How Dynamics of Urbanization Affect Physical and Mental Health in Urban China*

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Abstract

Using a 2011 national survey of urban residents, irrespective of their official *hukou* status, and the 2000–2009 night-time light data from the Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS), this paper goes beyond the simple dichotomy of migrant versus non-migrant or rural versus urban *hukou* to disentangle the processes of urbanization and migration and their complex associations with health, and assesses the impact of various levels and speed of urbanization on the physical and mental health of current residents in a city or town. By disaggregating urbanization into three discrete dimensions at sub-provincial levels, we find that while a higher absolute level of urbanization at the county level negatively impacted self-reported physical health, faster and accelerating urbanization had a positive impact which could be attributed to the demand-pull effect underlying the healthy migrant phenomenon. By contrast, all three dimensions of urbanization were associated with greater depressive distress and thus had an adverse effect on residents' mental health. Beyond demonstrating how variation in the process and location of urbanization affects individual health, we also illustrate more broadly the value of modelling locational parameters in analyses of individual outcomes based on national samples.

Keywords: urbanization; health; DMSP-OLS night-time light; survey; China

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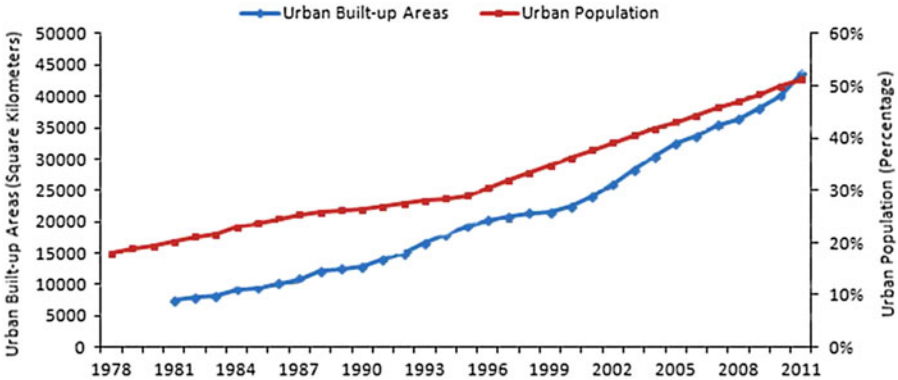
Figure 1: **Urban Built-up Areas and Urban Population, 1978–2011**



Source:

For urban built-up area, *China's Urban Construction Statistical Yearbook 2011*. For urban population, *China Statistical Yearbook 2011*, China Data Online.

(colour online)

Over the past three decades, China has decisively moved from being a rural and agrarian society to one where 51.3 per cent of citizens live in urban districts and work outside of agriculture (see Figure 1).[1] However, simple percentages fail to capture the heterogeneous living conditions that characterize areas officially designated as urban and ignore the fact that nearly half of the 440 million new urban residents have experienced in situ urbanization whereas the rest are temporary rural-to-urban migrants.[2] That is, besides the historically unprecedented internal migration of over 200 million people moving from rural to urban areas, more than 200 million new urbanites have actually never left their home village. Rather, the city came to them, either through relabelling their rural address as a city district or by rapidly expanding into the countryside that surrounded villages.[3]

Beyond these two distinct processes of urbanization, the dynamics of urbanization also vary significantly by decade as well as across the vast continental nation. During the first decade of marketization and the early relaxation of controls on domestic migration, the process of urbanization was mainly driven by rural industrialization through the promotion of township and village enterprises and rural migration to small towns.[4] As the economic reforms accelerated, urban leaders, particularly those in the eastern coastal regions, pushed for new investment and land policies that created dynamic urban economies with vast new infrastructure projects and real estate development that drew millions

1 National Bureau of Statistics of China 2012a. In 1978, 17.9% of the total population lived in cities and towns; by 2011, more than 50% had lived in a city or town during the past 6 months.

2 Chan 2013; National Bureau of Statistics of China 2012b.

3 Ministry of Housing and Rural–Urban Development of China 2012. The total urban built-up area in 2011 was 43,603 square kilometres, almost six times the figure for 1981.

4 Friedmann 2005; Yeh, Xu and Liu 2011.

from the villages of central and western China.[5] Between the 1990 and 2000 censuses, the urban population reported a net gain of 160 million residents.[6] After 2000, the dual processes of incorporating adjacent rural counties within city boundaries and accelerating migration from the countryside further increased the administrative reach of cities and enlarged the urban population. Between 1981 and 1999, the annual expansion of urban built-up areas averaged 800 square kilometres per annum. After 2000, the growth rate more than doubled to 1,700 square kilometres per annum.[7]

Yet, even as China has become an increasingly urbanized society, accurate measurement of both the urban population and the extent of urbanization over the entire land mass has been difficult to verify, and thus researchers assessing the consequences of urbanization on social, economic or political outcomes have yet to agree on a single metric. In this paper, we calibrate the dynamics of urbanization based on the Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS) night-time light data and demonstrate how the level, speed and acceleration/deceleration of urbanization impact physical and mental health.[8] First, we used the 2009 DMSP-OLS data to select our secondary sampling units for the 2011 Migration and Quality of Life Survey, which we conducted in collaboration with the Research Center for Contemporary China (RCCC) at Peking University, so that we could sample all those people living in an urban area, regardless of their *hukou* 户口 (household registration) status and if the area in which they lived had been officially designated as urban. Second, we employed the 2000–2009 DMSP-OLS night-time light data to measure the changing level and speed of urbanization in 31 counties or urban districts in our study sample. Linking the county-level urbanization measures with the survey data, we then were able to estimate the impact of the changing level and speed of urbanization on the physical and mental health of all residents residing in urban areas. In this way, we believe that, for the first time, social scientists have been able to estimate how the dynamics of urbanization affect the quality of life – in this case, the residents' health outcomes.

Measuring the Dynamics of Urbanization

Indicators capable of measuring urbanization as a process and sensitive enough to track changes over time and region are elusive, and only recently do we find work that has developed continuous measures of levels of urbanization. Two of the most comprehensive measures have been done by van de Poel, O'Donnell and van Doorslaer, who used data from the China Health and

5 Lin, George C.S. 2007; Yeh, Xu and Liu 2011.
6 Zhou and Ma 2003, 177.
7 Yeh, Xu and Liu 2011, 8.
8 The DMSP-OLS data are satellite images with a night-time light index ranging from 0 to 63 at the pixel level. The data are publicly available at: http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html. Accessed 18 October 2014.

Nutrition Survey to develop an index based on factor analysis of a broad set of community characteristics (e.g. population size, proportion of workforce engaged in agriculture, proximity to health and educational facilities, presence of paved roads, shops and restaurants), and Jones-Smith and Popkin, who added characteristics beyond those derived by van de Poel and her colleagues from factor analysis.[9] In a more recent study, Li Xinhu and colleagues used remote-sensing image analysis based on the night-time images gathered by the DMSP-OLS annually since 1992 and mapped urbanization dynamics on a national scale.[10] In addition, teams led by He Chunyang, Sun Rui, and Wang Lei 王雷 have also used night-time light change as metric of urban expansion.[11] Unfortunately, like Li Xinhu and colleagues, no one has yet considered the effects of changes in the night-time light over time. Moreover, Li Xinhu and colleagues only applied an urban–rural dichotomy in their analysis of the association between urbanization and human health at an aggregate level.

While the above-mentioned studies have concluded that the DMSP-OLS night-time light data can be used reliably as markers of urbanization in China, there are concerns that variation in night-time light does not accurately capture urbanization because it also reflects the location of large infrastructure projects or transportation hubs and corridors. Another concern is that heterogeneity of energy efficiency across space prevents accurate comparisons. In other words, because some of the largest cities may more effectively conserve night-time light than less completely urbanized areas, a night-time light index may misrepresent the level and degree of difference. Finally, because about 0.1 per cent of the data is censored at the maximum value of 63, one could also worry that the index understates the level of urbanization of the brightest areas.[12]

In our analysis, we used several strategies to address these concerns. First, we used processed images from which transient lights were already removed by DMSP-OLS, thus alleviating the concern that the brightness generated by fires, traffic or temporary industrial sites may contaminate the analysis. We then intersected the light data with the GIS shapefile of China at the county level, which allowed us to assign precisely each pixel to the county unit to which it belongs. This geo-referenced dataset, organized as a time-series cross section of pixels belonging to all county units in the sample, was then used to estimate the parameters of interest. We used multi-way "fixed effects" to peel away unobserved heterogeneity that might be otherwise due to unobserved characteristics of the

9 Van de Poel, O'Donnell and van Doorslaer 2009; Jones-Smith and Popkin 2010. The construction of such indices and scales requires longitudinal survey data that collects information at the neighbourhood and village level. In the China Health and Nutrition Survey, field interviews were held with community leaders to learn about the public infrastructure and with community health workers to gain information on health-care provision. The project is unique in its focus on the ways in which the social and economic transformation of Chinese society has affected its population's health. However, the longitudinal and multi-level data suffer from sampling bias, panel attrition and reporting errors.

10 Li, Xinhu, et al. 2012.

11 He et al. 2012; Sun, Zhang and Wang 2009; Wang et al. 2012.

12 Henderson, Storeygard and Weil 2012.

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satellite, the county, or the year of its observation.[13] We are thus confident that both the quality of the imagery and the specific techniques used to estimate our parameters of interest effectively rule out these possible objections to using these data at the county level.[14]

In Figure 2, we use a series of maps of China that present the intensity of night-time light of three values (10, 30 and 50) at the pixel level to illustrate the patterns of change at two points in time (1992 and 2009). Using a low benchmark of 10, a great deal of the territory would be considered urban, whereas a much stricter threshold of 50 shrinks urban spaces excessively. In our 2011 Migration and Quality of Life Survey, we chose a threshold of 30 to define the sample frame of physical areas deemed "urban." We chose this threshold iteratively, first by checking the night-time light data against available Google Earth imagery in order to ensure that we did not miss areas that were urban or include areas that were not urban. We also used the backlog of prior spatial samples taken by our partners at RCCC to compare the population density of sampling locations they had enumerated in the past with the locations we had chosen by the pixel values of night-time light data.[15] This process led to the decision that the value of 30 was the most appropriate threshold of urbanity. We thus assumed that every secondary sampling unit with an average reading of 30 or higher would be considered urban and included it in the sample frame to select the respondents for the survey. Using this threshold, we can see why the story of urbanization in China must go beyond the usual contrasts between coastal China versus the hinterland and also address the transformation of the North China Plain (see Figure 2).

Our goal is to see how variation in urbanization over time impacted subjects' health in 2011, and so we further use the DMSP-OLS night-time light data for the preceding decade (2000–2009) to measure the dynamics at the county level. To calculate the level and speed of urbanization, we first extracted the 2000–2009 DMSP-OLS night-time light data for all pixels in each of the 31 counties or city districts in our study sample. Using brightness as the dependent variable in an ordinary least squares (OLS) regression with time, county, and satellite fixed effects, we then estimated the intercepts and the coefficients on year and year-squared for each county.[16] We extracted the intercept for 2000 as the

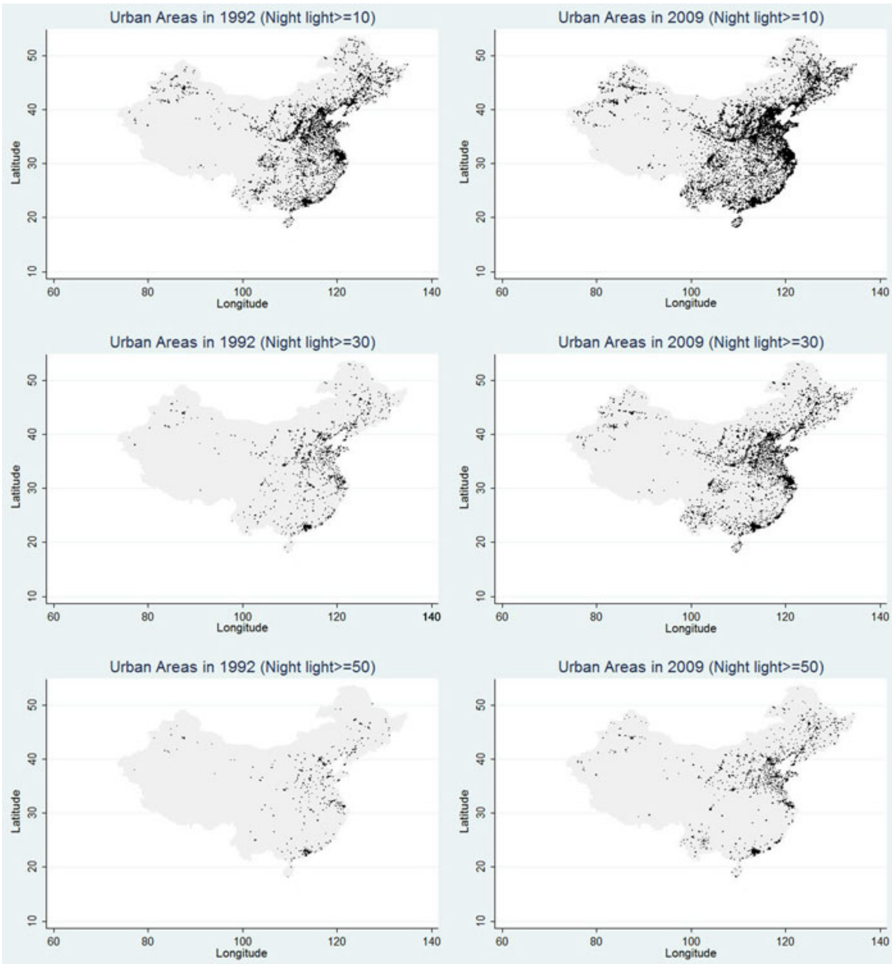
13 In our following estimation using the 2000–2009 DMSP-OLS night-time light data to measure the dynamics of urbanization at the county level, we controlled fixed effects by satellite, by county, and by year in the regression to remove the heterogeneity.

14 One may also note that the night-time light data are entirely independent of measures collected by local governments in China who may have strong incentives to overstate the true degree of urbanization in their localities in order to meet developmental targets assigned by higher-level authorities or fail to report disappointing statistics. In this regard, our measures are superior to government data.

15 Over the years, researchers and staff at RCCC have successfully designed, organized and conducted numerous survey projects in urban and rural areas using the GPS/GIS assisted area sampling method, which has the significant advantage of correcting the bias caused by coverage errors in list-based samples. For details, please see: http://www.rcccpku.org.

16 In addition to fixed effect by satellite, we also included fixed effects by county and by year. We thus computed parameters (county specific coefficients) that removed the heterogeneity that may be a concern while using night-time light data.

Figure 2: **Urban Areas Delineated by DMSP-OLS Night-time Light, 1992 and 2009**



Source:

DMSP-OLS night-time light data, http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html.

Note:

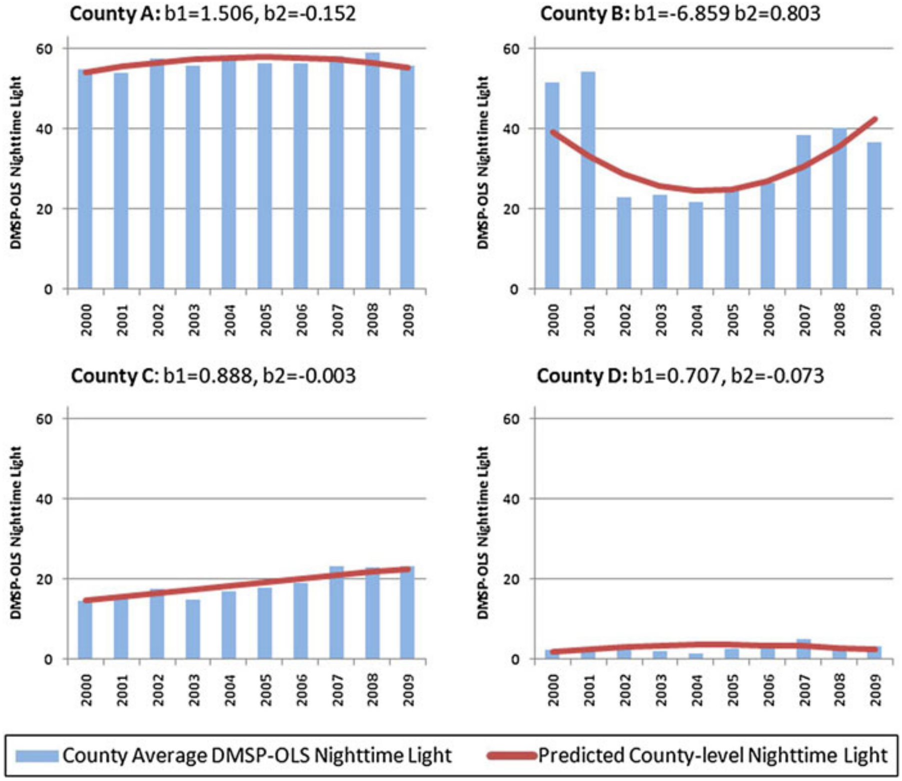
We only present the DMSP-OLS night-time light data in mainland China.

(colour online)

measure of the initial level of urbanization during the ten-year period, the coefficient on year as the measure of speed of urbanization between 2000 and 2009, and the coefficient on year-squared to indicate whether the process is accelerating or decelerating. In this way, we construct three measures that permit rigorous comparisons of the changing level of urbanization across counties from 2000 to 2009.

Figure 3 demonstrates the power of our approach by illustrating both the original level of night-time light and the distinctive estimated trajectories between 2000 and 2009 in four sample counties in our survey. County A is an urban

Figure 3: **Dynamics of Urbanization in Four Sample Counties, 2000–2009**



Source:

DMSP-OLS night-time light data, http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html.

Note:

b1, speed of urbanization between 2000 and 2009; b2, acceleration/deceleration between 2000 and 2009.

(colour online)

district in a provincial municipality on the east coast of China. The urban built-up area of County A more than doubled from 2000 to 2010. Although its *hukou* population remained stable, the total population residing in the area of County A, as of 2010, had increased by more than 40 per cent, mostly owing to an influx of urban and rural migrants from other provinces. As shown in Figure 3, even in 2000, the urbanization level in County A was already very high. During the following decade, the urbanization process continued but at a decelerating speed. To capture the speed of urbanization, we used the regression estimate of the impact of time. To estimate acceleration or deceleration, we used a second coefficient on time-squared. When the latter is positive, the county's trajectory accelerated. Thus, for County A, the speed of urbanization is represented by b1 = 1.056 and acceleration/deceleration is b2 = −0.152. County B is an urban district in a prefecture in southern China, where there has been a significant amount of demolition of old buildings and the construction of new urban developments since 2000. Owing to changes in administrative boundaries, the urban

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built-up area expanded nearly sixteen-fold from 2000 to 2010, and its urban population more than doubled due to both rural-to-urban migration and in situ urbanization. Also of note in Figure 3 is how the urbanization process in County B between 2000 and 2009 followed a U-shaped pattern, first decreasing and then later increasing rapidly. Thus, the speed of urbanization (b1 = −6.859) is the fastest of all counties after 2004 as is the acceleration (b2 = 0.803). The negative coefficient for b1 reflects the process of widespread urban reconstruction of the urban centre during which many pre-existing buildings were demolished. County C is a county-level city located in northern China. Its proportion of urban population increased steadily, from 39.4 per cent in 2000 to 46.8 per cent in 2010. As shown in Figure 3, the urbanization process in County C began at a much lower level than in counties A and B, and between 2000 and 2009 increased slowly but steadily (b1 = 0.888 and b2 = −0.003). At the very centre of the rapid urbanization of northern China as summarized by the maps in Figure 2, County C illustrates the typical story of steady urbanization across the North China Plain. County D is a traditional agricultural and migrant labour-outsourcing county in central China. Between 2000 and 2010, its *hukou* population increased by 137,300 but the total population of County D decreased by 151,700. Thus, the level of urbanization in County D shown in Figure 3 is consistently low and the overall pace of urbanization remains slow over the entire decade, and slightly decelerates after 2003 (b1 = 0.707 and b2 = −0.073). [17]

We are hardly alone in emphasizing how uneven China's urbanization has been and how the general label of urban, or even the distinction between city and town, fails to capture the heterogeneity of these locations. But, as these four examples indicate, our use of night-time light offers an especially accessible and transparent measure of the dynamic reality of urbanization. It allows us to define a threshold for "urban" and to create a metric that systematically estimates its variation over time. We thus capture the actual process of urbanization, regardless of the official categories that the government assigns to residents or county units. We turn now from this discussion of measurement of the intensity, direction and dynamics of urbanization to previous work on how urbanization impacts individual health.

Urbanization and Health

Urban living has both positive and negative consequences for individuals' health. On the one hand, cities may provide superior facilities than those in the countryside; on the other, rapid and continuing urbanization may increase environmental pollution and promote unhealthy life styles.[18] The negative effects can be

17 Data about the urban built-up area and population change in the four sample counties were retrieved from Ministry of Civil Affairs of China 2001, 2011, and National Bureau of Statistics of China 2002, 2012b, respectively.

18 Galea, Freudenberg and Vlahov 2005; Li, Xinhu, et al. 2012; Macintyre, Ellaway and Cummins 2002; Moore, Gould and Keary 2003; WHO 2008; WHO and UN Habitat 2010.

experienced directly, through poor air and water quality and physical exposure that damages human health, or indirectly, through perception of risk and attendant chronic stress, which also have a detrimental effect on health.[19] Studies have documented the various adverse effects of urbanization on both physical and mental health. For instance, urban noise has adverse effects on human health.[20] Growing reliance on automobiles, high calorie fast food and sedentary work may lead to unhealthy weight gain and cardiovascular diseases.[21] Meanwhile, the fast pace of urban life contributes to mental distress and its physical manifestations.[22] Traffic-related stress, in particular, can have a negative effect on self-rated physical health and increase depressive symptoms.[23]

China has not escaped these negative impacts of urbanization on health. Using data from a 2009 national survey, Chen, Chen and Landry found that perceived environmental hazards were associated with county-level industrialization and economic development, and that perceived environmental risk factors severely affected the physical and mental health of the respondents.[24] In an early community-based study, Weng Xiaoping and colleagues report that dwelling in urban areas is associated with higher dietary fat intake and lower occupational physical activity.[25] Basing their analysis on data from the China Health and Nutrition Survey, Keri Monda and colleagues used a detailed measure of urbanity that included ten dimensions of the urban experience and found that urbanization reduced the intensity of occupational activity.[26] Also using data from the China Health and Nutrition Survey, van de Poel, O'Donnell and van Doorslaer found that urbanization increases the probability of reported poor health and that the probability increases with the degree of urbanization; moreover, the effect appears to operate through certain health behaviour that is associated with urban lifestyle, particularly higher fat intake.[27]

Existing research on urbanization and health, however, has focused primarily on the association between level of urbanization and health outcomes and does not consider the consequences of the dynamics of urbanization or the high degree of unevenness both across space and over time. Moreover, the few studies that have examined urbanization and health in the Chinese context generally juxtapose permanent urban residents and rural residents according to *hukou* status, [28] and do not consider either rural-to-urban migrants, or in situ urbanized rural residents who make up a significant percentage of the current urban population.[29]

19 Peek et al. 2009; Chen, Chen and Landry 2013.
20 Fyhri and Aasvang 2010; King and Davis 2003; Rabinowitz 2005.
21 Popkin 2004.
22 Harpham 1994.
23 Gee and Takeuchi 2004.
24 Chen, Chen and Landry 2013.
25 Weng et al. 2007.
26 Monda et al. 2007.
27 Van de Poel, O'Donnell and van Doorslaer 2012.
28 Jones-Smith and Popkin 2010; Monda et al. 2007; Weng et al. 2007; van de Poel, O'Donnell and van Doorslaer 2009, 2012.
29 Chan 2013.

To date, one of the most robust findings coming from cross-national research on health is the phenomenon of the healthy migrant, whereby those who migrate from developing countries to the United States, Canada, Australia and Western Europe, tend to report better physical and mental health than the native-born population in the new countries of residence.[30] Previous research confirms that among internal rural-to-urban migrants in China, one observes the same pattern on physical health, that is, owing to self-selection, rural-to-urban migrants on average are healthier than both the urban population and their rural counterparts.[31] However, existing studies tend to focus on rural migrants in large cities such as Beijing, Shanghai, Guangzhou and Shenzhen. Much less research has been conducted in medium and small cities and towns, where more than three-quarters of rural-to-urban migrants reside[32] and where a faster and accelerated urbanization process is more likely (as indicated in Figure 3). The questions of whether the healthiest villagers move to first tier or second tier cities, or whether different dynamics of urbanization affect health differently have not been asked.

In this article, we want to emphasize that urbanization must be understood as a multi-faceted process in which one facet may work in an opposite direction to the others. Particularly, because we have a representative sample of people living in a range of settlements, including both those who are long-term urban residents and those who live in the city but retain a rural *hukou* (either rural-to-urban migrants or in situ urbanized rural residents), the research question we address is whether living in a city or town of more intense and speedy urbanization positively affects physical health as distinct from the overall correlation between higher levels of urbanization and poorer health. We speculate that the positive effects may actually occur either because of the benefits of superior or improved health-care facilities and services in urban areas or because the healthy migrant phenomenon is more likely to be observed in places experiencing faster and accelerated urbanization.

Previous research has repeatedly demonstrated that fast and accelerated urbanization can promote psychological distress and mental disorders. Long-term urban residents are likely to demonstrate negative mental health effects owing to increasing exposure to a crowded and polluted environment and harmful urban life.[33] For rural-to-urban migrants and in situ urbanized rural residents, mental health problems may be caused, or further aggravated, by the stresses of adaptation to an unfamiliar society and stressful lifestyle change. Studies have documented that the healthy migrant phenomenon was not observed among rural-to-urban migrants with regards to their mental health; instead, migrants report either a poorer or similar mental health status to that of

30 Escobar, Nervi and Gara 2000; Fennelly 2007; Frisbie, Cho and Hummer 2001; Mcdonald and Kennedy 2004.

31 Chen 2011; Hu, Cook and Salazar 2008; Mou et al. 2013; Tong and Piotrowski 2012.

32 National Bureau of Statistics of China 2012b.

33 Gong et al. 2012.

urbanites.[34] Thus, a more dynamic urbanization process may adversely affect the mental health status of both long-term urban residents and recent urbanites.

To our knowledge, no empirical study in China has yet rigorously tested the impact of the variation in the intensity or speed of urbanization at the county level or assessed the impact of the dynamics of urbanization on health while controlling for individual age, gender, marital status, ethnicity, education, employment, or household wealth.[35] Therefore, by linking estimates of county-level urbanization over the first decade of the 21st century with the results from a nationally representative survey of urban residents regardless of their official *hukou* status, our study for the first time offers robust statistical models that estimate the effects of the dynamics of urbanization on both physical and mental health status among all those currently residing in Chinese cities and towns.

We hypothesize that overall county-level urbanization will be negatively associated with individual physical and mental health status, but that the dynamics of urbanization (speed and acceleration/deceleration) will have additional, and independent, effects. More specifically, higher levels of urbanization are likely to have negative impacts on both physical and mental health, but the trajectories of the dynamics of urbanization will alter the strength and perhaps even the valence of the effect on physical and mental health in different ways. For physical health, faster and accelerating urbanization is likely to pull more healthy migrants from rural areas and thus will appear as a positive force on residents' self-rated health. By contrast, faster and accelerated urbanization will intensify psychological distress among all those living in urban areas and will therefore have an adverse effect on mental health.

Data and Measures

The health and socio-demographic data for this study came from the 2011 Migration and Quality of Life Survey we completed in collaboration with RCCC in May and June 2011. Using spatial probability sampling specifically designed to reach urban residents regardless of their *hukou* status,[36] we first randomly selected 26 primary sampling units (PSU) based on the local population density,[37] and then within each PSU randomly selected two secondary sampling units (SSUs) in areas where the average DMSP-OLS night-time light was higher than 30 on a scale of 0–63. From these 26 PSUs and 52 SSUs spread over 19 provinces, 27 prefectures and 31 counties or city districts, we randomly sampled a total of 1,906 households and successfully interviewed 1,288 individuals,

34 Chen 2011; Li, Lu, et al. 2007; Li, Xiaoming, et al. 2009.

35 Jones-Smith and Popkin 2010; Monda et al. 2007; Weng et al. 2007; van de Poel, O'Donnell and van Doorslaer 2009, 2012.

36 Landry and Shen 2005.

37 The PSUs were randomly selected within strata using the probability proportionate to size (PPS) method from a spatial sampling frame of China. The strata were seven geographical areas in nature. The local population density was computed by combining census statistics with information gained from satellite images of the sampled spaces.

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achieving a response rate of 67.6 per cent.[38] Twenty-nine cases were excluded owing to missing data, leaving a sample of 1,259 for the analysis.

To assess a respondent's physical health, we used the respondents' self-rated health status on a five-point scale, where 1 was "very poor" and 5 was "very good."[39] Mental health was assessed using the short form of the Center of Epidemiological Studies Depression Scale (CES-D), which ranges from 0 to 24.[40] Demographic characteristics included age, gender, marital status and ethnicity. Socio-economic status was gauged by education, employment and household wealth.[41] We coded current migration and *hukou* status into five categories: urban residents with urban *hukou* in the county; cross-county urban-to-urban migrants with urban *hukou* not in the county; cross-county rural-to-urban migrants with rural *hukou* not in the county; within-county rural-to-urban migrants with rural *hukou* in the county; and in situ urbanized rural residents with rural *hukou* in the county. Length of residence in the current locale was measured in years, ranging from 0.083 (one month) to 70 years.

In Table 1, we summarize the descriptive statistics on all variables in the analysis.

Dynamics of Urbanization and Physical Health

In Table 2, we display the ordered logistic regression results on self-rated physical health.[42] Model 1 only includes individual socio-demographic characteristics, migration and *hukou* status, and length of residence in the current locale. The results indicate that younger and married people reported better heath with statistical significance. However, education, work status and household wealth had no statistically significant impact. Minority ethnicity did not make a statistically significant difference either. Compared with urban residents with *hukou* in the county, cross-county rural-to-urban migrants reported significantly better self-rated physical health, which is consistent with the healthy migrant phenomenon.

In Models 2 and 3 in Table 2, we weigh the impact of the characteristics of the county or city district in which respondents currently reside. Model 2 includes

38 All interviews were conducted in person by trained interviewers. The average length of the interviews was 38.3 minutes. To ensure quality control, a random sample of participants was called back to validate the data.

39 The self-rated physical health measure has been used in numerous health and social surveys in China, including a number of our prior studies. See Chen 2011, 2012, 2013; Chen, Chen and Landry 2013.

40 The short form CES-D, an 8-item questionnaire that measures depressive symptoms experienced during the previous week, was administered in the survey. The CES-D was first introduced in China in the 1990s and its validity and reliability have been tested in various studies. See, e.g., Boey 1999; Chen 2013; Chen, Chen and Landry 2013; Yang et al. 2005; Zhang et al. 2011. The Cronbach's α was 0.76 for the study sample. The final score is calculated by the sum of the scores for each response, ranging from 0 to 24, with higher scores indicating higher levels of depressive distress.

41 To estimate household wealth, we used an index which is the sum of ownership of motor cycle, car, refrigerator, colour TV, computer, camera, telephone, cellphone, washing machine, water dispenser, piano and video camera, ranging from 0 to 12. Similar indices have been used by Landry, Davis and Wang 2010 and Adams and Hannum 2005.

42 We estimated ordered logistic regressions because self-rated physical health was an ordinal variable measured on a five-point scale.

Table 1: **Descriptive Statistics of Individual and County-Level Variables**

	Mean/ percentage	Standard deviation	Min	Max
Individual characteristics (n = 1,251)				
Self-rated physical health (mean)	4.125	0.096	1	5
CES-D depressive distress (mean)	6.203	0.590	0	24
Age (years, mean)	42.737	2.285	18	70
Gender (female, %)	50.089		0	1
Marital status (married, %)	86.258		0	1
Ethnicity (ethnic minority, %)	2.857		0	1
Education (years of schooling, mean)	9.089	1.180	0	22
Employment (employed, %)	62.398		0	1
Household wealth (index, mean)	6.121	0.713	0	12
Migration and *hukou* status (%)				
Urban residents (urban *hukou* in current county)	52.116		0	1
Cross-county urban-to-urban migrants (urban *hukou* not in current county)	5.124		0	1
Cross-county rural-to-urban migrants (rural *hukou* not in current county)	16.336		0	1
Within-county rural-to-urban migrants (rural *hukou* in current county)	1.742		0	1
In situ urbanized rural residents (rural *hukou* in current county)	24.683		0	1
Length of residence in current locale (years, mean)	27.781	5.277	0.083	70
County-level urbanization measures (n = 31)				
Level of urbanization in 2000 (mean)	10.607	14.126	0.020	54.110
Speed of urbanization 2000–2009 (mean)	−0.365	2.791	−8.002	1.651
Acceleration/deceleration 2000–2009 (mean)	0.050	0.277	−0.152	0.842

Note:

Survey design effects (strata, clusters and sampling weights) are adjusted in the mean/percentage estimations of individual characteristics.

county-level fixed effects and shows the coefficients of the four sample counties illustrated in Figure 3. As shown by the coefficients reported, the relationship between urbanization and physical health among these four sample counties is portrayed as an inverted U-shaped pattern. Respondents in counties A, B and D reported poorer physical health than those in County C. The negative and significant coefficients of the more urbanized counties (A and B) support the view that urbanization has a negative effect on physical health. Still, the respondents in County D, the least urbanized county, also reported poorer physical health. Also of note in Model 2 is that once we included county-level fixed effects, the significant coefficient of cross-county rural-to-urban migrants in Model 1 shrank from 1.344 to 0.453 and became insignificant, which indicates that certain county-level characteristics are correlated with individual migration and *hukou* status.

Model 3 in Table 2 includes the three measures of the dynamics of urbanization during the past decade for each county: level in 2000, speed between 2000

Table 2: **Ordered Logistic Regressions on Self-Rated Physical Health (n = 1,251)**

	Self-Rated Physical Health		
	Model 1	**Model 2**	**Model 3**
Individual characteristics			
Age (years)	−0.072***	−0.059**	−0.061***
	(0.016)	(0.016)	(0.015)
Gender (female)	0.026	0.070	0.019
	(0.212)	(0.259)	(0.205)
Marital status (married)	1.293*	1.454*	1.267*
	(0.497)	(0.546)	(0.497)
Ethnicity (ethnic minority)	−0.585	−0.562	−0.783*
	(0.389)	(0.306)	(0.372)
Education (years of schooling)	0.030	0.103**	0.053**
	(0.018)	(0.028)	(0.018)
Employment (employed)	−0.467	−0.315	−0.412
	(0.349)	(0.419)	(0.341)
Household wealth (index)	−0.016	−0.052	−0.013
	(0.098)	(0.096)	(0.106)
Migration and *hukou* status			
Urban residents (reference group)	–	–	–
	–	–	–
Cross-county urban-to-urban migrants	0.055	−0.695	−0.397
	(0.479)	(0.497)	(0.568)
Cross-county rural-to-urban migrants	1.344*	0.453	0.928
	(0.515)	(0.384)	(0.555)
Within-county rural-to-urban migrants	0.563	0.289	0.189
	(0.831)	(0.568)	(0.788)
In situ urbanized rural residents	−0.134	−0.134	−0.168
	(0.260)	(0.115)	(0.256)
Length of residence in current locale (years)	0.014	−0.009	0.004
	(0.007)	(0.009)	(0.008)
County-level fixed effects			
County A		−2.889***	
		(0.474)	
County B		−2.281***	
		(0.281)	
County C (reference)		–	
		–	
County D		−2.975***	
		(0.243)	
Other counties		Available upon request	
County-level urbanization measures			
Level of urbanization in 2000			−0.018*
			(0.008)
Speed of urbanization 2000–2009			0.737*
			(0.306)
Acceleration/deceleration 2000–2009			6.510*
			(2.829)

Continued

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Table 2: **Continued**

	Self-Rated Physical Health		
	Model 1	**Model 2**	**Model 3**
Constants			
Cut 1	−6.774***	−8.201***	−6.517***
	(1.331)	(1.579)	(1.357)
Cut 2	−4.343**	−5.639**	−4.059*
	(1.472)	(1.534)	(1.497)
Cut 3	−3.061*	−4.203**	−2.749
	(1.396)	(1.454)	(1.413)
Cut 4	−1.098	−1.989	−0.735
	(1.454)	(1.565)	(1.466)
Wald F statistics	33.24 (12,19)	196.07 (42,19)	42.09 (12,19)

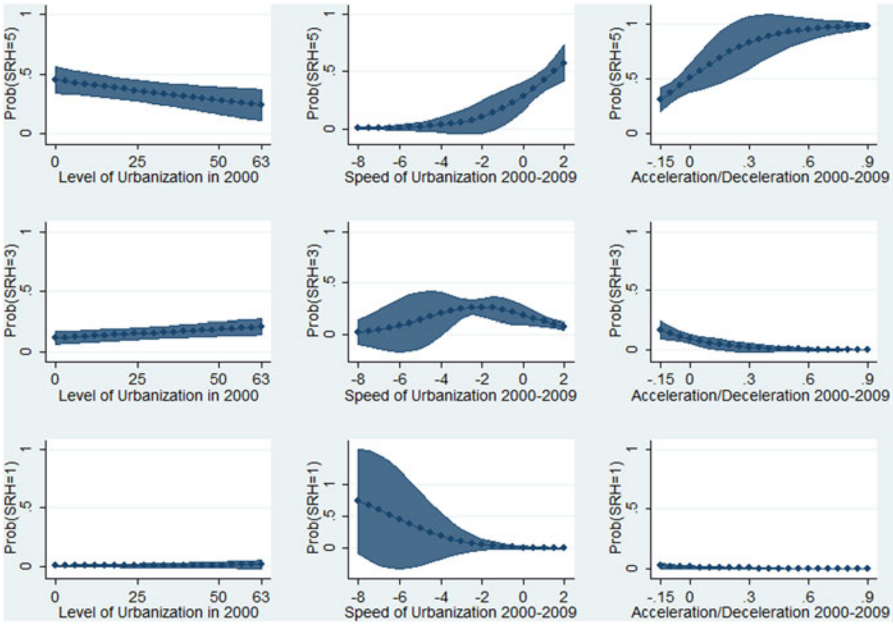
Notes:

Survey design effects (strata, clusters and sampling weights) are adjusted in the model estimations. Coefficients are reported; standard errors in parentheses. * $p<0.05$, ** $p < 0.01$, *** $p < 0.001$.

and 2009, and acceleration/deceleration between 2000 and 2009. Here, we begin to see why both single measures of urbanization and measures that fail to capture variation at the county level cannot accurately estimate how urbanization affects an individual's health after one has controlled for the key individual demographic and socio-economic characteristics and length of residence in the current locale. The coefficients on the three measures of urbanization in the ordered logistic regression indicate that while overall higher level of urbanization continues to be significantly associated with worse self-rated physical health, a faster and accelerating urbanization leads to better self-rated physical health. In short, urbanization must be understood as a multi-faceted process in which one facet may work in an opposite direction from the others. Again, the prior significant coefficient of cross-county rural-to-urban migrants in Model 1 was reduced from 1.344 to 0.928 and became insignificant in Model 3, which suggests that a faster and accelerating urbanization process could attract healthy migrants who choose to cross county borders.

To illustrate more fully the complex associations between the separate dynamics of urbanization and physical health, we further graph the predicted probabilities of self-rated physical health (SRH), being "very good" (SRH = 5), "fair" (SRH = 3), and "very bad" (SRH = 1), with 95 per cent confidence intervals according to the level, speed and acceleration/deceleration of urbanization in Figure 4. The three graphs in the top row demonstrate how the probability of self-rated physical health being "very good" (SRH = 5) changes as the three measures of urbanization vary, but other variables are held at their means. We can see from the first graph in the top row, as the level of urbanization increases from 0 to 63, the predicted probability of SRH = 5 decreases from 0.443 to 0.207. In contrast, the second graph in the top row shows that as the speed of urbanization changes from −8 to 2, the predicted probability of SRH = 5 increases from 0 to 0.595. The third graph further demonstrates that when the acceleration/deceleration changes from −0.15 to 0.9, the predicted probability of SRH = 5 increases from 0.272 to

Figure 4: **Predicted Self-Rated Physical Health and Dynamics of Urbanization**



Note:

The graphs are drawn based on results from the ordered logistic regression of Model 3 in Table 2. The graphs present the predicted probabilities of self-rated physical health (SRH) being "very good" (SRH = 5), "fair" (SRH = 3), and "very bad" (SRH = 1) with 95% confidence intervals, respectively, when the level of urbanization, the speed of urbanization, and the acceleration/deceleration change from minimum to maximum, holding other variables at their means.

(colour online)

0.997. Now we look at the three graphs in the bottom row that display the predicted probabilities of self-rated physical health being "very bad" (SRH = 1) according to the three measures of urbanization. The most prominent effect we notice in the second graph is that, holding other variables at their means, when the speed of urbanization changes from -8 to 2, the predicted probability of SRH = 1 decreases from 0.770 to 0.002. These results indicate that faster and accelerating urbanization appears to be a positive force on residents' self-rated physical health by increasing the predicted probability of self-rated physical health being "very good" and decreasing the predicted probability of self-rated physical health being "very bad."

Dynamics of Urbanization and Mental Health

In Table 3, we turn from analysis of self-rated physical health to that of CES-D depressive distress. Model 1 presents the OLS regression results when we consider only individual characteristics, and Models 2 and 3 add the county effects.[43] The results in Model 1 with only individual characteristics indicate that older people,

43 We estimated OLS regressions because CES-D depressive distress was coded as a continuous variable ranging from 0 to 24.

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Table 3: **OLS Regressions on CES-D Depressive Distress (n = 1,251)**

	CES-D Depressive Distress		
	Model 1	Model 2	Model 3
Individual characteristics			
Age (years)	0.076**	0.025	0.036
	(0.024)	(0.023)	(0.022)
Gender (female)	0.556**	0.345	0.504**
	(0.150)	(0.178)	(0.160)
Marital status (married)	−0.510	−0.373	−0.163
	(0.363)	(0.306)	(0.335)
Ethnicity (ethnic minority)	2.632**	3.412***	3.374***
	(0.696)	(0.793)	(0.634)
Education (years of schooling)	−0.042	−0.109***	−0.062*
	(0.035)	(0.024)	(0.029)
Employment (employed)	0.976*	0.426	0.728
	(0.355)	(0.482)	(0.398)
Household wealth (index)	−0.023	−0.192	−0.202
	(0.118)	(0.133)	(0.118)
Migration and *hukou* status			
Urban residents (reference group)	–	–	–
	–	–	–
Cross-county urban-to-urban migrants	−3.251*	−2.766***	−3.048**
	(1.193)	(0.603)	(0.796)
Cross-county rural-to-urban migrants	−1.324	−0.186	−0.909
	(0.704)	(0.708)	(0.783)
Within-county rural-to-urban migrants	−1.633	−1.059	−0.333
	(1.513)	(1.360)	(1.563)
In situ urbanized rural residents	0.811	−0.393	0.504
	(0.503)	(0.312)	(0.447)
Length of residence in current locale (years)	−0.052**	−0.006	−0.023
	(0.016)	(0.015)	(0.017)
County-level fixed effects			
County A		2.211*	
		(0.786)	
County B		0.457	
		(0.406)	
County C (reference)		–	
		–	
County D		−1.291***	
		(0.269)	
Other counties		Available upon request	
County-level urbanization measures			
Level of urbanization in 2000			0.068**
			(0.021)
Speed of urbanization 2000–2009			2.097*
			(0.809)
Acceleration/deceleration 2000–2009			20.210*
			(7.704)
Constant	4.584*	8.325***	5.293**
	(1.844)	(1.823)	(1.787)

Continued

Table 3: **Continued**

	CES-D Depressive Distress		
	Model 1	**Model 2**	**Model 3**
Wald F statistics	51.91 (12,19)	6405.44 (42,19)	27.14 (15,19)

Notes:

Survey design effects (strata, clusters and sampling weights) are adjusted in the model estimations. Coefficients are reported; standard errors in parentheses. * $p<0.05$, ** $p < 0.01$, *** $p < 0.001$.

women and ethnic minorities reported higher levels of depressive distress with statistical significance. Compared with urban residents with current *hukou* in the county, only cross-county urban-to-urban migrants reported a statistically significant lower level of depressive distress, while cross-county rural-to-urban migrants did not show any significant difference. Thus, in contrast to what we observed in the predictors of physical health, those migrating from the villages were not better off than non-migrants on mental health. In addition, length of residence in the current locale significantly reduced the level of depressive distress.[44]

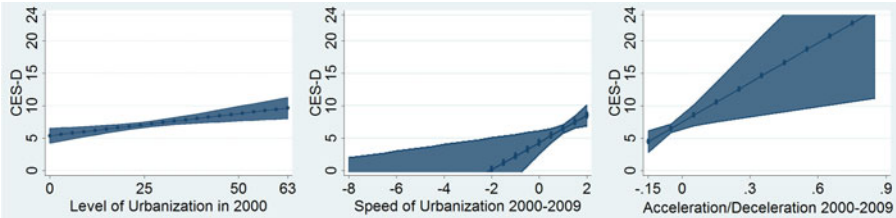
Model 2 in Table 3 includes county-level fixed effects in the OLS regression. The reported coefficients of the four sample counties demonstrate a linear, and negative, relationship between urbanization and mental health: respondents in the most urbanized county (A) reported the highest levels of depressive distress (coefficient = 2.211, $p < 0.05$), whereas those in the least urbanized county (D) reported the lowest level of CES-D (coefficient = −1.291, $p < 0.001$).

Model 3 in Table 3 includes the three measures of the dynamics of urbanization at the county level. The coefficients of the three measures are all significant and positively associated with levels of distress, which suggests that the higher the level of urbanization (coefficient = 0.068, $p < 0.01$), the faster the speed (coefficient = 2.097, $p < 0.05$), and the acceleration of the speed (coefficient = 20.210, $p < 0.05$), the greater depressive distress the respondents present.

To further illustrate the associations between the dynamics of urbanization and mental health, we again graph the marginal effects of the level, speed, and acceleration/deceleration on the level of CES-D depressive distress with 95 per cent confidence intervals, holding other variables at their means. As indicated in the first graph of Figure 5, when the level of urbanization increases from 0 to 63, the predicted level of CES-D depressive distress increases from 5.396 to 9.667. The second and third graphs further demonstrate that when the speed of urbanization changes from -8 to 2, the predicted depressive distress increases from 0 to 8.555, and that when the acceleration/deceleration changes from −0.15 to 0.9, the predicted depressive distress increases from 4.520 to 24. These results confirm

44 However, because age and length of residence were highly correlated, when we included country-level fixed effects or urbanization measures in Models 2 and 3, their coefficients changed in opposite directions and both became statistically insignificant.

Figure 5: **Predicted CES-D Depressive Distress and Dynamics of Urbanization**



Note:

The graphs are drawn based on results from the OLS regression of Model 3 in Table 3. The graphs present the predicted levels of CES-D depressive distress with 95% confidence intervals when the level of urbanization, the speed of urbanization, and the acceleration/deceleration change from minimum to maximum, holding other variables at their means.

(colour online)

that the three measures of the dynamics of urbanization all contribute to psychological distress and, thus, in contrast to the multi-dimensional story about urbanization and self-reported physical health, all dimensions of urbanization have adverse effects on mental health. [45]

Conclusion and Discussion

Linking the 2000–2009 DMSP-OLS night-time light data to the 2011 Migration and Quality of Life Survey, we systematically integrated estimates of the dynamics of urbanization (level, speed and acceleration/deceleration) to the individual level data from our survey of 1,288 current urban residents. Our innovative use of the DMSP-OLS night-time light data to measure the urbanization process captured dramatic variations in the spatial and temporal dynamics of urbanization in China between 2000 and 2009. As we demonstrate in the four sample counties, high levels of urbanization were sustained or grew only slowly in some counties and city districts; in others, urbanization first declined and then rose; elsewhere, there was a relatively low level of urbanization with no significant change over the decade. Thus, in terms of the national story, night-time light data draws attention to the dramatic spread of cities and towns across the North China Plain.

Integrating the three measures of urbanization constructed from the DMSP-OLS night-time light data into analysis of the Migration and Quality of Life Survey, we estimated the effects of county-level urbanization on individual physical and mental health status. After controlling for the county-level fixed effects in the ordered logistic or OLS regressions on self-rated physical health and depressive distress, we found major variations in the county coefficients.

45 We conducted additional analysis to test our hypothesis. We included interactions between the three measures of urbanization and the five categories of migration and *hukou* status in both ordered logistic and OLS regressions reported as Model 3 in Table 2 and Table 3, respectively. The coefficients on the interaction terms indicate that the positive effects of speed of urbanization and acceleration/deceleration on self-rated physical health were only significant on cross-county rural-to-urban migrants, but not on other migrant and resident groups, whereas the negative effects of all three urbanizations measures on mental health were the most prominent among urban residents. The results are consistent with our speculation and available upon request.

The results clearly demonstrate the effects of place on individual health outcomes. When we then included the three measures of county-level urbanization in the analysis, the results further indicate that the effects of urbanization vary according to its level, speed, and acceleration/deceleration, and follow different trajectories for physical and mental health. As we hypothesized, higher levels of urbanization have adverse effects on both physical and mental health but a faster and accelerated urbanization process appears to benefit physical health. All three dimensions of urbanization at the county level harm mental health.

The generally adverse effects of the level of urbanization on both physical and mental health are consistent with findings in existing research, but the positive force associated with faster and accelerating urbanization on self-rated physical health, to the best of our knowledge, has not been documented by other scholars. We consider two possible explanations for this phenomenon. First, the benefits of superior or improved health-care facilities and services may be strong enough to offset the adverse effects of the urban environment and lifestyle on physical health in places with faster and accelerating urbanization. Second, the findings may primarily indicate the demand-pull effect underlying the healthy migrant phenomenon. Places undergoing fast and accelerated urbanization draw physically healthy migrants across county borders, as we have discussed earlier in this article, and this pull may override the generally adverse impact of urban living on the health of other urbanites.

The derivation of measures of urbanization from the DMSP-OLS night-time light data allowed us to measure the dynamics of urbanization and identify their net effects on reported health and mental health outcomes. However, the limitation of our measure of urbanization is that it does not discriminate the specific aspects of urban life that are either beneficial or detrimental to health. Therefore, in the present study, we are not in a position to determine what the positive driving force is on self-rated physical health in places with faster and accelerated urbanization. Nonetheless, based on our review of existing literature examining the urban–rural divided health-care system and recent health-care reforms and on our understanding of the healthy migrant phenomenon during the internal migration process, we speculate that the second statement will be a more plausible reason to explain the phenomenon. As a result of China's divided health-care system, the majority of rural-to-urban migrants and in situ urbanized rural residents are still enrolled in the New Rural Cooperative Medical Scheme, which restricts their access to the urban health-care system.[46] In recent years, China has implemented a series of reforms to its health-care system. The government's ambitious plans to expand health insurance enrolment and health-care coverage have produced impressive results. Yet, the efficacy of these newly established schemes in providing medical services and treatments is limited.[47] We

46 Hesketh et al. 2008; Mou et al. 2009; Peng et al. 2010; Qiu et al. 2011; Zhao, Rao and Zhang 2011.

47 Griffiths and Tang 2011; Lei and Lin 2009; Lin, Wanchuan, Liu and Chen 2009; Ling et al. 2011; Wagstaff et al. 2009; Yip and Hsiao 2009.

therefore further postulate that the adverse effects of an urban environment and lifestyle on respondents' physical health in locations undergoing faster and accelerating urbanization are not likely to be offset by the superior health-care facilities and services; rather, it is the demand-pull effect underlying the healthy migrant phenomenon that overrides the generally adverse impact of urban living on the physical health of other urbanites. Nonetheless, to confirm our speculation, future studies need to decipher the dynamics of urbanization further and compare its health consequences among different migrant and resident groups.

China's urbanization is likely to continue to follow diverse trajectories. Our findings from this study draw particular attention to the spatial unevenness in the level, speed and acceleration/deceleration of urbanization across counties and over time. We document more precisely than previous work how spatial variation in urbanization across China at the county rather than provincial level has significant impact on the quality of life, independent of a subject's or household's socio-demographic characteristics. The range of effects of the dynamics of urbanization may also present on economic, social and political outcomes other than health, such as employment, poverty, crime, neighbourhood cohesion, community participation and political trust, just to name a few. Social science research focusing on China thus has an urgent need to investigate further the consequences of urbanization from both more dynamic and geographically specific perspectives. Finally, this article also demonstrates most broadly the value of modelling variation in locational parameters for analyses of individual or household-level data in projects that address nationwide outcomes.

摘要: 本文基于 2011 年全国城镇居民流动与生活质量调查和 2000–2009 年 DMSP-OLS 夜间灯光数据, 重新梳理了中国城镇化和人口流动的过程及其与居民健康的复杂关联, 并评估了不同的城镇化水平与速度对目前居住在城镇的居民身体和精神健康的影响。通过将城镇化的过程在县级分解成三个维度, 我们发现县级城镇化的绝对水平对居民的身体健康有负面影响, 而快速和加速度的城镇化则对居民的身体健康有正面影响, 但后者可能与健康移民现象有关。与对身体健康的影响相反, 城镇化的三个维度都与居民更多的抑郁症状相关联, 由此显示出城镇化对居民精神健康的负面影响。本文除了论证城镇化过程和地域对个人健康的影响, 同时也演示了将地域参数引入分析全国性的个人层面的变量模型中所具有的更广泛的价值。

关键词: 城镇化; 健康; DMSP-OLS 夜间灯光; 社会调查; 中国

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