Construction of an area-deprivation index for 2869 counties in China

The construction of an area deprivation index for 2869 counties in China: a census-based approach

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What is already known on this subject:

- Ecological deprivation indices have been established from census data in many developed countries.
- Several studies in China have made noteworthy attempts to measure area deprivation on different levels; however, existing studies on developing an area deprivation index (ADI) in China are either limited in scale or study area.

What this study adds:

- This study presents an approach to calculate area deprivation based exclusively on county-level population census data in China.
- The county-level area deprivation index (CADI) is robust and can identify deprived counties that were not included in the national poverty-stricken areas lists issued by the Chinese government.
- The index can be practically used as an alternative method of measuring China's deprived areas on various levels.

ABSTRACT

Background: A paucity of data has made it challenging to construct a deprivation index at the lowest administrative, or county, level in China. An index is required to guide health equity monitoring and resource allocation to regions of greatest need. This study used China's 2010 census data to construct a county-level area deprivation index (CADI).

Methods: Data for 2,869 counties from China's 2010 census were used to generate a CADI. Eleven indicators across four domains of deprivation were selected for principal component analysis with standardisation of the first principal component. Sensitivity analysis was used to test whether the population size and weighting method affected the index's robustness. Deprived counties identified by CADI were then compared with China's official list of poverty-stricken counties.

Results: The first principal component explained 60.38% of the total variation in the deprivation indicators. The CADI ranged from the least deprived value of -2.71 to the most deprived value of 2.92, with a standard deviation of 1. The CADI was found to be robust against county-level population size and different weighting methods. When compared with the official list of poverty-stricken counties in China, the deprived counties identified by CADI were found to be even more deprived.

Conclusion: Constructing a robust area deprivation index for China at the county level based on population census data is feasible. CADI is a potential policy tool to identify China's most deprived areas. In the future, it may support health equity monitoring and comparison at the national and subnational levels.

1 INTRODUCTION

The Chinese government has long supported health development in poverty-stricken areas in China. In 2012, the Chinese government identified 832 national poverty-stricken counties primarily based on income, historical designation as impoverished areas, and rural regions. However, these criteria unfortunately do not allow for standardised comparisons outside China's political context to other countries, especially as this method of identification excluded impoverished counties in urban areas.[1] Since China has committed to eliminating absolute poverty (per capita annual income less than RMB 2,300 or about USD 340 in 2010) by 2020, counties identified as poverty-stricken are expected to be phased out at the same time.[2] After 2020, strategies for reducing the development imbalance across China will need to be multifaceted and based on more accurate identification of the neediest areas. To this end, China has planned to enhance the ongoing efforts to restructure health resource allocation and service planning in the least developed regions with the greatest need.[3] An accurate, standardised assessment of area deprivation is urgently needed for health resource allocation, policy development, and planning.

Deprivation encompasses poverty as well as other forms of social and material deprivation such as goods, services, resources, physical environment, social relationships, and rights and responsibilities of society members.[4] Several high-income countries, such as the United Kingdom (UK),[5,6] the United States,[7] and France,[8,9] have developed area-based indices of deprivation to measure health inequities and the contextual effect of area deprivation on health. The UK, for example, has applied such an area-based index towards addressing inequalities in allocations for health funding, which resulted in the reduction of health inequities.[10] In addition to developing nation-specific indices, there have been attempts to build a cross-nationally comparable deprivation index in European countries.[11] These indices, however, focus on high-income countries. The development of similar indices in low- and middle-income countries has unfortunately been hindered by the paucity of data at the lowest geographic levels. China, as a middle-income country, can serve as an example for low- and middle-income countries (LMICs)

where such indices are in need to understand the unique aspects of deprivation for countries in economic transition.

Given China's immense population distribution, a regional or area-based approach is needed at the lowest possible geographic area. This will support the development and monitoring of interventions to be implemented as per the geographic administrative level, which would allow health resources, planning, and evaluation to be directed to areas of greatest need. As of 2010, mainland China's hierarchical administrative structure of government includes a central or national government divided into 31 provinces, which are subdivided into 333 prefectures or cities, which are further divided into 2,872 county-level areas including rural counties and urban districts.[12] The county serves as the lowest administrative level of government with complete authoritative, legislative, jurisdictive, and administrative functions. County-level governments play a major role in China's local governance, as they are responsible for not only providing adequate public services and infrastructure but also promoting employment and economic growth locally.[13]

Prior studies have been able to construct area-based indices down to the county level. Such an index, for example, was constructed for Guangdong province but was limited by being locally rather than nationally representative.[14] In another attempt to measure patterns of deprivation in China, the Integrated Social Deprivation Index was constructed for all 333 prefectures or cities nationwide.[15] However, China's prefectures or cities are large and not only include populations in the millions but also encompass multiple counties that range from urban to rural. Each prefectural city, on average, contains nine counties with varying levels of development and urbanisation. Thus, prefectural level indices would mask major disparities by grouping more developed urban counties with less developed rural counties. In China, current research on constructing a county-level deprivation index (CADI) has been limited.

Given the urgent need to better understand the varying levels of inequality in China to develop more targeted strategies in poverty reduction, health resources allocation, and health inequity monitoring, this study aims to construct a CADI for China. We aim to describe the methodology in constructing

149 such an index at the lowest administrative level of government as well as discuss how it may be
150 applied in future studies.

151 2 DATA AND METHODS

152 Data

153 Census data was used to build an area deprivation index in China. China conducts a population census
154 every ten years, the most recent of which occurred in early November 2010.[12] The census covers
155 basic information (e.g. age, sex, *hukou* status, education, and marital status) about all residents. More
156 detailed information (e.g. working status, occupation, housing conditions, tap water, toilet availability)
157 was additionally collected from 10% of the population through systematic sampling. Nationwide
158 publicly available census data is only aggregated at the county level. The county-level aggregated
159 census data were based on the 2009 China administrative boundaries that encompassed 2,872
160 counties. Among these counties, three were islands in the South China Sea which were excluded due
161 to incomplete data, thus leaving 2,869 counties for inclusion in the analysis. For county-level
162 population, the 25th percentile corresponds to 221,569 people, 50th percentile to 380,083 people, and
163 75th percentile to 625,119 people. For county-level surface area, the 25th percentile corresponds to
164 711 km^2, 50th percentile to 1,543 km^2, and 75th percentile to 2,723 km^2.[16]

165 Construction of the area deprivation index

166 The CADI in China was constructed based on procedures proposed by Noble et al.[17] and Allik et
167 al.[18] Figure 1 depicts the procedures that were used to develop the index.

168 [Insert Figure 1]

169 Choosing the initial conceptual framework

170 The framework for developing the CADI was based on the concept of deprivation developed by Peter
171 Townsend. He conceived of deprivation as a multidimensional concept that includes both material and
172 social disadvantages that inhibit individuals from achieving the highest quality of life.[4] Area

deprivation is the aggregated material and social deprivation experienced by a population in a certain area.[17]

Deprivation dimensions and indicators

Indicators directly related to personal experiences of deprivation were chosen across dimensions of education, income, living conditions, and rural-urban differences. We chose deprivation indicators considering both deprivation conceptual framework and data availability. Of the 167 raw variables captured by county-level aggregated census data, 13 candidate indicators related to areas of deprivation were initially calculated, while two indicators were excluded because the indicators (living space per person and housing tenure) were pertinent to deprivation in urban areas. Since many county-level areas contains both rural regions and urban regions, thus we only kept 11 deprivation indicators for the final analysis.

Education. Education deprivation was measured using the following indicators: average years of education for people over 6 years of age, illiteracy rate among people over 15 years of age, and percentage of people over 6 years of age not completing junior high school. In China, it is compulsory to complete junior high, and thus, a failure to do so suggests a low level of educational achievement.

Income. Income deprivation consisted of two indicators: (i) percentage of people over 16 years of age losing working ability (this indicator is calculated by the number of people who lost working ability due to disability, illness, etc. divided by the total number of people over 16 years of age, excluding students, retirees, and people who chose not to work); and (ii) percentage of people over 16 years of age working in low-income industries. Drawing upon the 2013 data from the National Bureau of Statistics of China,[19] low-income industries are defined as industries where the average annual income per person was less than RMB 43,000 (about 6356 USD in 2013). A total of six industries were classified as low-income: agriculture, manufacturing, construction, hotel services, domestic services, and water, environmental, and infrastructural management.

Living conditions (indoor). The indicators measuring poor living conditions were the percentage of

households without indoor facilities of water, sanitary toilet, kitchen, or shower.[4]

Rural-urban differences. Rural-urban differences reflect both material and social deprivation. Within each county, there are rural areas and urban areas, which are defined by public facility availability per the National Bureau of Statistics.[20] We used the percentage of people living in rural areas to reflect limited access to public infrastructure (material deprivation). *Hukou* is a government household registration system that usually limits where a person is allowed to live. People with rural *hukou* experience institutionalised discrimination and have less access to social welfare.[21] For our index, the percentage of people with rural *hukou* was chosen to reflect discrimination against rural people (social deprivation).

Aggregating indicators into an area deprivation index

Deprivation is a multidimensional phenomenon. Although individual indicators can measure socioeconomic disadvantage, they are often highly correlated with each other. Therefore, this study aimed to generate a robust composite index that would not only capture multiple deprivation domains but also be less susceptible to minor changes in a single indicator.[22] We chose principal component analysis (PCA) to allow each indicator to be uniquely represented and to avoid the problem of 'double counting'.[23] The use of statistical methods to derive the weights is also consistent with prior studies in China studying deprivation.[14,15] Eleven standardised indicators were chosen to construct the CADI via PCA. The first principal component score was extracted and standardised for the CADI. The average value of the index was 0 and the standard deviation was 1. PCA is sensitive to the scale of indicators; therefore, prior to extracting the first area deprivation component, equation (1) was used to standardise all indicators:

$$z_{ij} = \frac{x_{ij} - x_{i\_mean}}{sd_i} \quad (1)$$

Where, z_{ij} is the normalised deprivation indicator *i* for county *j*, x_{ij} is the original deprivation indicator *i* for county *j*, and x_{i_mean} and sd_i are the mean value and standard deviation of indicator *i,* respectively.

Sensitivity analysis

China's county-level areas vary substantially in population size. Therefore, we performed a sensitivity analysis with consideration of population extremes to ensure that our index was robust when compared to all counties with all levels of population size. Excluding 266 counties with populations of fewer than 100,000 people and 195 counties with populations of over 1 million, there were 2,408 counties remaining for building the CADI. We then examined the correlation between the CADI using 2,869 counties and the CADI using 2,408 counties.

In addition, consistent with weighting methods in building composite index,[23] we also assigned equal weight to each deprivation indicator to construct CADI as part of the sensitivity analysis. We then examined the correlation between the CADI using PCA and the CADI using equal weight.

Comparison with national poverty-stricken areas

To test the validity of the CADI, we compared our index with the 2012 State Council Office of Poverty's official list of 832 national poverty-stricken counties.[2] Since administrative county divisions have undergone slight revisions, China's official list of poverty-stricken counties was based on the 2012 standards. Therefore, the 832 counties identified in 2012 were collapsed into the 830 counties included in the 2010 census to allow direct valid comparison of the two metrics.

3 RESULTS

The 11 deprivation indicators from China's 2010 census demonstrate the extensive development imbalance across China as shown in Table 1. For all 11 indicators, except for average years of education, a higher indicator value represents a higher level of deprivation for that indicator.

[Insert Table 1]

The PCA results indicated that only the eigenvalue of the first (6.64) and second (1.53) principal components were larger than one. The first principal component explained 60.38% of the total variance amongst deprivation indicators. The first principal component can be calculated via equation

(2).

$$pc1 = (-0.36 \times z_{01}) + 0.24 \times z_{02} + 0.35 \times z_{03} + 0.27 \times z_{04} + 0.33 \times z_{05} + 0.30 \times z_{06} + 0.24 \times z_{07} + 0.23 \times z_{08} + 0.27 \times z_{09} + 0.36 \times z_{10} + 0.33 \times z_{11} \quad (2)$$

We used a standardised score for only the first principal component of the CADI, which ranges from the least deprived value -2.71 to the most deprived value of 2.92, with a higher CADI value representing relatively more deprivation in a specified area. We divided the 2,869 counties into ten deciles according to their degree of deprivation. We found deprivation in China's county-level regions to be consistent with the geographic distribution of China's social and economic development. Specifically, the deprivation in Western China is much more severe, while the Northeast and Southeast coastal areas are less deprived (Figure 2).

[Insert Figure 2]

Sensitivity analysis

The correlation coefficient between the CADI using all counties and the CADI using counties with a population between 100,000 and 1 million is over 0.999. The correlation coefficient between CADI using PCA and CADI using equal weight is 0.989. These findings indicate that the CADI is robust against different county-level population sizes and weighting methods.

Comparison with national poverty-stricken areas

China's official list of poverty-stricken counties was compared against the index developed in this study. After matching, four types of counties were generated:

- *Type 1 (586)*: Deprived according to both CADI and China's 2012 official list.
- *Type 2 (244)*: Deprived according to CADI but not on China's 2012 official list
- *Type 3 (244)*: Listed as poverty-stricken as per China's 2012 official list but not deprived according to CADI
- *Type 4* (*1,795*): Not identified as deprived in either approach

[Insert Table 2]

Amongst the 830 counties as poverty-stricken in 2012, the index developed in this study found 586 of

these counties (70.60%) to be deprived according to CADI. For all 11 indicators, the level of deprivation ranges from the highest with type 1 counties to the lowest with type 4 counties (Table 2). Notably, type 2 counties revealed greater levels of deprivation than type 3 poverty-stricken counties on China's 2012 official list. For example, the percentage of people working in low-income industries was 86.90 in type 2 counties, which was 6.71% higher than the percentage in type 3 counties (80.19%). This suggests that the CADI can identify additional regions experiencing deprivation by offering more details about deprived counties.

4 DISCUSSION

In this study, we successfully developed the first nationwide population-based CADI for mainland China. Previous deprivation indices have been mostly developed in high-income countries rather than LMICs, such as China. We chose indicators from the 2010 census that bridge this gap by not only representing various domains of material and social deprivation, but also by being relevant to LMICs undergoing the rapid development experienced by China. The census data, drawn from the national census conducted every 10 years for the entire population in China, helped us create an area-deprivation index at the county level, which is China's lowest administrative level with complete government functions.

We found that the first principal component explained 60.38% of the total variation of area deprivation in China, which was slightly lower than that in the United States (61%),[7] and South Korea (64%),[24] although higher than that in France (57%),[8] South Africa (50%).[25] This finding indicates that the standardised first principal component (i.e. the CADI) can extract most of the variation in deprivation across various domains. We further demonstrated that our index is robust against both large and small population extremes and weighting methods at the county level via sensitivity analysis.

According to findings from CADI, China's deprived counties largely coincided with the 2012 State Council's official list of poverty-stricken counties. However, we found that there were still gaps in the

identification of deprived counties because the list was mainly based on income, historical designation, and rural regions and not on multiple domains of material and social deprivation as was used in the CADI. Some counties not included in the official list were found to have a greater degree of deprivation by the CADI, likely because they had not been previously identified and therefore had been ineligible to benefit from China's government programs for poverty-stricken areas.[26] Additionally, according to the list of national poverty-stricken counties, a county can only be poverty-stricken or not, while the CADI provides a continuous value of deprivation for each county and allows counties to be compared based on deprivation. Thus, CADI may be used to better identify regions of China with the greatest need and offer a deeper understanding of China's socioeconomic development by using standardised criteria nationwide.

Future application of China's area deprivation index

The CADI can be updated based on the 2020 census and used to serially monitor improvements over time. Given the Chinese central government's declaration in 2018 to allocate more health funds to deprived provinces,[3] this index can also be used to determine the counties within these provinces that need the greatest level of resources.

For future studies on health equity, it would be interesting to measure the association between the index and a measure of population health status such as mortality. National and subnational health equity assessment requires not only health data but also reliable and accurate measures of a population's socioeconomic status at all geographic levels.[27] In combination with various county-level health data sources, this index offers a standardised way to measure socioeconomic status at both the national and provincial levels within China. Comparisons at both levels will make health equity governance accountable and accelerate the reduction of health inequity. From a global perspective, the creation of similar indices in other countries would allow for standardised inter-country comparisons of health inequity.

In addition, there is an increasing interest in epidemiological studies concerning the contextual effect

of area socioeconomic status on health in China, and various area-level socioeconomic measures have been used in such research.[28,29] However, there is some inconsistency in the socioeconomic indicators used in their analyses. This inconsistency may hinder comparisons and generalisability across China. In the present study, we effectively developed an area deprivation index for further epidemiological research in China to gain a better understanding of how area deprivation affects health.

There are several limitations of this study. First, whilst we have used the data from the latest national census to construct this index, there is considerable lag between the year of data collection, 2010, and the publication of this index. Notwithstanding this, the index is still superior to the National Poverty-Stricken County List of 2012 that is currently being used by the Chinese government for policy and planning. As such, the index considers relative deprivation across multiple domains, and is more relevant to the government's current agenda for eradicating relative deprivation. This work also offers foundational data and methodology that may be applied for data from the upcoming 2020 Census data. Second, whilst this current index is based upon the lowest level of administration attempted to date for national-level multiple deprivation indices for China, Chinese counties are still large in geographic area and population. In building multiple deprivation indices, the smaller the geographic areas, the more precise the index.[18] Furthermore, the index is also not rural-urban sensitive. This is because most Chinese counties contain both rural and urban communities, making it impossible to distinguish rural-urban differences. In order to account for such differences, lower-level data will be needed. For rural areas, this would be the level of township, and for urban areas, the level of street. Unfortunately, nationwide lower levels census of data is currently not publicly accessible. However, in order to advance research and to improve the quality of deprivation indices for assisting the government's social policy endeavours, we strongly urge the Bureau of Statistics to consider making such data publicly available.

In conclusion, we have generated a county-level area deprivation index based on China's census data. This approach can be used as an alternative method of measuring China's deprived areas on various levels, to support health equity monitoring and comparison at national and subnational levels, and for

365 future studies about the effect of area deprivation on health.

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Indicator	Mean	SD	Min	Max
Education				
Average years of education for people over 6 years of age (z_{01})	8.71	1.47	2.00	13.14
Illiteracy rate among people over 15 years of age (z_{02})	6.34	7.21	0.09	66.22
Percentage of people over 6 years of age not completing junior high school (z_{03})	77.33	13.10	27.14	98.18
Income				
Percentage of people over 16 years of age losing working ability (z_{04})	5.92	2.27	0.00	15.39
Percentage of people over 16 years of age working in low-income industries (z_{05})	74.80	16.66	3.82	98.36
Living conditions (indoor)				
Percentage of households without tap water (z_{06})	3.79	2.72	0.00	11.92
Percentage of households without a toilet (z_{07})	3.28	2.41	0.00	10.82
Percentage of households without a kitchen (z_{08})	1.81	1.84	0.00	10.59
Percentage of households without a shower (z_{09})	5.28	2.71	0.08	12.22
Rural-urban differences				
Percentage of people living in rural areas (z_{10})	53.09	25.68	0.00	98.62
Percentage of people with rural *hukou* (z_{11})	70.47	23.56	0.60	98.42

[1] All numbers are presented as a percentage, except for average years of education for people over 6 years of age.

Table 2. Incidence of different deprivation indicators among four county types *mean(sd)*[1]

Indicator	Type 1	Type2	Type 3	Type 4
Education				
Average years of education for people over 6 years of age	7.05(1.41)	8.11(0.49)	8.50(0.65)	9.37(1.14)
Illiteracy rate among people over 15 years of age	14.38(11.82)	6.65(3.56)	5.32(3.70)	3.81(2.53)
Percentage of people over 6 years of age not completing junior high school	88.01(4.38)	86.09(3.37)	81.25(6.50)	72.12(13.56)
Income				
Percentage of people over 16 years of age losing working ability	7.47(1.89)	7.18(1.43)	6.36(1.88)	5.19(2.20)
Percentage of people over 16 years of age working in low-income industries	87.24(6.09)	86.90(5.55)	80.19(10.42)	68.35(17.23)
Living conditions (indoor)				
Percentage of households without tap water	6.58(2.04)	6.42(1.73)	4.05(2.01)	2.49(2.08)
Percentage of households without a toilet	5.53(2.50)	4.67(2.27)	2.90(1.98)	2.41(1.83)
Percentage of households without a kitchen	3.72(2.44)	2.70(1.78)	1.59(1.41)	1.09(0.96)
Percentage of households without a shower	8.18(1.64)	6.72(1.51)	6.27(1.88)	4.00(2.29)
Rural-urban differences				
Percentage of people living in rural areas	77.28(8.83)	70.95(7.04)	64.14(14.30)	41.26(24.56)
Percentage of people with rural *hukou*	88.4(5.07)	86.97(5.63)	76.81(13.73)	61.52(24.92)

1. All numbers are presented as percentages, except for average years of education for people over 6 years of age.

2. Type 1 counties are deprived according to both CADI and China's 2012 official list; type 2 counties are deprived according to CADI but not on China's 2012 official list; type 3 are listed as poverty-stricken as per China's 2012 official list but not deprived according to CADI; type 4 are not identified as deprived in either approach.

Figure 1: Flowchart for constructing the county-level area deprivation index (CADI)

Figure 2: Geographic distribution of county-level area deprivation throughout China