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The development of the Community Deprivation Index and its application to accountable care organizations

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Abstract

There is strong interest among policymakers to adjust for area-level deprivation when making payments to providers because such areas have traditionally been underserved. The Medicare Accountable Care Organization Realizing Equity, Access, and Community Health (ACO REACH) model provides higher payments to ACOs serving areas with greater deprivation. Area Deprivation Index (ADI) is the primary component to measure deprivation for ACO REACH. The ADI is a commonly used deprivation index, but there are concerns about its methodology, primarily its use of nonstandardized deprivation factors. Prior research indicates the ADI is mainly determined by home values, which does not allow it to adequately capture deprivation in urban areas. This paper revises and updates the ADI, using American Community Survey data to compute a census block group deprivation index, the Community Deprivation Index (CDI). The CDI standardizes the deprivation factors to be unit neutral, applies statistical shrinkage to account for the imprecise measurement of the factors, updates several factors, and reweights the factors using the most recently available data. Validation tests suggest the CDI exhibits higher correlations with several health outcome/utilization measures than the ADI. The CDI will better serve policymakers by improving identification of urban areas with higher deprivation.

Key words: social determinants of health; health equity; payment; health financing; community health.

Introduction

In recent years, health equity has become an increasingly high priority in the public health space. The emphasis on addressing the disparity in health outcomes in the United States has galvanized policymakers to implement new approaches for the health system to identify and better serve the populations who most need targeted resources to improve their health status. Identifying these segments, however, remains difficult as populations who are underserved by the health system are often difficult to identify, almost by definition. However, a substantial body of research exists dedicated to the empirical definition and identification of deprived regions, which have been used as proxy tools to help identify the segments of the population most in need of intervention.

The notion of a local Area Deprivation Index (ADI), comprised of several markers for socioeconomic status (SES), is well explored in the literature. The ADI uses 17 SES markers aggregated via principal component analysis (PCA) into a fixed-range rank of area deprivation.[1] The original ADI was developed at the Census tract level, but was expanded upon to create data at the block group level.[2] The use of the ADI is widespread and it has since been used by various government agencies and in several Medicare programs and demonstrations, including the Medicare Shared Savings Program, Accountable Care Organization Realizing Equity, Access, and Community Health (ACO REACH), and Guiding an Improved Dementia Experience. Payments to providers that serve areas with higher levels of deprivation advance equity, and investing in these providers given they are historically underfunded can increase care delivery investments in underserved populations. Thus, payments, such as those in ACO REACH, are an important component for advancing health equity. Given the goal is to "right-size" payments for these providers, it is especially important that policymakers are equitable in the distribution of these investments.

The ACO REACH model uses a financial benchmark to evaluate an ACO's financial performance and is testing a health equity benchmark adjustment (HEBA) designed to provide incentives, as well as resources, for ACOs to work with clinicians providing healthcare services to underserved populations.[3] The HEBA is a composite measure that uses both the ADI and Medicare–Medicaid dual eligibility or low-income subsidy status of the ACO's aligned beneficiaries. Overall, the purpose of the HEBA is to provide additional resources to ACOs serving underserved populations by increasing the ACO's financial benchmark. While ACOs serving underserved areas will tend to have their financial benchmarks increased by the HEBA, ACOs not serving underserved areas could have their financial benchmarks decreased by the HEBA (although downward adjustments tend to be relatively small on net).

However, several studies have questioned whether the ADI measures deprivation in certain urban centers. For example, the ADI does not meaningfully track with life expectancy in urban areas such as New York City, San Francisco, and Washington, DC.[4] The primary concern involves the lack of standardization of variables in the construction of the ADI.[5-9] While it is not necessary to standardize variables for PCA, it is important to standardize variables when using

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PCA results to compute factor scores. Standardization prevents giving undue weight in an index to variables with larger nominal values. In its unstandardized form, the ADI is >90% correlated with median home value and is essentially a two-variable index (home values and income). For example, a 98% correlation was found between ADI rank and median home value in New York State.[10] Other concerns with the ADI include that the original factor variables and weights are from data over 20 years old, and updates to the variables and weights may be needed.[11]

The goal of this paper is to test revisions to the deprivation index used in the HEBA adjustment applied in ACO REACH, including standardizing the input variables, applying shrinkage to reduce uncertainty,[12-14] updating several index variables, and employing more recent data to estimate factor weights. We refer to this revised deprivation index as the Community Deprivation Index (CDI). We also examine how these changes affect measured deprivation and provide results to validate the revised deprivation measure.

Methods

Data

The data used in this study are from the American Community Survey (ACS) administered by the US Census Bureau. The survey is given every year and survey data are posted in 1- and 5-year estimates at multiple geographic levels. We are using the 5-year estimates from the period between 2015 and 2019 at the census block group level to align with the 2019 ADI currently used to create the HEBA. The data contain estimates of the components of each of our relevant variables, along with the margin of error for that estimate, provided at a 90% confidence level. We accessed the data by means of an application programming interface using the R package tidycensus as an interface.

Updating variables and weights

Updates included exploring the addition of new variables to the model, updating several existing variables in the model, and estimating new factor weights. The variables in the ADI were found to be fairly stable. We tested 10 additional variables in the index and most contributed a trivial weight to the index. Additional detail on the variables tested is provided in the Supplementary material. The percent uninsured was the only variable that had a nontrivial weight, and thus, we added percentage uninsured in the block group to the index.

We also updated the education, income, and phone variables in the 2019 ADI. For low education, we replaced the percentage with ≤8 years of schooling with the percentage with 12 or fewer years, but no diploma. To denote a block group has a higher educated population, we replaced the proportion with a high-school diploma or higher with the proportion with a bachelor's degree or higher. The income levels used to measure income disparity were updated from 1990 to 2019 based on the Consumer Price Index; the lower level of $10 000 was increased to $20 000 and the upper level of $50 000 was increased to $100 000. Finally, we replaced the percentage without a telephone with the percentage without high-speed internet.

New factor weights were also estimated for the variables using PCA. The factor weights in the original ADI were estimated using 1990 census data and thus are outdated, and more recent census data were used to estimate the new factor weights. In addition, adding a new variable and revising several variables necessitated estimating new factor weights.

Creating a standardized index

We develop a factor-weighted composite score using PCA based on 18 (standardized) variables using 2019 ACS census block group (see Supplementary material for more details). To construct a standardized index, each of the input variables is standardized to have a mean of 0 and an SD of 1 across all block groups in the nation. Implicitly, standardizing the input variables ensures that all components of the index are at the same scale, and does not allow large raw home values to have a disproportionate effect. The standardized block group values are ranked on a national scale to create a percentile rank such that the ADI scores for all block groups range from 1 to 100.

Incorporating shrinkage

Measurement error may also be a challenge in small area indices. To address concerns that sampling error may be affecting the standardized index, we include a shrinkage adjuster that accounts for sampling error. The University of Wisconsin incorporated a shrinkage methodology into version 4.0 of the 2020 ADI to account for uncertainty. Due to challenges with assigning 2020 census block groups in Medicare enrollment data, the ADI used in the HEBA has been based on the 2019 ADI and thus has not included a shrinkage adjustment.

The shrinkage estimator is incorporated prior to standardization and is based on empirical Bayesian estimation and involves adjusting block group measures toward larger area tract measures.[15-17] The actual mechanism of the procedure is to estimate each variable in a particular block group with a weighted combination of data from that block group and data from the larger census tract. If the block group has a relatively high SE and there is less variation across block groups within a tract, then the block group moves toward the tract score. Although most scores typically move a small amount, the variables measured with large SE may move significantly. The shrunk estimate of a block group variable is a weighted average of the block group variable and the corresponding tract variable. The weights used are determined by the relative magnitudes of the within block group and the between block group variability within a tract.

The Margin of Error for each block group is converted into an SE (s_j) and along with the standardized variable values for the block group X'_{ij} and tract X'_j are used to generate shrinkage adjusted variables X^*_{ij} for each block group. Each variable is adjusted separately and thus incorporates uncertainty at the variable/block group level. Once we have shrinkage adjusted variables, we follow the same methodology to generate the final shrinkage adjusted standardized index as we did to generate the standardized index.

Validation

To validate the deprivation measure, we explore the changes between the ADI and the CDI for two areas highlighted as problematic in prior literature (New York City and Washington, DC), those census block groups with the largest changes in measured deprivation, as well as how index changes are associated with the 17 original model factors across all census block groups.

Table 1. Factor weights based on American Community Survey variables.

Variable	Factor weights		
	Original variables	Updated data, updated variables	Updated data, updated and shrunk variables
% with 9 years or less of education	0.085	—	—
% with 12 years or less of education, no diploma	—	0.091	0.090
% with high-school diploma	−0.097		
% with 16+ years schooling	—	−0.105	−0.101
% employed in white collar jobs	−0.087	−0.101	−0.099
% families below poverty line	0.098	0.096	0.096
% households >1 person per room	0.056	0.043	0.044
% households with no telephone	0.088	—	—
% households without high-speed internet	—	0.094	0.093
% households with no vehicle	0.069	0.053	0.049
% households with incomplete plumbing	0.051	0.019	0.022
Income disparities (old)	0.094	—	—
Income disparities (new)	—	0.115	0.111
Median household income	−0.098	−0.115	−0.110
Median gross rent	−0.078	−0.087	−0.083
Median home value	−0.069	−0.081	−0.077
Median monthly mortgage	−0.077	−0.089	−0.085
% one parent households	0.072	0.076	0.078
% owner-occupied housing	−0.062	−0.067	−0.063
% below 150% of poverty line	0.104	0.112	0.109
% unemployed	0.081	0.059	0.062
% uninsured	—	0.070	0.069

Authors' analysis of 2019 ACS. Baseline weights from Singh.[1] Updated factor weights are estimated using principal components analysis in SAS statistical software.

Finally, we assess the correlation between several measures of deprivation, healthcare utilization, and health outcomes and the two indices to determine whether the CDI exhibits a stronger correlation than the ADI. Correlating deprivation indices with health outcomes are often a preferred method for validation.[18] The HHS Health Resources and Services Administration Area Health Resources File contains county-level data on emergency room visits, the rate of preventable hospitalizations, and the readmission rate for Medicare beneficiaries; Area Health Resources Files (hrsa.gov). The Centers for Disease Control has developed life expectancy estimates at the Census tract level (https://www.cdc.gov/nchs/nvss/usaleep/usaleep.html). Finally, the HHS Agency for Healthcare Research and Quality Social Determinants of Health database (https://www.ahrq.gov/sdoh/data-analytics/sdoh-data.html) contains a wide array of measures, including the CDC's Social Vulnerability Index, the Census Bureau's Community Resilience Estimates risk factors, disease prevalence, and availability of health care services. We use the percentage of adults reporting no physical exercise, the proportion of adults with asthma due to the well-known link between poverty and asthma,[19] and the distance to the closest Federally Qualified Health Center/Rural Health Center since they are intended to serve an underserved population.

Limitations

Census block groups are used as the geographic areas for measuring deprivation. While the ADI also uses these groups, it is unclear whether they represent the best options for measuring deprivation. Similarly, while the ACS is also used to generate the ADI and is the most comprehensive data available, there are some shortcomings. Some variables are measured using relatively small sample sizes. Home values, a key variable for the ADI, are only available for owner-occupied housing. Finally, the shrinkage adjuster has been previously used in the construction of small area indices, and more extensive research should provide a stronger theoretical justification for the use of a normal distribution and the relative weights of the census block groups and tract measures.

Results

Table 1 contains the (1) original factor weights, (2) factor weights when updating the data and variables, and (3) factor weights when both updating the data and variables and when incorporating shrinkage to adjust the variables. The coefficients from some variables changed notably between Singh's model and a model estimated with 2019 data. For example, factor weights are larger in magnitude for the updated income disparities measure, median income, and the updated measures for higher schooling. Factor weights decline for percent without a vehicle, percent without household plumbing, and percent of households with >1 person per room, perhaps reflecting the declining importance of these measures. The factor weights for the updated variables are used to generate the standardized index, while the updated and shrunk weights are used to develop the final index.

The results are presented in two stages, the first showing the effects of standardization, and the second showing the impact of using shrinkage. Figure 1 illustrates the decile rankings comparing the ADI to the standardized index without shrinkage. There are wide differences between the ADI and the standardized index. Most block groups change deciles with standardization; 70.4% or 151 690 of the 215 620 block groups are in a different decile with the standardized index. There are 198 census block groups that shift from the lowest decile of deprivation in the ADI (decile 1) to the highest decile of deprivation in the standardized index (decile 10).

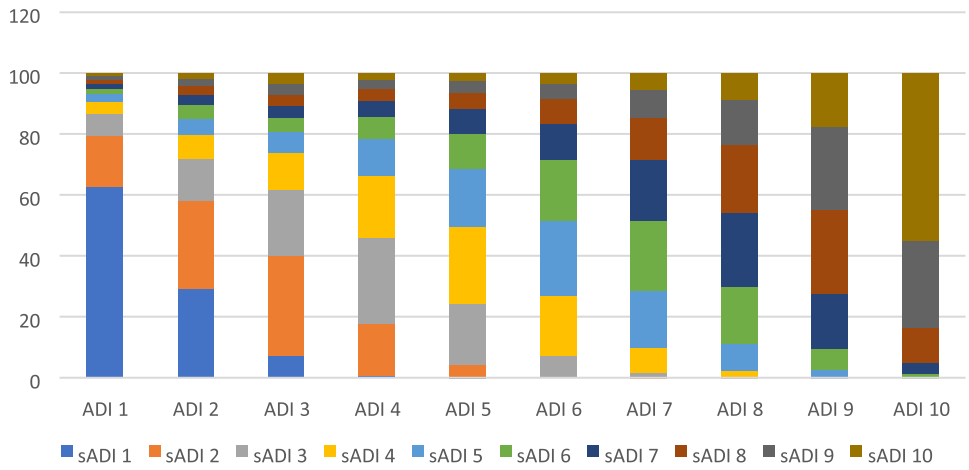

Figure 1. Decile comparison of Area Deprivation Index (ADI) vs standardized ADI (sADI) Index Decile. Source: Author's analysis on the 2015-2019 American Community Survey data. The figure shows the distribution of census block groups in standardized ADI deciles for each decile of the ADI.

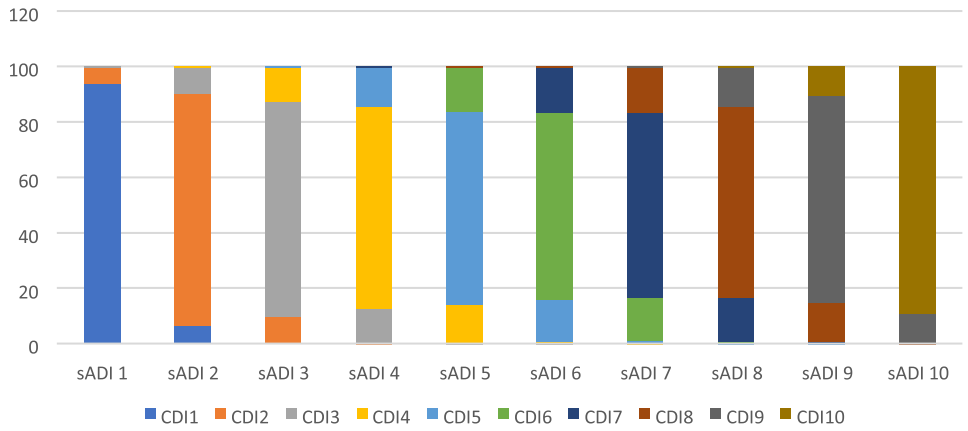

Figure 2. Decile comparison of the standardized Area Deprivation Index (ADI) with the Community Deprivation Index (CDI). Source: Author's analysis on the 2015-2019 American Community Survey data. The figure shows the distribution of census block groups in CDI deciles for each decile of the standardized ADI.

Figure 2 illustrates a comparison of the standardized index without shrinkage (standardized ADI) and the standardized index with shrinkage (CDI). Most block groups remain in the same decile with shrinkage (76.5% or 164 886 of the 215 620 block groups). However, 23.5% of block groups changed at least one decile in measured deprivation with shrinkage imposed. Overall, the results imply that standardization has a substantive effect on measured deprivation, while shrinkage also has notable impacts.

For ACO REACH, the 30th and 70th percentiles are important thresholds for distinguishing block groups where ACOs are eligible to receive an increase in benchmarks due to the HEBA, and block groups where ACOs receive a reduction in benchmarks due to the HEBA. The HEBA also accounts for dual Medicare–Medicaid enrollment in determining a total score. Thus, the 30th and 70th percentiles based solely on the deprivation index are only an approximation of the actual HEBA thresholds. Out of 64 686 block groups in the bottom 30% of the ADI, 73.7% (47 703 of 65 664) of the block groups are also in the bottom three deciles of the CDI. There are 4695 block groups (7.2%) in the bottom three deciles of the ADI that are in the top three deciles of the CDI. Similarly, 71.1% (46 025 of 64 686) of block groups in the top three deciles of the ADI are also in the top three deciles of the CDI.

Evaluating the impact of standardization and shrinkage

Prior research critiquing the ADI has focused on specific urban areas, New York City and Washington, DC, to illustrate the potential shortcomings. Comparison of the ADI and the CDI indicates substantial increases in measured deprivation, particularly in the Bronx (ADI = 27, CDI = 77) and Brooklyn (Kings County, ADI = 9, CDI = 50). For Washington, DC, block groups were sorted into deciles based on average household income. As expected, the poorest block groups see large increases in measured deprivation (eg, decile 1: ADI = 35, CDI = 90; decile 2, ADI = 31, CDI = 78), while the highest decile sees little change (decile 10, ADI = 2.2, CDI = 1.7).

The CDI appears to address the concerns in prior research regarding specific areas. However, New York City and Washington, DC are not the only areas in the country where we see large changes in measured deprivation. In the 43 block

Table 2. Coefficients relating the change in deprivation index (Community Deprivation Index minus Area Deprivation Index) and Singh's model variables.

Parameter	Estimate	SE	*T*-value	$P > t$
Intercept	17.405	0.467	37.24	<.0001
% with 9 years or less of education	25.476	0.639	39.88	<.0001
% with high-school diploma	−20.154	0.467	−43.17	<.0001
% employed in white collar jobs	−18.049	0.201	−89.64	<.0001
% families below poverty line	6.704	0.323	20.76	<.0001
% households >1 person per room	61.684	0.494	124.84	<.0001
% households with no telephone	−0.293	0.783	−0.37	.7081
% households with no vehicle	10.218	0.239	42.69	<.0001
% households with incomplete plumbing	12.526	1.361	9.20	<.0001
Income disparities	−0.640	0.031	−20.75	<.0001
Median gross rent	−0.002	0.000	−36.14	<.0001
Median household income	0.000	0.000	−61.48	<.0001
Median home value	0.000	0.000	113.53	<.0001
Median monthly mortgage	0.009	0.000	133.00	<.0001
% one parent households	6.484	0.232	27.91	<.0001
% owner-occupied housing	−11.877	0.144	−82.27	<.0001
% below 150% of poverty line	2.750	0.301	9.14	<.0001
% unemployed	13.316	0.434	30.65	<.0001

Authors' analysis of 2015-2019 ACS.

Table 3. Correlation between indices and health/health equity measures.

Variable	Geographic area	Correlation	
		ADI	CDI
Deprivation measures			
Social vulnerability index: percentile ranking for socioeconomic theme	Tract	0.64	0.91
Percentile ranking for overall social vulnerability index	Tract	0.53	0.85
Percentile ranking for overall minority health social vulnerability index	County	0.23	0.49
Rate of individuals with three or more CRE risk factors (%)	Tract	0.48	0.68
Percentage with Medicaid	Tract	0.46	0.78
Utilization and outcomes			
ED visits per 1k Medicare beneficiaries	County	0.38	0.45
Preventable hospital stay rate	County	0.42	0.44
Readmission rate	County	0.22	0.27
Distance to FQHC/RHC	Tract	−0.01	−0.14
Life expectancy	Tract	−0.65	−0.67
% of adults reporting no exercise	Tract	0.74	0.88
% of adults with asthma	Tract	0.61	0.67

Author's analysis on the 2015-2019 ACS, HRSA Area Health Resource File, CDC USALEEP, and AHRQ Social Determinants of Health Database.
Abbreviations: ADI, Area Deprivation Index; CDI, Community Deprivation Index; CRE, Census Resilience Estimates; ED, emergency department; FQCH, Federally Qualified Health Center; RHC, Rural Health Center.

groups that had index increases of >90 points, all variables except for median mortgage and median home values are consistent with high levels of deprivation. In the 64 block groups that had index declines of >50 points, all variables except for median income, median mortgage, and median home values are consistent with low levels of deprivation.

It is noteworthy that median home values are over $1 million in the 43 block groups with the largest increases in measured deprivation, which explains why their ADI scores indicate little deprivation. The ACS reports home values only for owner-occupied housing. For these 43 block groups, the percentage of owner-occupied housing averaged 1.5%, compared with a national average of 64.8%. Thus, home values, which account for a disproportionate share of the ADI, are based on such a small share of housing in these block groups that they do not correlate with the other variables in the model.

Table 2 contains regression results with the CDI–ADI difference regressed on the 17 original unstandardized variables in the ADI. The changes to the index described in this paper result in an index more highly correlated with the original input variables. Variables indicative of social and economic disadvantage tend to be associated with higher levels of measured deprivation in the CDI than the ADI (eg, <9 years schooling, poverty, crowded housing, no vehicle, incomplete plumbing, and unemployment). Variables indicative of social and economic advantage tend to be associated with lower levels of measured deprivation (eg, high-school diplomas, white collar jobs, income disparity, higher rents, and higher rates of owner-occupied housing). Higher home values, mortgage payments, and income were associated with a marginal increase in measured deprivation.

Finally, we examine the correlation between the two indices, alternative measures of deprivation, and several health outcome/utilization measures. The results in Table 3 show that the CDI exhibits a stronger correlation than the ADI with each of the deprivation and health-related measures. For example, the correlation coefficients for the CDI and ADI and the CDC's Social Vulnerability Index are 0.85 and 0.53, and for emergency department visits are 0.46 and 0.38, respectively.

Discussion

The ADI is currently used as a measure of deprivation for certain Medicare programs and demonstrations (eg, ACO REACH). This paper examined the impact on measured deprivation when making several changes to the ADI to refine the measure of deprivation, which we refer to as the CDI. Incorporating updated data and variables, standardizing variables, and incorporating a shrinkage adjuster provides an index more highly correlated with characteristics associated with deprivation than the ADI. The effects are greatest for block groups where home values are not strongly correlated with other indicators of deprivation. For example, block groups within urban areas with low owner occupancy rates exhibited large changes in measured deprivation. Home values for some block groups are not reflective of deprivation because they only reflect a very small proportion of housing. The challenges in using median home values, while mitigated in the CDI, suggest that future research could explore modifications to better incorporate aspects of housing as they relate to deprivation. Nonmodel measures, such as percentage with Medicaid, life expectancy, percentage of adults reporting no exercise, and percentage of adults with asthma also exhibit a stronger correlation with the CDI than ADI.

The suggested use of the CDI will also address questions in the literature concerning the ADI. In particular, certain block groups within large metropolitan areas were found to have low measured deprivation with the ADI despite having characteristics associated with high levels of deprivation. The changes incorporated into the CDI will help to address these

issues, aligning with the policy goal of identifying neighborhood deprivation even in areas of high housing costs.

However, changes in an index should not be driven by a few specific urban areas.[20] Indeed, this analysis found that there are substantive differences between the ADI and CDI across census block groups in the country and that these differences are correlated with variables associated with deprivation. Hence, the results suggest that while there are increases in measured deprivation in the specified urban areas discussed in the literature, the impact is seen on a larger scale and in a direction that correlates with characteristics of deprivation.

Given that a deprivation index is essentially a ranking of scores, an increase in measured deprivation for some areas must be offset by a decline in measured deprivation for others. In general, we expect the largest effects on measured deprivation when home values are not strongly correlated with the other model variables. For example, we expect measured deprivation to increase among urban block groups that have high property values but other model variables suggesting substantial deprivation. Similarly, measured deprivation will decline among block groups that have low property values but other model variables suggesting little deprivation. We do not expect systematic changes when home values are correlated with the other model variables. As such, despite the attention to specific urban areas, there should not be a systematic decrease in measured deprivation in rural areas that have variables broadly associated with deprivation.

Conclusion

The Medicare ACO REACH model has used the ADI to provide higher payments to ACOs serving areas with greater deprivation. Our analysis found that the CDI more accurately targets urban areas with greater deprivation and does not systematically impact measured deprivation in rural areas. As such, given a stronger association with variables denoting deprivation, the use of the CDI to compute the HEBA will direct more resources in the ACO REACH model to areas with greater deprivation. This would help the Medicare program to provide Medicare ACOs with stronger incentives to provide care management and care coordination to the Medicare beneficiaries residing in the most deprived areas.

Supplementary material

Supplementary material is available at *Health Affairs Scholar* online.

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Conflicts of interest

Please see ICMJE forms for author conflicts of interest. These have been provided as supplementary materials.

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