas at 63, but as we focus on the lower tail of the distribution, the top coding is of no concern. The nighttime light data we use for China is from six different satellites with partial overlap across years, so we have 31 data sets in total (see

[4] The dollar-a-day measure was established in 1990, based on the observation that many developing countries shared a common poverty line at an income level of about USD 370 per year (Alexander 2012). This was slightly higher than the poverty line used in India at the time (Chen et al. 1994), which in turn had a normative foundation based on nutritional needs and calculated as the expenditure equivalent of 2,100 calories per person per day for urban areas and 2,400 calories for rural areas. However, neither the World Bank nor the Indian government now anchors their respective poverty lines to any specific calorie norm and we must therefore consider both the one-dollar- and two-dollar-a-day measures to be somewhat arbitrary (World Bank 1990; Government of India 2009).

Table 1). We use all the observations we have for the different satellites in our analysis. For a more detailed description of the satellite light data, see, e.g., National Oceanic and Atmospheric Administration (2013), Chen and Nordhaus (2011), Henderson et al. (2012), and Michalopoulos and Papaioannou (2013).

[Table 1 about here.]

Our population data are from the Gridded Population of the World (GPW) data set Version 3 (see also Alesina et al. 2012 for use of the same data in another analysis of nighttime light). Developed by the Center for International Earth Science Network at Columbia University, these data depict the distribution of the human population around the globe. Estimates of population are provided for 2.5 arc-minute grid cells (approximately 5 km^2) for the following years: 1990, 1995, 2000, 2005, and 2010. We use linear interpolations between 1990 and 2010 and adjust the population measures to match the United Nations estimates at the country level (see e.g., CIESIN 2013 for a more detailed description of the population data).

3 Empirical results

3.1 Some descriptive results

Figure 2 shows the prevalence of nighttime light in China for 1992 and 2010. We can see that the light is quite concentrated in the eastern coastal areas, areas characterized as the growth engines of China (Chen and Groenewold 2010, Fu 2004).

[Figure 2 about here.]

Figure 3 depicts the Chinese population density in 1990 and 2010. While some of the areas without light are indeed unpopulated, many areas are populated but have no nighttime light. From 1990 to 2010, the population density in the central urban areas appears to increase, reflecting the increasing pace of urbanization in China.

[Figure 3 about here.]

3.2 Findings

Our first finding is of a steady decline in the percentage of populated areas that have no nighttime light from 1992 to 2010. The upper diagram in Figure 4 displays the change in the percentage of populated areas with no nighttime light. The fitted line is from a quadratic regression explaining no nighttime light by year and year squared, and the results from the spatial regression are presented in column S1 in Table 2. We can see that the fitted line implies that the initial poverty level (populated areas without light) is around 86 percent in 1990, and that it decreases to about 75 percent in 2010. The satellite plots give the fraction of areas with no nighttime light measured by each satellite in each year. These results are based on robust linear probability estimation with satellite fixed effects, and the coefficient estimates are presented in column S2 in Table 2. Both year coefficients (-0.011 and -0.005) imply a significant poverty reduction in this period.[5]

[Figure 4 about here.]

[Table 2 about here.]

The lower diagram in Figure 4 displays the percentage of the Chinese population without nighttime light. The initial poverty level indicated by the population measure is just below 50 percent in 1992, falling to about 30 percent in 2010. As before, the fitted line is from a population-weighted robust linear probability regression with the dependent variable specified as nighttime light and the explanatory variables as the year and year squared (column P1). The satellite plots display the results from a robust linear probability regression adjusted using population weights and satellite fixed effects, with the results presented in column P2 in Table 2. Again, we can see that both year coefficients (-0.026 and -0.008) imply a steady decrease in poverty.

Our second finding states that the declining poverty trend does not continue after 2005. The coefficient estimates in column S1 and P1 (-0.011 and -0.026) suggest that the reduction in poverty is highest in the earliest years as the year coefficient is negative and significant, while the squared year term is significant and positive (0.0002 and 0.007).

[5] The results in column S1 predict that in 2002 the percentage of areas with no nighttime light is equal to 78 percent ($0.8654372 - 0.0109112 * 10 + 0.0002424 * 10^2 = 0.7805652$). The results in column P1 predict the percentage of the population living in areas with no nighttime light to be equal to 33 percent ($0.5074293 - 0.0255278 * 10 + 0.0007416 * 10^2 = 0.3263113$).

In columns S2 and P2, we present the results from robust linear probability regressions with yearly fixed effects and show that the spatial poverty measure declined from 86 percent of populated areas without light in 1992 to 74.8 percent in 2010 (column S2). We also note that while the reduction between 1992 and 2005 averaged 0.8 percentage points ((0.86-0.756)/13) per year, it was less than 0.1 percentage points ((0.752-0.748)/6) per year between 2005 and 2010. Similarly, in column P2 we can see that the decline in the share of population without light decreased by about 1.5 percentage points on average per year until 2005, and then by 0.2 percentage points per year on average between 2005 and 2010.

Hence, although the regression results confirm that for the entire sample period 1992–2010 there has been a decline in poverty in China, Figure 4 suggests that there has been no such decline for the subperiod 2005–2010. The last four columns in Table 2 detail the regression results for this subsample and show that, in fact, we are able to identify a small but significant *increase* in both the percentage of areas and of people with no nighttime light in this period. Although the effect is statistically significant, we can see that the magnitude of the increase is very small and thus may not be significant in an economic sense.

How then do these findings relate to the World Bank results in Figure 1? With the exception of Chen and Ravallion (2013), most of these studies do not cover the period after 2005, but those that do indicate the continuing decline in poverty. Thus, our results for this latter period contrast with the findings in Chen and Ravallion (2013).

4 Concluding remarks

We identify poverty using data on nighttime light, considering an area poor if it has no prevalence of nighttime light. We find that there has been a steady decrease in the prevalence of no nighttime light since 1992, but no significant decrease after 2005. Our approach provides an alternative indicator of poverty that is complementary to existing measures. While the approach addresses some of the difficulties related to measuring and comparing real income across time and space, it cannot capture all dimensions of a complex phenomenon such as poverty. However, several studies have illustrated how nighttime light data can be used for the study of wellbeing. For countries and areas where income and price data are scarce, for developing countries experiencing large transitions, and in settings where normative foundations for measurement matters and comparability issues are endemic, such as poverty measurement, nighttime light data provide a sound complement to existing measures. Hence, our results, together with existing measures, can help us increase knowledge of poverty development in China. Future research will reveal whether the nighttime light data also prove useful in other studies of wellbeing in China, such as in comparisons of cost of living and real income across space and time.

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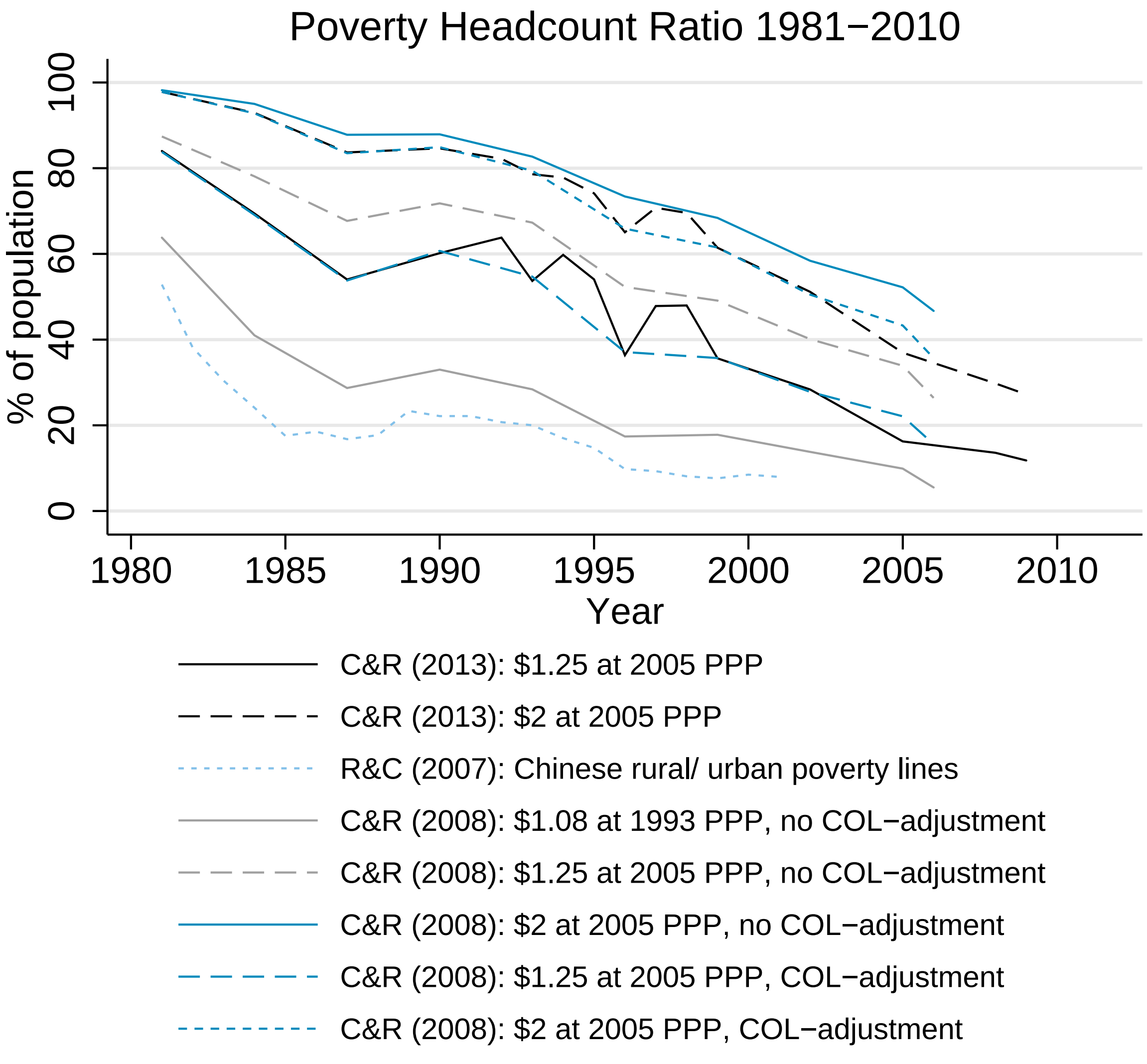
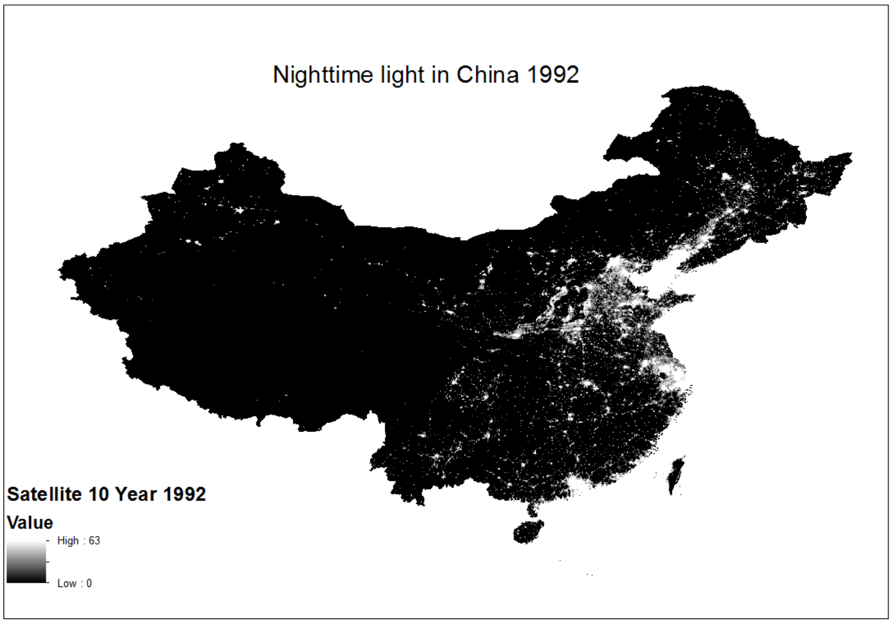
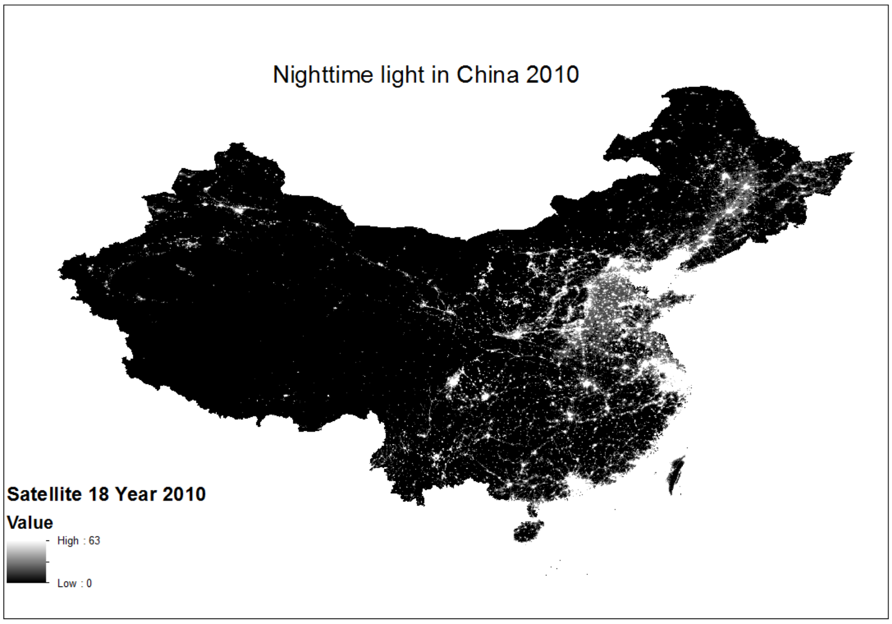
Figure 1: World Bank studies on poverty in China



Note: This figure displays different poverty estimates using the headcount measure for China, all calculated by the World Bank. The differences result from using different purchasing power parity (PPP) measures, different national poverty lines (USD 1.08, USD 1.25 and USD 2.00 a day (2002 prices: CNY 1200 urban, CNY 850 rural), and adjusting for cost-of-living (COL) differences within China.

Figure 2: Nighttime light in China in 1992 and 2010





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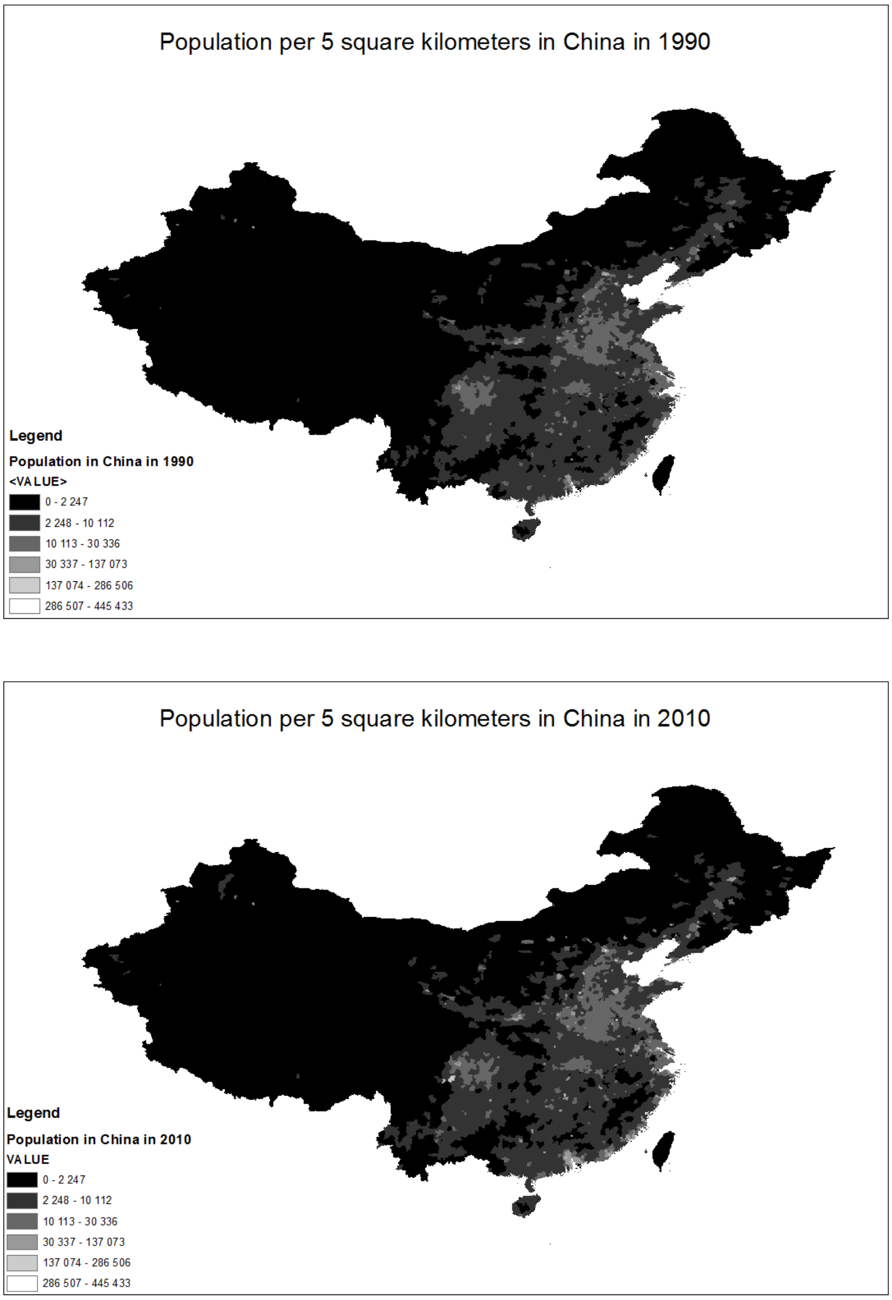
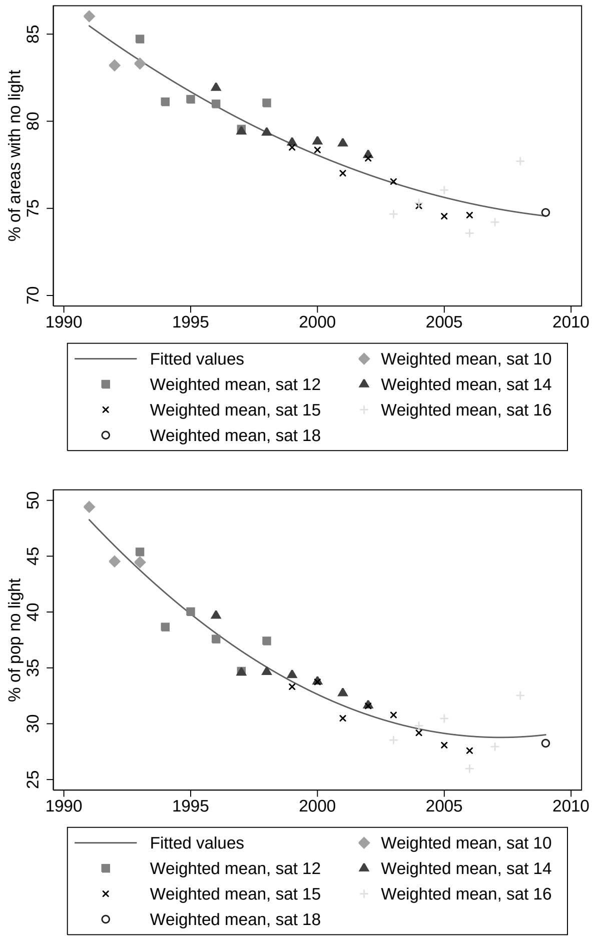
Note: These figures displays the prevalence of nighttime light per 1 km^2 for 1992 and 2010, respectively. Nighttime light for 1992 is provided by satellite F10 (see Table 1), and for 2010 by satellite F18. The lowest value attainable is zero, and this corresponds to the black areas. Light increases in value, and the highest attainable value is 63, which within China only occurs in large metropolitan areas such as Shanghai.

Figure 3: Population for 1990 and 2010



Note: These figures display the population density per 5 km^2 for 1990 and 2010, respectively, divided into different color categories. Brighter colors are associated with higher population densities. The black areas have a population density of less than 2,248 people per 5 km^2, the dark gray areas denote areas with between 2,248 and 10,112 people per 5 km^2, and so on.

Figure 4: Poverty results



Note: The upper part of the diagram displays the change in the percentage of areas where people live that have no nighttime light, and the lower part of the diagram illustrates the change in the percentage of people living in areas with no nighttime light. We use all available satellites in the estimation and the squares represent the estimation results from each satellite.

Table 1: The satellites

Average Visible, Stable Light, & Cloud-free Coverage						
Year\Sat.	**F10**	**F12**	**F14**	**F15**	**F16**	**F18**
1992	F101992	——	——	——	——	——
1993	F101993	——	——	——	——	——
1994	F101994	F121994	——	——	——	——
1995	——	F121995	——	——	——	——
1996	——	F121996	——	——	——	——
1997	——	F121997	F141997	——	——	——
1998	——	F121998	F141998	——	——	——
1999	——	F121999	F141999	——	——	——
2000	——	——	F142000	F152000	——	——
2001	——	——	F142001	F152001	——	——
2002	——	——	F142002	F152002	——	——
2003	——	——	F142003	F152003	——	——
2004	——	——	——	F152004	F162004	——
2005	——	——	——	F152005	F162005	——
2006	——	——	——	F152006	F162006	——
2007	——	——	——	F152007	F162007	——
2008	——	——	——	——	F162008	——
2009	——	——	——	——	F162009	——
2010	——	——	——	——	——	F182010

Note: This table displays the name of the six satellites we used and the years each satellite provided data coverage.

Table 2: Empirical results: areas/population without nighttime light

	S1	P1	S2	P2	S3	P3	S4	P4	S5	P5
Year	-0.011***	-0.026***	-0.005***	-0.008***			0.002***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
Year^2	0.002***	0.007***								
	(0.000)	(0.000)								
F12			-0.011***	-0.042***						
			(0.000)	(0.000)						
F14			-0.016***	-0.057***						
			(0.001)	(0.000)						
F15			-0.027***	-0.066***						
			(0.001)	(0.000)						
F16			-0.027***	-0.054***			0.004***	0.010***		
			(0.001)	(0.000)			(0.000)	(0.000)		
F18			-0.015***	-0.034***			-0.008***	-0.006***		
			(0.001)	(0.000)			(0.001)	(0.000)		
1992					0.860***	0.494***				
					(0.000)	(0.000)				
1993					0.832***	0.445***				
					(0.001)	(0.000)				
1994					0.840***	0.449***				
					(0.000)	(0.000)				
1995					0.811***	0.387***				
					(0.001)	(0.000)				
1996					0.813***	0.400***				
					(0.001)	(0.000)				
1997					0.815***	0.386***				
					(0.000)	(0.000)				
1998					0.795***	0.346***				
					(0.000)	(0.000)				
1999					0.802***	0.360***				
					(0.000)	(0.000)				
2000					0.786***	0.338***				
					(0.000)	(0.000)				
2001					0.786***	0.338***				
					(0.000)	(0.000)				
2002					0.779***	0.316***				
					(0.000)	(0.000)				
2003					0.780***	0.316***				
					(0.000)	(0.000)				
2004					0.756***	0.297***				
					(0.000)	(0.000)				
2005					0.752***	0.295***				
					(0.000)	(0.000)				
2006					0.753***	0.292***				
					(0.000)	(0.000)				
2007					0.741***	0.268***				
					(0.000)	(0.000)				
2008					0.742***	0.279***				
					(0.001)	(0.000)				
2009					0.777***	0.325***				
					(0.001)	(0.000)				
2010					0.748***	0.283***				
					(0.001)	(0.000)				
Const	0.865***	0.507***	0.851***	0.478***			0.717***	0.261***	0.735***	0.278***
	(0.000)	(0.000)	(0.000)	(0.000)			(0.003)	(0.000)	(0.002)	(0.000)
Obs	16 899	2126 399	16 899	2126 399	16 899	2126 399	4 907	629 063	4 907	629 063
R^2	0.005	0.013	0.005	0.013	0.787	0.351	0.000	0.000	0.000	0.000

Note: Standard errors in parentheses, *p<0.1, **p<0.05, ***p<0.01. Observations in thousands. Year^2 has been scaled up by a factor of 10. Fx denotes an indicator variable for satellite x (see Table 1), and 1992–2010 denote indicator variables for the corresponding years. The dependent variable in the regressions denoted Sx (spatial) is the percentage of populated areas with no nighttime light. The dependent variable for the regressions denoted Px (population-weighted) is the percentage of the total population that lives in areas with no nighttime light.