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Abstract

Deprivation indices are often used as proxies to identify geographic areas with high levels of health problems. Two such indices, the Townsend Material Deprivation Index and the Jarman Underprivileged Area Score, are adapted to US populations and fit for census tracts in New York and Bronx Counties using American Community Survey data. Deprived regions are identified, approximately matching those established by the Index of Medical Underservice and Health Professional Shortage Areas; however, internal consistency measures show that the validity of these indices is questionable in the wider US context.

Acknowledgements

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1 Introduction

In the United States, certain key health indicators have improved over time, such as life expectancy at birth and infant mortality rates (CDC/NSHS, National Vital Statistics System). However, relative to other countries around the world, the US does not fare as well; for example in 2011, the US ranked 40th out of 197 countries in terms of life expectancy and 43rd out of 195 countries in infant mortality rates despite substantial spending on health care [34]. According to

the Centers for Medicare and Medicaid Services, roughly $2.9 trillion was spent on healthcare in the US in 2013, comprising more than 17% of GDP [6].

To track health-related inequality geographically, researchers in the UK developed deprivation indices. These indices correlate highly with physical and mental health variables, even though they use factors such as unemployment and overcrowding. We adapt two of these indices, the Townsend Material Deprivation Index and the Jarman Underprivileged Area Score to the US setting using 2012 five-year American Community Survey data. We then apply both methods to census tracts in Bronx County and New York County (essentially Manhattan) in New York state. We find that the Townsend and Jarman indices do identify deprived neighborhoods, although the constituent variables of the Jarman index are less appropriate for New York County.

This paper is organized as follows. In Section 2, we differentiate the concept of poverty from that of deprivation and review previous research in this area outlining the two major types of indices: summated and those based on factor analysis loadings. We start in Section 3 by giving a brief overview of our data source, the American Community Survey, which is administered by the U.S. Census Bureau. We then describe the Townsend and Jarman indices and describe how to apply these methods to a US population. We examine the results in Section 4 along with comparing them to the Index of Medical Underservice and Health Professional Shortage Areas both used by the U.S. Department of Health and Human Services. Finally, we validate the internal consistency of our methods using Cronbach's α. We conclude in Section 5.

2 Background

"Health care" covers a considerable range of topics: environmental, behavioral, demographic, access, hospital quality, and so forth [7]. Data on many of these

factors is not collected regularly, if at all, especially for local geographies and at synchronized time intervals. Consequently, deprivation indices were developed as a practical alternative. Deprivation is generally linked to poverty; however, they are not identical concepts. In the US, poverty has a strict definition: in 2013, a household was considered poor if its income was below $11,490 for one person or below $15,510 for two. These values applied to those living in the contiguous US (i.e., not Alaska or Hawaii) or the District of Columbia [1]. Deprivation, on the other hand, encompasses multiple factors such as diet, car and/or house ownership, family support, health, and work conditions. While more deprived people tend to be poorer, one can be deprived of some elements without being poor. The idea here is that deprivation is a broader construct than poverty.

Deprivation indices were first developed in the 1980s in the UK. Specifically, two types of techniques have been proposed: summated indices and indices constructed from factor loadings. The second type of index is based on performing a factor analysis on the selected variables and to use the factor loadings to construct an index for each region. Examples include the Index of Multiple Deprivation [9, 12], one of the indices proposed in Eibner and Sturm (2006) and the social deprivation index developed in Butler, Petterson, Phillips, and Bazemore (2013). The major downside of such an index is that factor loadings change annually resulting in an index which is not comparable longitudinally, a key purpose for constructing it [14]. Therefore, we focus on summated indices in this paper.

Examples of summated indices include the Townsend Material Deprivation Index [30], which was later modified into the Carstairs Deprivation Index for Scotland [5], and the Jarman Underprivileged Area Score [20], which was adapted to the Swedish population with the Care Need Index [27]. The

Townsend and Carstairs indices were used to identify areas with higher rates of health problems and the Jarman index for allocating extra resources to physicians who worked in deprived areas. They are based on standardizing and summing variables thought to be correlated highly with health-related factors across individual areas within a region. For example, the Townsend index is constructed from the percent of households with no vehicle, the percent of households with more than one occupant per room (i.e., overcrowding), the percent of dwellings which are renter-occupied, and the percent of people who are unemployed [25, 30]. The actual value of the index for each area is meaningless, only the rank matters. We will adapt the Townsend and Jarman indices to US data; in Section 3, we give more details in calculating both indices.

As you can see with the Townsend index, the selected variables are not directly related to health; however, deprivation indices have been shown to be good proxies for health-related issues [4]. We provide a few examples next. The Townsend index is correlated with rates of long-term limiting illnesses [22], poor overall health [11, 23], and depression [33, 11]. The Carstairs index is also correlated with rates of long-term limiting illnesses [3]. The Jarman and Care Need Indices are correlated with admission rates to psychiatric hospitals and ER visits [27]. Finally, the Index of Multiple Deprivation is correlated with physical and mental health outcomes [32, 11]. Given the relationships between health and deprivation, these indices have become popular since they are easier to estimate both temporally and geographically.

In the US, the Index of Medical Underservice, which designates Medically Underserved Areas based on a summated index, was developed later and incorporated factors such as infant mortality rates and poverty levels [19]. A similar scale identifies Health Professional Shortage Areas for primary care, dental, and mental health [8]. Physicians and psychiatrists can receive bonus payments for

working in such areas[1]. We examine these indices further in Section 4.2.

A downside of both summated and factor analysis-based indices is that deprived areas can be identified, but the fraction of deprived persons within an area is not available. Not all of the residents of a deprived area are deprived; similarly, there are always some deprived residents in non-deprived areas [13]. We do not address this issue in our paper.

3 Data and Methods

In this section, we outline the procedures for the Townsend Material Deprivation Index and Jarman Underprivileged Area Score and describe how to adjust these methods to (a) be appropriate for a US population and (b) make use of publicly available data. We start by describing our data source, the American Community Survey.

3.1 American Community Survey

The American Community Survey (ACS) is administered by the U.S. Census Bureau, replacing the Census Long Form after 2000. Data is collected continuously throughout the year on demographic, economic, housing, and social characteristics of the US population (and Puerto Rico). This information is used by a variety of entities including governments and businesses and is accessible to the general public. Estimates are published for a range of geographic levels (nation, state, county, etc.) according to a schedule based on population size. While more than three million households are sampled each year nationally, it still may result in only a few households per year for small regions; consequently, in those cases, data is aggregated over several years to reduce

[1] Associated programs and laws: Medicare Physician Bonus, Medicare Surgical Bonus, Surgical Incentive Payment, Social Security Act, Public Health Service Act, and the Affordable Care Act.

the variability in the estimates. In particular, annual estimates are published for regions with more than 65,000 people, three-year estimates for regions with more than 20,000 people, and five-year estimates for all regions. These three- and five-year estimates (referred to as multi-year estimates) combine data across several years and should be interpreted as an estimate for the entire period (for more details, see [1, 24]).

Census tracts are subdivisions of counties defined by the U.S. Census Bureau. They have no legal status and are used only for statistical purposes. Tracts are designed to have roughly 4,000 inhabitants and are redrawn after every decennial census. We will fit the Townsend and Jarman indices on census tracts in Bronx County (339 tracts) and New York County (288 tracts), both in New York state using data available through the ACS.

The U.S. federal government assigns a unique Federal Information Processing Standard code (FIPS) to each geographic region. New York state's FIPS code is 36 whereas Bronx County's code is 005 and New York County's is 061. Census tracts have 5-digit codes. For example, Central Park in Manhattan (New York County) is in census tract 143 with FIPS code 014300. The full geographic ID for this census tract would be a concatenation of the state, county, and census tract FIPS codes: 36061014300 [31].

Examining deprivation indices at the census tract level allows us to examine local patterns by neighborhood. The downside is that tracts are small and so ACS estimates are published only for five-year periods. In this paper, we use data from the 2008-2012 period[2]. The variables used along with summary statistics are discussed in Sections 3.2 and 3.3. References to the ACS data for each variable are provided in Tables 1 and 4.

[2]Note that Eibner and Sturm (2006) fit the Townsend index on all census tracts in the US but used Census Long Form data from 2000, which the ACS replaced. They did not, however, use any index validation methods like we do in Section 4.3.

Table 1: ACS variables used for the Townsend Material Deprivation Index

variable	ACS variable (table number/variable code)
% of households with no vehicle	DP04/HC03_VC82
% of households with more than one occupant per room (i.e., overcrowding)	subtract variable DP04/HC03_V110 (% one or fewer occupants per room) from 100%
% of dwellings renter-occupied (i.e., housing tenure)	DP04/HC03_VC64
% of people above 16 years who are unemployed	unemployment, above 16, civilian labor force: DP04/HC03_VC08

3.2 Townsend Material Deprivation Index

The Townsend Material Deprivation Index was developed by Townsend, Phillimore, and Beatie (1988) to measure material deprivation in Northern England and identify areas with high levels of health problems. The index requires four variables for each region in the area: (a) percent of households with no vehicle, (b) percent of households with more than one occupant per room (i.e., overcrowding), (c) percent of dwellings which are renter-occupied (i.e., housing tenure), and (d) percent of people above 16 years who are unemployed [25, 30] (see Table 1).

Summary statistics for each variable and correlations between variables are given in Tables 2 and 3 respectively for both counties across census tracts (note: variables for both indices are included in Table 2). A higher value for each variable is intended to indicate an area with a higher level of deprivation; in effect, the variables should not be "canceling" each other out. All correlations are positive (or approximately zero), which bodes well for our index. In theory, each variable is intended to capture a different component of deprivation. Consequently, the correlations between variables should not be very high. This does not seem to be the case for the "no vehicle" and "rental" variables; high correlations are observed, especially for Bronx County (0.859). This could be

Table 2: Summary statistics for Townsend Material Deprivation Index (T) and Jarman Underprivileged Area Score variables (J6 is Jarman 6, J8 is Jarman 8). All values expressed as a percent.

Bronx County

variable	index	min.	median	max.	mean	std. dev.
high school or less	J6, J8	12.00	59.60	100.00	58.08	13.68
< 5	J6, J8	0.00	7.30	16.70	7.40	3.03
> 65 and alone	J8	0.00	0.31	1.00	0.33	0.17
moved	J8	0.00	11.00	93.90	12.19	8.28
no vehicle	T	0.00	63.65	91.40	57.50	20.62
overcrowd.	T, J6, J8	0.00	10.50	100.00	11.48	8.88
poor English	J6, J8	0.00	25.60	56.90	24.13	12.48
rental	T	0.00	86.95	100.00	78.22	22.29
single parent	J6, J8	0.00	22.95	63.00	21.98	10.24
unemp.	T, J6, J8	0.00	8.30	26.00	8.51	3.98

New York County

variable	index	min.	median	max.	mean	std. dev.
high school or less	J6, J8	1.70	17.75	100.00	27.75	22.47
< 5	J6, J8	0.00	4.90	13.70	4.71	2.41
> 65 and alone	J8	0.00	0.43	0.94	0.43	0.16
moved	J8	2.20	15.30	73.90	18.03	10.69
no vehicle	T	21.10	79.10	94.70	77.54	9.74
overcrowd.	T, J6, J8	0.00	4.60	23.80	5.89	4.99
poor English	J6, J8	0.00	9.35	63.80	14.90	13.96
rental	T	10.40	81.30	100.00	78.17	18.59
single parent	J6, J8	0.00	4.30	33.30	7.42	7.45
unemp.	T, J6, J8	0.00	5.15	50.00	5.85	4.07

because of the real estate dynamics in the New York metropolitan area.

To compute the Townsend index, we follow the steps below [25, 29]. Let x_{ij} denote the value of the j^{th} variable for the i^{th} geographic area. All variables should be in percent, not decimal, form. in our context, i refers to a census tract in the selected county. To both reduce skewness and stabilize the variance, transform the variables from Table 1 (see Gilthorpe, 1995 for discussion on this issue):

$$\begin{aligned} t_{i,\,no\,car} &= \sqrt{x_{i,\,no\,car}} \\ t_{i,\,oc} &= \log\left(x_{i,\,oc}+1\right) \\ t_{i,\,rent} &= \log\left(x_{i,\,rent}+1\right) \\ t_{i,\,unemp} &= \log\left(x_{i,unemp}+1\right) \end{aligned}$$

where "no car" refers no vehicle, "oc" is overcrowding, "rent" is rental, and "unemp" denotes unemployment. Next, the variable means $\bar{t}_j$ and standard deviations s_j are computed, which are used to standardize the values for each region i and variable j:

$$z_{ij} = \frac{t_{ij}-\bar{t}_j}{s_j}. \tag{1}$$

Finally, the Townsend index value for region i is:

$$Townsend_i = \sum_{j=1}^{4} z_{ij}. \tag{2}$$

The index values themselves are not interpretable, only the sign of the score and the relative rankings are important. A negative Townsend value indicates a *less* deprived region, whereas a positive score signifies a *more* deprived region. A score of 0 corresponds to roughly the average level of deprivation across the

Table 3: Correlation matrices for Townsend Material Deprivation Index variables for Bronx and New York Counties. Values in *italics* are not statistically significantly different from zero at the 0.05/68 level (note: Bonferroni correction applied; between Tables 3 and 5, a total of 68 hypothesis tests were run.).

Bronx County

	rental	unemp.	overcrowd.	no vehicle
rental	1.000	0.375	0.467	0.859
unemp.	–	1.000	*0.169*	0.390
overcrowd.	–	–	1.000	0.321
no vehicle	–	–	–	1.000

New York County

	rental	unemp.	overcrowd.	no vehicle
rental	1.000	0.360	0.455	0.510
unemp.	–	1.000	0.363	*0.103*
overcrowd.	–	–	1.000	*0.133*
no vehicle	–	–	–	1.000

regions in the geographic area. Using the Townsend scores, we can rank the census tracts from least to most deprived.

3.3 Jarman Underprivileged Area Score

The Jarman Underprivileged Area Score is also a summated index resulting in a relative ranking of geographic areas. Its interpretation is identical to the Townsend index and was developed in the UK to identify wards which tended to have more demand for health care services. Physicians working in the most deprived wards would receive additional compensation [20, 21]. This scheme is similar in spirit to the one used for physicians working in Health Profession Shortage Areas in the US (designated by the Health Resources and Services Administration).

The Jarman index requires the eight variables listed in the left-most column of Table 4. The index is constructed by taking the *weighted* sum of the transformed and standardized variables. These weights were determined by how important medical practitioners thought the variables were in increasing their workload (weights listed in the middle column of Table 4).

To apply this index to the U.S. population, we need to make a few adjustments. First, because the weights were computed in the 1980s for a UK population, we cannot determine whether they are appropriate for our data; therefore we compute our index unweighted.

Second, not all of the variables are available using ACS data. Some can be constructed by combining available information; for example, the percent of elderly people living alone can be determined by determining the number of people who are over 65 years old and those who are over 65 and living alone.

For other variables, we have to find an acceptable equivalent. For instance, the last variable in Table 4 is the percentage of people in social class 5. The UK government divides its population into the following social classes: 1 (professional), 2 (managerial and technical positions), 3N (skilled, not manual), 3M (skilled, manual), 4 (partly skilled), 5 (unskilled), and 6 (armed forces). Those in class 5 are in jobs such as air transport, road construction, vehicle valet, water and sewage treatment plan operations, or window cleaning, to name a few [10]. The US does not have a similar classification system; as a proxy, we constructed a variable of the percentage of people who are 25 years and over and have at most a high school degree. This is not a perfectly analogous variable because some of these people could have gone to do a vocational degree or apprenticeship which would have placed them in a higher "social class"; however, we feel this is an acceptable substitute for our exploratory goals. A full description of the variables we chose (or constructed) are listed in the final column of Table 4.

Table 4: Variables used to compute the Jarman Underprivileged Area Score with US-based adjustments.

Jarman variable	weight	ACS variable, or composite variable (table number/variable code)
% elderly living alone	6.62	compute % by using number of people who are over 65 (DP05/HC01_VC26) and number above 65 and live alone (DP02/HC01_VC15)
under 5	4.64	% under 5 (DP05/HC03_VC07)
% persons living in a single parent household	3.01	add % households with single father (DP02/HC03_VC10) and % households with single mother (DP02/HC03_VC12)
% unemployment, above 16	3.34	% unemployment, above 16, civilian labor force (DP04/HC03_VC08)
% persons living in a household with more than 1 person per room	2.88	subtract variable DP04/HC03_V110 (% one or fewer occupants per room) from 100
% moved within the last year	2.68	add % moved within US (DP02/HC03_VC119) and % moved from abroad last year (DP02/HC03_VC124)
% born overseas from a non-English speaking country	2.50	% 5 years and over who speak English less than "very well" (DP02/HC03_VC170)
% in social class 5, unskilled (e.g., road construction, water and sewerage plant operator, window cleaner)	3.74	add for people 25 years and over: % less than 9th grade (DP02/HC03_VC85), % 9-12th but no diploma (DP02/HC03_VC86), and % high school graduate (or equivalent) (DP02/HC03_VC87)

Summary statistics across census tracts for each variable are given in Table 2 and pairwise correlations between variables in Table 5. As we discussed in Section 3.2, an increase in the value of a variable is expected to lead to an increase in deprivation level. However, the variables "moved within the last year" and "over 65 and live alone" are negatively correlated with nearly all of the other variables in New York County violating this implicit assumption (although not all are statistically significant). Therefore, we decided to fit two versions of this method: (a) the Jarman 8, including all variables and (b) the Jarman 6 omitting "moved within the last year" and "over 65 and live alone." We will discuss these excluded variables in more detail in Section 4.3.

In each case, we compute the index as follows. Let x_{ij}, as with the Townsend index, signify the value of the j^{th} variable for the i^{th} geographic area and express all values in percent form. First, transform the data [20, 21]:

$$t_{ij} \quad = \quad \arcsin \sqrt{\frac{x_{ij}}{100}}.$$

Next, compute the corresponding variable means $\bar{t}_j$ and standard deviations s_j and standardize:

$$z_{ij} \quad = \quad \frac{t_{ij} - \bar{t}_j}{s_j}. \tag{3}$$

Finally, for each geographic area, compute the sum[3]:

$$\text{Jarman}_i \quad = \quad \sum_{j=1}^{8} z_{ij}. \tag{4}$$

The final index values are interpreted in the same way as the Townsend index. To summarize, for the Jarman index, we adapted several of the variables to the

[3]If we were computing the original Jarman index, we would be computing the *weighted* sum instead: $\text{Jarman}_i = \sum_{j=1}^{8} z_{ij} w_j$.

US context, omitted the weights, and computed two versions of the index, one of which excludes two variables which are negatively correlated with the others.

Table 5: Correlation matrices for Jarman Underprivileged Area Score variables for Bronx and New York Counties. Values in *italics* are not statistically significantly different from zero at the 0.05/68 level (note: Bonferroni correction applied; between Tables 3 and 5, a total of 68 hypothesis tests were run.).

Bronx County

	rental	over-crowd.	single parent	moved	high school or less	poor English	< 5	> 65 and alone
rental	1.000	*0.169*	0.423	*0.132*	0.290	0.230	0.185	*0.073*
overcrowd.	–	1.000	0.245	0.193	0.287	0.494	0.245	*-0.133*
single parent	–	–	1.000	0.287	*0.624*	0.477	0.445	*0.082*
moved	–	–	–	1.000	0.163	0.240	0.219	*0.031*
high school or less	–	–	–	–	1.000	0.655	0.313	*0.167*
poor English	–	–	–	–	–	1.000	0.376	*0.136*
< 5	–	–	–	–	–	–	1.000	*0.091*
> 65 and alone	–	–	–	–	–	–	–	1.000

New York County

	rental	over-crowd.	single parent	moved	high school or less	poor English	< 5	> 65 and alone
rental	1.000	0.363	0.510	*-0.183*	0.460	0.402	*0.157*	*-0.043*
overcrowd.	–	1.000	0.493	*-0.140*	0.674	0.752	*0.151*	-0.353
single parent	–	–	1.000	-0.443	0.773	0.555	0.378	*-0.145*
moved	–	–	–	1.000	-0.452	-0.288	-0.377	*0.004*
high school or less	–	–	–	–	1.000	0.808	*0.187*	-0.238
poor English	–	–	–	–	-	1.000	*0.111*	-0.334
< 5	–	–	–	–	–	–	1.000	*-0.059*
> 65 & alone	–	–	–	–	–	–	–	1.000

4 Results

4.1 Comparing deprivation levels across tracts

We fit the Townsend, Jarman 6, and Jarman 8 to census tracts in New York County and Bronx County. We fit these two counties separately because they are two very different boroughs of New York. The maps Figures 1 and 3 correspond to results for New York County and Figures 2 and 4 for Bronx County. In these figures, each region represents a census tract in the county. Note that the edges of these maps do not exactly match existing land borders. Those tracts which border water include a bit of the water within the tract [26]. New York County is almost completely surrounded by water[4]; Bronx County borders water on its southern and eastern sides. Furthermore, some of the tracts are actually islands which are "connected" to adjacent tracts because of the bodies of water in between. Four examples: the large tract at the bottom of New York County is Governors Island, the large tract on the east of New York County is Randall's Island, the strip of two tracts to the south of Randall's Island is Roosevelt Island (and Mill Rock), and the southernmost tract in Bronx County is Riker's Island, a prison [17, 18, 26].

The census tract scores have been color-coded with red representing the most deprived areas and purple representing the least deprived. Tracts which are white are those with missing data, most often representing non-residential areas. For example, in Figure 1, the large, white rectangle in the middle represents Central Park in Manhattan[5]. Scores were assigned to a color by quantile

[4]New York County is comprised of the islands Manhattan, Ellis Island, Liberty Island (Statue of Liberty), Governors Island, Roosevelt Island, Randall's Island, Mill Rock, and Belmont Island along with a small portion of the mainland to the north called Marble Hill.

[5]In New York County, the tracts with missing data (with tract numbers) are, from north to south: Inwood Hill Park (297), Highbridge Park (311), The City College of New York (217.03), Randall's Island (240) , Central Park (143), the tract directly north of Bryant Park (96), international territory for United Nations Headquarters (86.02), Battery Park (319), Governors Island (5), Ellis Island (1), and Liberty Island (1) [18, 26]. In Bronx County, the tracts with missing data (with tract numbers) are, from west to east: Bronx Community

(approximate due to rounding); therefore, the red tracts are in the top decile and the purple tracts in the bottom decile. This allows us to do some rough comparisons across the three indices.

For New York County, the least deprived neighborhoods are mostly around the Upper East Side, known to be a wealthy area of New York. The most deprived areas are in north Manhattan in East Harlem up to Inwood and Marble Hill; in general, the East Village is more deprived than the West Village. Relatively speaking, the Upper West Side is more deprived than the Upper East Side, but is less deprived than north of Central Park, the East Village, and the Lower East Side. In Bronx County, we see that the most deprived areas are those directly north of Manhattan and become less deprived in Riverdale (on the west) and as we move towards the east. All three methods seem to identify similar regions as deprived and they approximately match poverty estimates as well. We study these patterns more closely in the next section.

College (census tract 249), Claremont Park (171), Saint Mary's Park (37), Crotona Park (163), Riker's Island (1), Soundview Park (24), and Ferry Point Park (110) [17, 26].

Figure 1: Townsend Material Deprivation Index Scores for New York County (2008-2012 ACS Data).

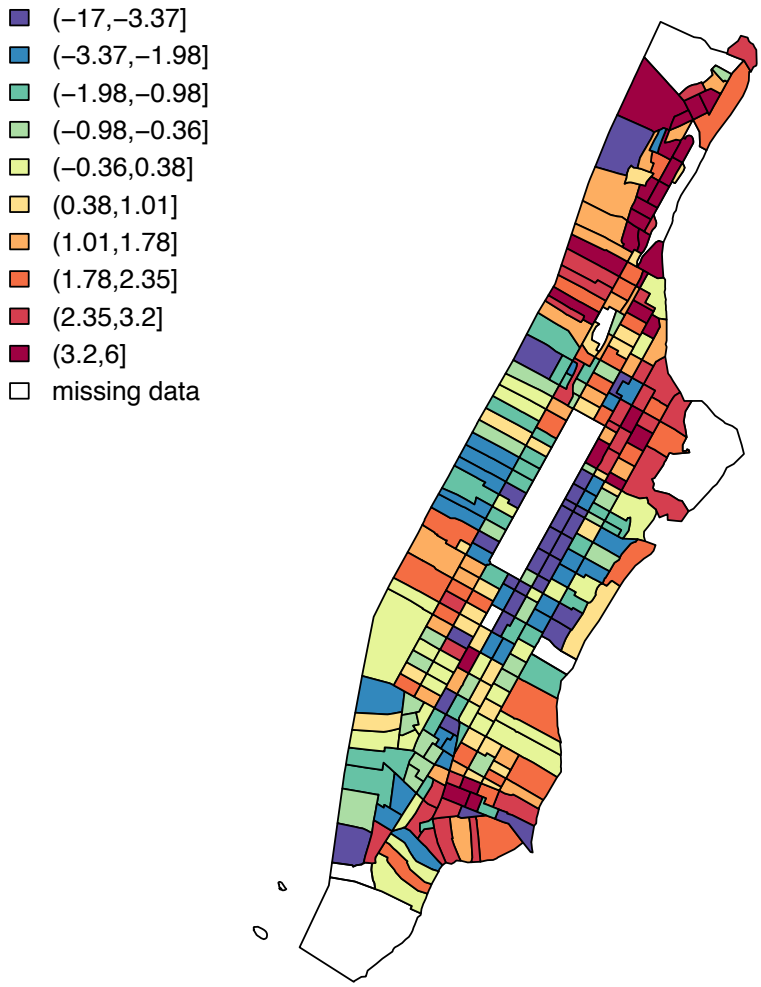


Figure 2: Townsend Material Deprivation Index Scores for Bronx County (2008-2012 ACS Data).

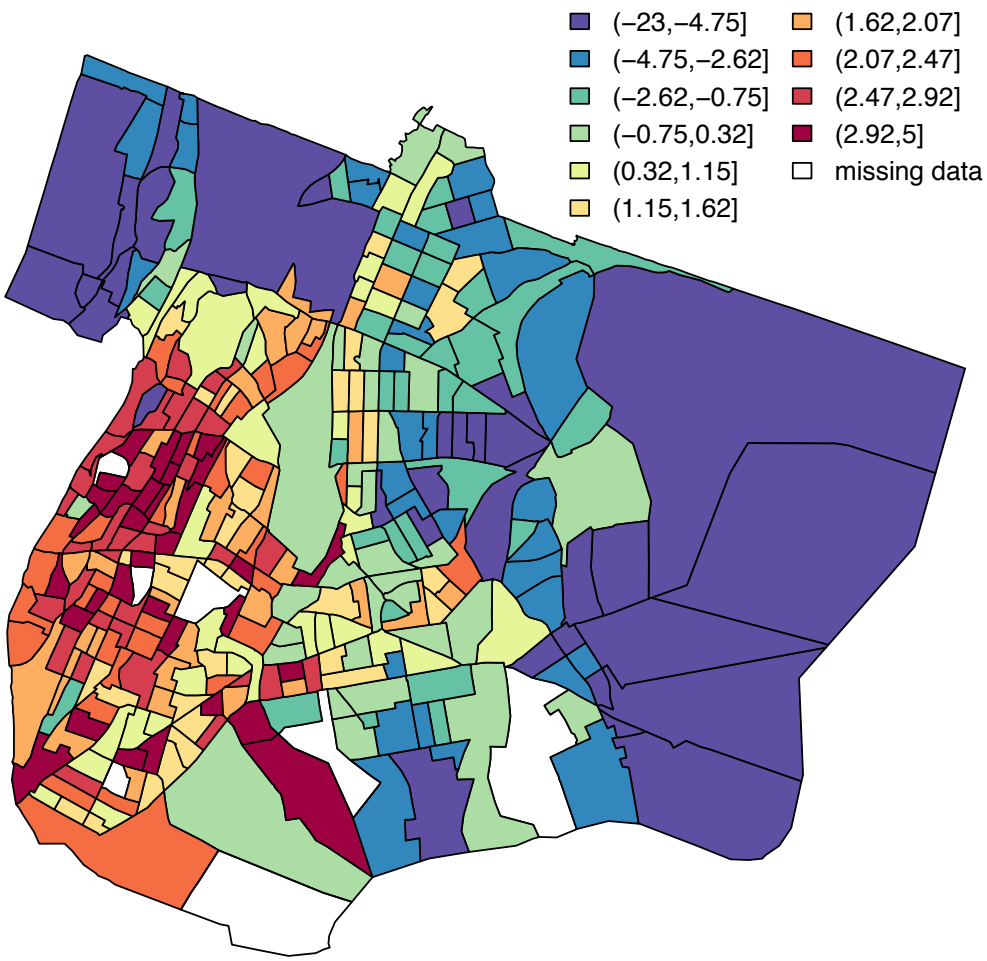


Figure 3: Jarman 6 and Jarman 8 scores for New York County (2008-2012 ACS Data).

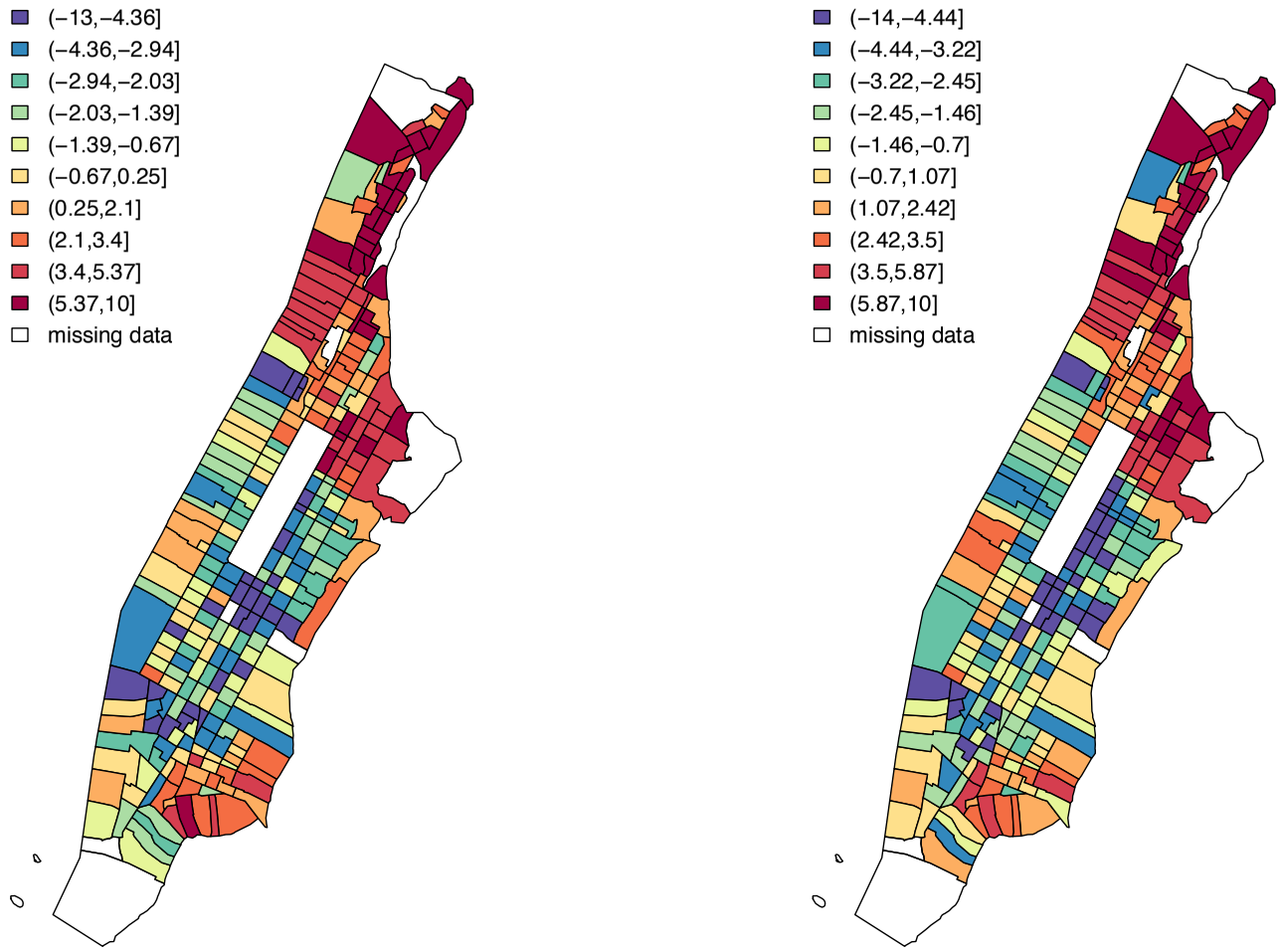
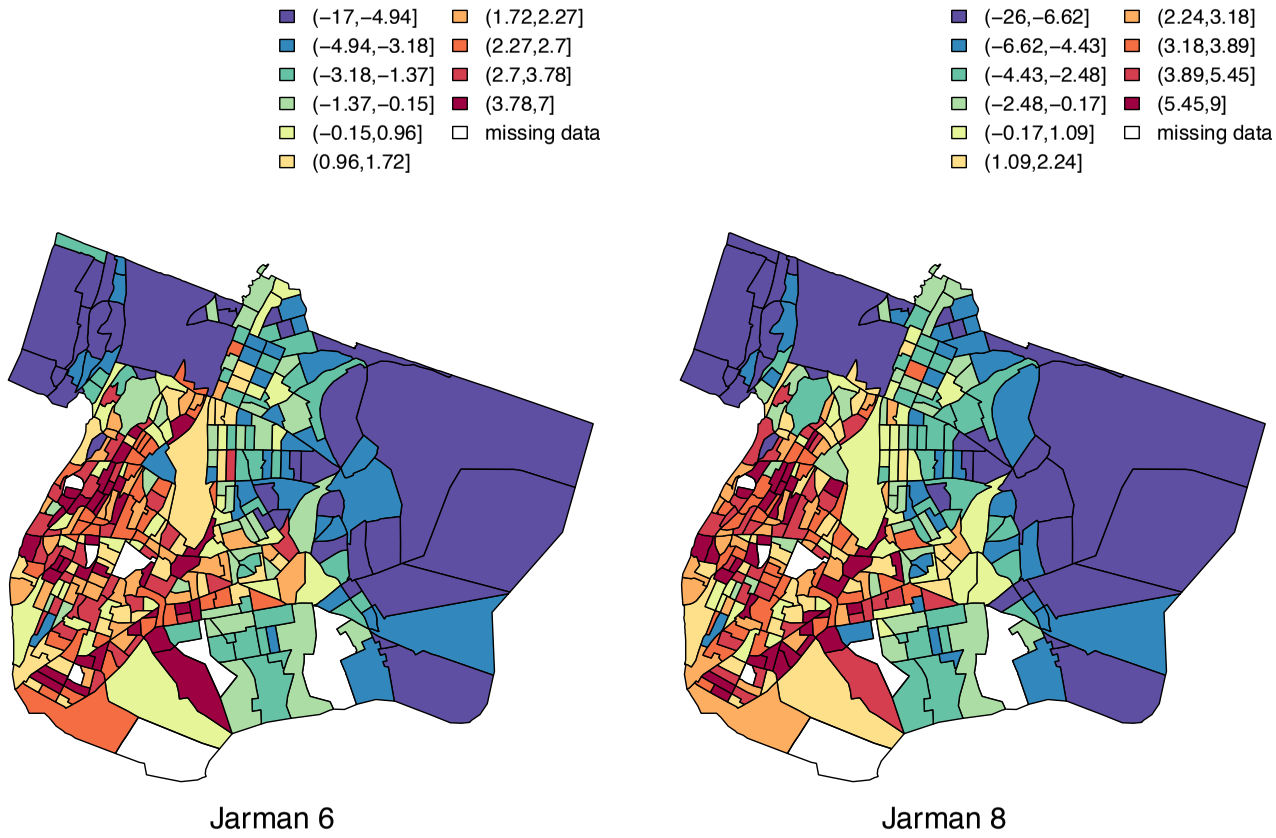


Figure 4: Jarman 6 and Jarman 8 scores for Bronx County (2008-2012 ACS Data).



4.2 Comparing indices

Visually, from the maps in Section 4.1, we can see that the three indices produce similar results. To see how close the rankings really are, we compute the rank correlation coefficients between the census tract rankings between each pair of indices; results are given in Table 6. Note that a rank of 1 denotes the *most* deprived census tract in the region. The correlations are low/negligible between the indices; this means that the methods do not assign similar deprivation ranks to the census tracts. The correlations seem to be lower for Bronx County compared to New York County.

These indices are often used to identify the most (or least) deprived areas; that is, we are more interested in the extremes of the spectrum than the middle. In Tables 7 and 8, we identify the ten most and ten least deprived census tracts identified by each of the three indices. Between 40-60% of tracts are common to all three index types and 60-90% are common between the Jarman 6 and Jarman 8. There is a bit more overlap at the extremes than is indicated by the rank correlations.

We began this discussion with the technical differences between poverty and deprivation. Consequently, the next comparison we will make is between index rank and public assistance rate ranks[6]. In particular, we compute the percentage of people who received cash public assistance or participated in the Supplemental Nutrition Assistance Program (SNAP) within the last twelve months (called the Food Stamp program prior to October 1, 2008 and is administered by the Food and Nutrition Service of the U.S. Department of Agriculture [15])[7]. We then ranked the public assistance rates. The rank correlations are shown in

[6]Note that we do not compare the index rankings specifically with health-related variables given the dearth of such information in the ACS.

[7]To obtain these rates, divide the ACS variable B19058/HD01_VD01 (total number of people) by B19058/HD01_VD02 (number of people with cash public assistance or Food Stamps/SNAP), where the variable is identified by table number/variable code.

Table 6: Spearman's rank correlation coefficients between Townsend Material Deprivation Index, Jarman 6, Jarman 8, and public assistance rates for Bronx and New York Counties (2008-2012 ACS Data).

Bronx County

	Townsend	Jarman 6	Jarman 8	public assistance
Townsend	1.000	0.117	0.093	0.022
Jarman 6	–	1.000	0.136	-0.007
Jarman 8	–	–	1.000	0.136
public assistance	–	–	–	1.000

New York County

	Townsend	Jarman 6	Jarman 8	public assistance
Townsend	1.000	0.256	0.212	0.104
Jarman 6	–	1.000	0.255	0.160
Jarman 8	–	–	1.000	0.125
public assistance	–	–	–	1.000

the final column of Table 6; we can see that the correlations are much lower (at times almost negligible) than between the indices themselves. This is possibly indicative of deprivation indices capturing a different construct than simply poverty-related variables.

As discussed in Section 2, the Index of Medical Underservice which designates Medically Underserved Areas and the Health Professional Shortage Areas are summated indices [8, 19]. In Figure 5, we plot both indices for New York County. Each color represents an "area" and by comparing them to the maps in Section 4.1, we can see that many (but not all) of the same census tract areas match the most deprived areas in our work. More study is needed to determine whether the Townsend and Jarman indices, which are more easily calculated, can be suitable substitutes for these methods.

Table 7: Ten most deprived census tracts; rank of 1 indicates most deprived tract in county.

Bronx County

	Townsend		Jarman 6		Jarman 8	
rank	tract	FIPS code	tract	FIPS code	tract	FIPS code
1	159	015900	220	022000	220	022000
2	220	022000	221.02	022102	159	015900
3	241	024100	245.02	024502	143	014300
4	245.02	024502	241	024100	121.02	012102
5	147.02	014702	197	019700	379	037900
6	221.02	022102	239	023900	50.02	005002
7	237.04	023704	221.01	022101	245.02	024502
8	197	019700	159	015900	79	007900
9	117	011700	121.02	012102	39	003900
10	149	014900	379	037900	197	019700

New York County

	Townsend		Jarman 6		Jarman 8	
rank	tract	FIPS code	tract	FIPS code	tract	FIPS code
1	251	025100	291	029100	293	029300
2	285	028500	293	029300	249	024900
3	261	026100	285	028500	291	029100
4	293	029300	245	024500	243.01	024301
5	291	029100	261	026100	285	028500
6	180	018000	249	024900	243.02	024302
7	245	024500	309	030900	261	026100
8	269	026900	269	026900	232	023200
9	232	023200	243.02	024302	245	024500
10	14.02	001402	251	025100	251	025100

Table 8: Ten least deprived census tracts. Highest ranked tract indicates least deprived tract. Note that 7 tracts from Bronx County and 10 tracts from New York County are omitted because of missing data; this is why the highest rank does not equal the total number of census tracts in each county.

Bronx County

	Townsend		Jarman 6		Jarman 8	
rank	tract	FIPS code	tract	FIPS code	tract	FIPS code
332	435	043500	435	043500	504	050400
331	301	030100	504	050400	435	043500
330	310	031000	130	013000	261	026100
329	288	028800	516	051600	130	013000
328	293.01	029301	261	026100	516	051600
327	274.02	027402	301	030100	301	030100
326	516	051600	274.02	027402	293.01	029301
325	337	033700	293.01	029301	307.01	030701
324	118	011800	307.01	030701	276	027600
323	274.01	027401	288	028800	274.02	027402

New York County

	Townsend		Jarman 6		Jarman 8	
rank	tract	FIPS code	tract	FIPS code	tract	FIPS code
278	112.02	011202	94	009400	102	010200
277	94	009400	112.01	011201	94	009400
276	150.01	015001	104	010400	112.01	011201
275	130	013000	102	010200	114.02	011402
274	142	014200	103	010300	104	010400
273	150.02	015002	92	009200	150.01	015001
272	86.03	008603	150.01	015001	130	013000
271	102	010200	205	020500	112.02	011202
270	109	010900	119	011900	150.02	015002
269	14.01	001401	130	013000	160.01	016001

Figure 5: Maps of Medically Underserved Areas and Health Professional Shortage Areas for New York County. Each colored region represents a unique shortage area.

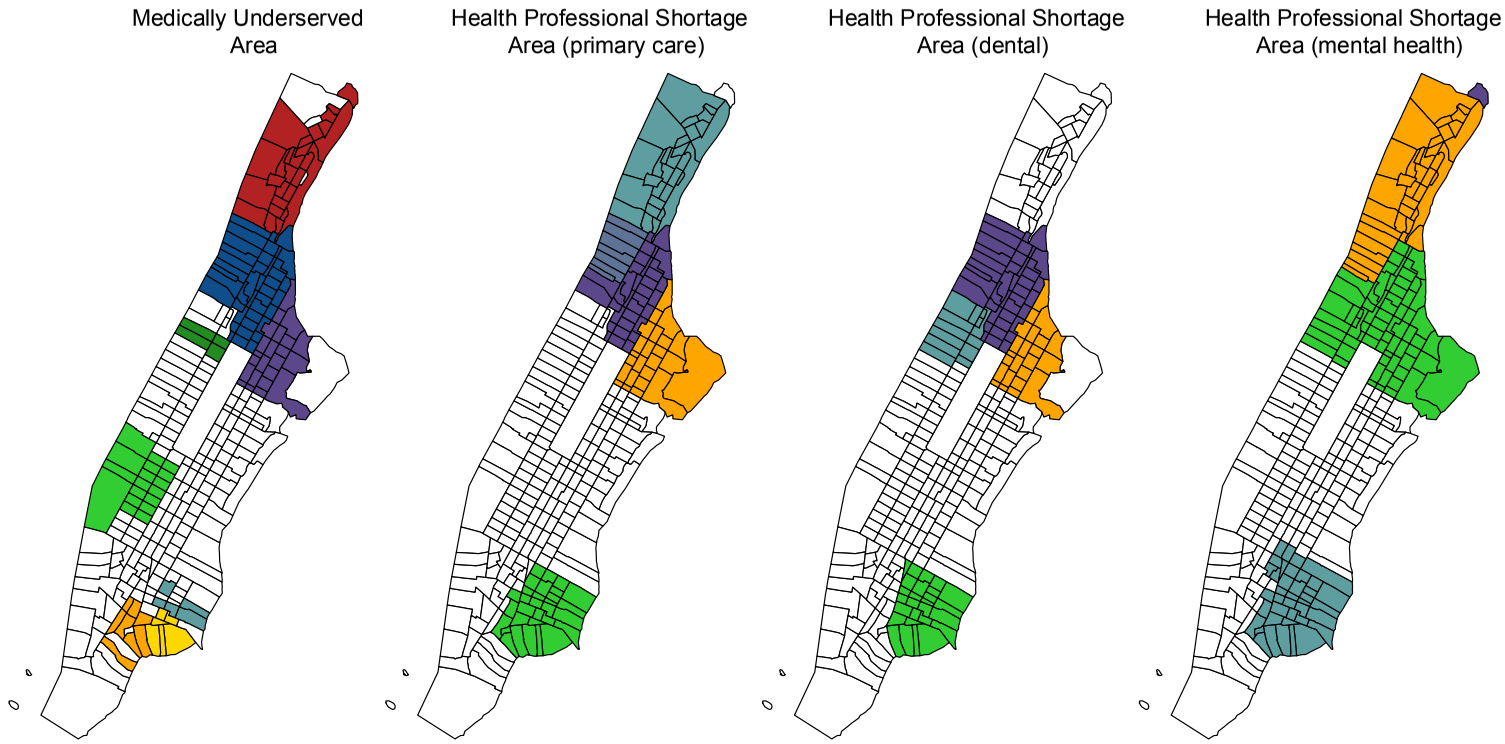


Table 9: Standardized Cronbach's α values.

	Townsend	Jarman 6	Jarman 8
Bronx County	0.82	0.80	0.76
New York County	0.70	0.84	–

4.3 Scale validation

Both the Townsend and Jarman scores are summated indices computed on a standardized scale. The implicit assumption of such an index is that a higher value of a component variable should indicate a higher level of deprivation. Cronbach's α measures this type of internal consistency and is computed by examining cross correlations of index items. We compute this measure for each county and method combination; results are listed in Table 9. The α values are high, indicating relatively strong internal consistency. The only exception is the Jarman 8 index value for New York County. We have left this cell blank because two of the constituent variables are negatively correlated with the index: % moved within the last year and % 65 years or older and living alone, violating the key assumption. Consequently, the computed α value is irrelevant. The social dynamics of Manhattan, which attracts many transplants, may be key to understanding why these variables are not indicative of deprivation in New York County but are in, say Bronx County. Note that these were the two variables identified in Section 3.3 as being negatively correlated with many of the other variables (see Table 5). We had omitted these two variables to construct the new Jarman 6, which is internally consistent for both counties.

5 Discussion

Summated indices allow one to track neighborhood rankings longitudinally without the components of the index also changing. In our analysis, we adapted the

Townsend Material Deprivation Index and the Jarman Underprivileged Area Score for US populations and applied it to New York and Bronx Counties. We chose these two indices because we could fit them using publicly available data from the American Community Survey. Constructing an index that is practical is important if it is to be adopted for general use. In our simple analysis, several issues arose resulting in a few avenues to take this work further statistically.

As we showed in Section 4.3, there are questions about the validity of these scales for a US population. In particular, applying these indices on a routine basis like in Eibner and Sturm (2006) may not be wise. We saw the problems in internal consistency when we applied the indices on two urban and *adjacent* counties. The US is an extraordinarily diverse country and using these scores on a larger scale would inevitably cause problems. In particular, we feel that comparing rural and urban areas within the same index would be problematic. For example, in rural communities not owning a car (required for the Townsend index) would be far more indicative of deprivation than in a metropolitan area, like New York with a well developed public transport system and high costs for owning a car. Talbot (1991) grazes on this issue. This would necessitate identifying other variables which may work better for US populations and making some adjustment for the type of population (rural versus urban); the downside of this is more information, possibly difficult to obtain, is required to keep the index calculable.

The key statistical issue is that the constituent variables which comprise these indices are estimates themselves. The American Community Survey publishes margins of error, which we have (as all other research in this area) have ignored. Unfortunately, this means that in our analyses, we have attributed the indices with far more precision than is justified. For small areas, these errors can be substantial and given their use in identifying neighborhoods in need of

extra funds or personnel, precision and accuracy are vital. Consequently, methods which handle measurement with error should be developed possibly drawing from the shrinkage methods used in the Index of Multiple Deprivation [9, 12].

The Townsend and Jarman indices show that practical options exist for identifying deprived areas and, with some additional research, can be adapted to US populations; however, internal consistency of these indices along with evidence of a correlation between the indices and health variables need to be shown first. With such indices, organizations can identify neighborhoods which may benefit from extra resources with existing data.

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