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Public Health Spending and Medicare Resource Use: A Longitudinal Analysis of U.S. Communities

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Objective. To examine whether local expenditures for public health activities influence area-level medical spending for Medicare beneficiaries.

Data Sources and Setting. Six census surveys of the nation's 2,900 local public health agencies were conducted between 1993 and 2013, linked with contemporaneous information on population demographics, socioeconomic characteristics, and area-level Medicare spending estimates from the Dartmouth Atlas of Health Care.

Data Collection/Extraction. Measures derive from agency survey data and aggregated Medicare claims.

Study Design. A longitudinal cohort design follows the geographic areas served by local public health agencies. Multivariate, fixed-effects, and instrumental-variables regression models estimate how area-level Medicare spending changes in response to shifts in local public health spending, controlling for observed and unmeasured confounders.

Principal Findings. A 10 percent increase in local public health spending per capita was associated with 0.8 percent reduction in adjusted Medicare expenditures per person after 1 year ($p < .01$) and a 1.1 percent reduction after 5 years ($p < .05$). Estimated Medicare spending offsets were larger in communities with higher rates of poverty, lower health insurance coverage, and health professional shortages.

Conclusions. Expanded financing for public health activities may provide an effective way of constraining Medicare spending, particularly in low-resource communities.

Key Words. Public health services, medical care spending, health economics

Preventable health conditions account for more than 75 percent of annual health care expenditures in the United States (CDC 2009), yet less than 5 percent of these expenditures are devoted to public health programs and services that are designed to prevent and control disease and injury rather than to treat the downstream consequences of these conditions (Miller et al. 2008; CMS 2016). Such limited expenditures for public health activities may contribute to the higher rates of preventable mortality experienced in the United States compared to other high-income countries, and to widely varying life expectancies for communities within the United States (IOM 2012, 2013; Chetty et al. 2016). Public health activities include efforts to monitor community health status, investigate and control disease outbreaks, educate the public about health risks and prevention strategies, implement community-wide health promotion and disease prevention programs, develop and enforce laws and regulations designed to reduce health risks, and inspect and assure the safety of water, food, air and other resources necessary for health (IOM 1988). In the United States, public health activities are financed through a patchwork of federal, state, and local funding streams that vary widely across communities and change over time. More than 80 percent of governmental public health expenditures are financed from state and local sources, which are highly sensitive to economic conditions and which reflect the underlying inequities in household income, housing wealth, and tax revenue across communities (CMS 2016). As a consequence, per capita governmental public health expenditures vary by a factor of 13 between the wealthiest 20 percent and poorest 20 percent of communities in the United States (Mays and Smith 2009).

Limited and unstable financing for public health activities poses significant challenges to improving health status and reducing health disparities on a population-wide basis. Preventable risk factors including smoking, blood pressure, blood glucose, physical inactivity, and adiposity account for large shares of the racial, ethnic, and geographic disparities in U.S. health status (Danaei et al. 2009). Lowering these risk factors to recommended levels could reduce health disparities in cardiovascular disease, diabetes, and cancer deaths by 30 to 80 percent (Danaei et al. 2010). Numerous efficacious interventions exist for reducing preventable risk factors, such as those based on the Diabetes Prevention Program recently approved for Medicare coverage, and those used as part of the federal Million Hearts Cardiovascular Risk Reduction Model now being tested in Medicare (Sanghavi and Conway 2015; Alva et al. 2017). However, feasible mechanisms for implementing these interventions on a broad, population-wide basis, particularly for underserved populations,

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remain unclear (Mays et al. 2009). The nation's public health infrastructure—including state and local governmental public health agencies and the community organizations with which they work—plays important roles in implementing prevention programs and health policies, particularly for underserved populations (IOM 2012). Limited and inequitable financing for this infrastructure may constrain the nation's implementation capacity for prevention and diminish its potential to reduce health disparities. In view of these findings, a 2012 consensus study report from the National Academy of Sciences Institute of Medicine recommended that the federal government double its current level of spending on public health activities, and retool existing financing mechanisms to give state and local agencies greater flexibility in the use of these funds (IOM 2012).

A growing body of research indicates that local variation in public health resources contributes to differences in health outcomes observed across communities (Grembowski et al. 2010; Mays and Smith 2011; Brown 2014, 2016; Mays, Mamaril, and Timsina 2016). These findings raise the possibility that expanded financing for public health activities could lower overall disease burden and thereby constrain medical spending. One study of U.S. medical spending over a decade found that approximately one quarter of the growth in spending was attributable to increases in treated disease prevalence, suggesting an important role for public health activities in bending the medical cost curve through disease prevention (Roehrig and Rousseau 2011). Recognizing this potential, the Patient Protection and Affordable Care Act of 2010 created the Public Health and Prevention Fund and authorized up to $15 billion in new federal spending on public health and prevention strategies over the next decade. This component of federal health reform has remained controversial, in large part because of uncertainties about its effectiveness in improving health outcomes and constraining future medical spending (Haberkorn 2012).

Because many preventable health conditions accumulate with age, public health's potential to offset medical spending may be particularly pronounced in the Medicare population. Wide geographic variation in Medicare resource use is well documented in the United States through the Dartmouth Atlas studies and related research (Fisher et al. 2003a,b; Fisher, Bynum, and Skinner 2009), but to date no studies have examined whether public health resources and activities contribute to this variation. In this study, we use data on local public health spending over a 20-year period from 1993 to 2013, combined with area-level Medicare expenditure estimates from the Dartmouth Atlas, to estimate whether public health expenditures offset Medicare spending over time. Medicare expenditure measures provide only a partial view of area-level medical care resource use because Medicare spending constitutes only about 20 percent of total medical care spending in the United States (CMS 2016). Nevertheless, if local public health spending helps to constrain overall medical care use by reducing the incidence of preventable diseases and comorbidities, then some of the largest medical cost offsets may accrue in Medicare where the prevalence and treatment costs of preventable diseases such as cardiovascular disease, diabetes, cancer, and influenza are high.

This study focuses on spending in local geographic areas because local public health agencies, rather than their state and federal counterparts, assume primary responsibility for directly implementing public health activities in most communities (Halverson et al. 1996). Most federal, state, and local funding for public health activities—and significant amounts of private philanthropic funding—are channeled through local public health agencies. These agencies also are charged with mobilizing and coordinating the public health activities contributed by other community organizations (Mays et al. 2010). As such, these agencies and the communities they serve provide instructive settings in which to study the interplay between public health and medical care resource use.

Data and Methods

Study Population

A longitudinal, retrospective cohort design was used to analyze changes in spending patterns within service areas of the nation's nearly 3,000 local public health agencies between 1993 and 2013. The study population included all organizations operating during this time period that met the National Association of County and City Health Officials' (NACCHO) definition of a local health department: an administrative or service unit of a local or state government that has responsibility for performing public health functions for a geopolitical jurisdiction smaller than a state (NACCHO 2014). NACCHO maintains active and historical lists of these organizations. During the study period, all U.S. states except Rhode Island contained agencies that met this definition. In 2013, approximately 73 percent of these agencies served county jurisdictions or combined city-county jurisdictions, with the remaining agencies serving city or township jurisdictions (16 percent) or multicounty or regional jurisdictions (11 percent).

Data Sources

NACCHO collected expenditure data along with organizational and operational characteristics of local public health agencies through census surveys fielded in 1993, 1997, 2005, 2008, 2010, and 2013, with response rates varying from 68 to 80 percent. While the content of the survey changed from year to year, a core set of variables reflecting annual agency expenditures, jurisdiction size, service offerings, and governance structures were collected in each year of the survey. Observations were linked across the six waves of the survey using identifying information on each public health agency. A total of 3,115 unique agencies responded to one or more survey waves, with 2,670 agencies (86 percent) responding to at least two waves and 1,184 agencies (38 percent) responding to all six waves.

Using identifying information about each local public health agency's service area, we linked the NACCHO survey data with contemporaneous information from several other data sources. We used the Dartmouth Atlas of Health Care as the source of data on area-level medical spending for Medicare beneficiaries (Dartmouth Institute 2016). For years 2003 through 2014, we used the claims-based measures of Medicare expenditures per person at the hospital service area (HSA) level, adjusted for price, age, sex, and race (Skinner, Gottlieb, and Carmicheal 2011). For the earlier years of our study period prior to 2003, we used the older Continuous Medicare History Sample (CMHS) measures of expenditures per person adjusted for age, sex, and race. We linked agency-level NACCHO survey data with HSA-level Dartmouth Medicare data using a crosswalk of the zip codes contained in each public health agency service area and in each HSA. For public health agency service areas that fall within more than one HSA, we computed the weighted average of HSA-level variables using as weights the estimated fraction of the service area population that falls within each HSA.

County-level data on population characteristics and health resources were obtained from the Area Health Resource File, a collection of more than 50 data sources, including the American Medical Association Physician Masterfile, the American Hospital Association Annual Hospital Survey, and U.S. Census Bureau data sources (HRSA 2016). County-level variables reflecting direct federal public health expenditures were constructed from the U.S. Consolidated Federal Funds Report (GSA 2016). State-level data on public health expenditures were obtained from the U.S. Census Bureau's 1992, 1997, 2002, 2007, and 2012 Census of Governments using expenditure function category 32 that excludes hospital care and most other medical care expenditures (U.S. Census Bureau 2016). For public health agencies serving service areas of more than one county, we aggregated county-level data to the service area level.

Measures and Model Specification

Area-Level Medicare Spending. Our dependent variable measures average Medicare spending per person in the hospital service area (HSA), adjusted for price, age, sex, and race using Dartmouth's methodology (Skinner, Gottlieb, and Carmicheal 2011). For years prior to 2003, this measure is not directly adjusted for price, but the price-adjusted and non-price-adjusted measures are highly correlated ($r \geq .97$). We constructed an adjustment factor for each HSA and each year equal to the percent difference between the price-adjusted and nonprice-adjusted measures, averaged across the 10 years (2003–2013) for which both measures are available. We then applied this adjustment factor to the nonprice-adjusted measures for years 1993–2002, in order to obtain pre-2003 measures that are more comparable with the price-adjusted measures available after 2003. We use the gross domestic product implicit price deflator to adjust all Medicare and public health spending measures to 2013 constant dollars (Dunn, Grosse, and Zuvekas 2016).

Public Health Spending. The primary independent variable in this analysis, local public health spending per capita, is calculated as the total annual expenditures of the local public health agency from all revenue sources as reported on the NACCHO survey, divided by the total population residing within the service area of the agency. We use two additional measures of public health spending to account for state and federal expenditures that are not passed through to local public health agencies. First, we constructed a measure of residual state public health spending per capita using annual data from the U.S. Census Bureau (2016). This measure was calculated for each state and each year as the total amount expended by state government for public health activities, net of all intergovernmental transfers to local governments for public health activities. Second, we constructed a measure of residual federal spending on public health activities using data from the U.S. Consolidated Federal Funds Report (GSA 2016), in order to account for federal public health funds provided directly to nongovernmental grantees and therefore not included in our local or state spending measures. We constructed this measure by taking the total annual amount of federal public health funding awarded to recipients in each county, and subtracting the federal awards received by local or state public health agencies. For simplicity, we defined federal public health spending to include all federal grant-in-aid programs administered by the U.S. Centers for Disease Control and Prevention (CDC).

Other Explanatory Variables. Isolating the relationship between local public health spending and Medicare spending requires controlling for confounding characteristics that influence community-level variation and change in Medicare resource use. Informed by Andersen's behavioral model of health care utilization and previous studies of medical care utilization (Fisher et al. 2003a, b; Pathman et al. 2005; Shi et al. 2005; Starfield et al. 2005; Ricketts and Holmes 2007; Fisher et al. 2009), we control for demand-side demographic and socioeconomic characteristics in the community that reflect underlying health needs and care-seeking behavior, along with supply-side medical resource characteristics that influence access to and delivery of care (Andersen 1995). Demand-side characteristics include population size and density, number of Medicare beneficiaries residing in the community, racial and ethnic composition, age distribution, educational attainment, poverty level, and the health insurance coverage rate. Supply-side characteristics include the number of active nonfederal physicians per 100,000 residents, the number of hospital beds per 100,000 residents, and the number of federally qualified health centers per 10,000 low-income residents. Descriptive statistics for all of the variables used in the analysis are summarized in Table 1.

Empirical Model

Multivariate regression models for panel data are used to estimate the association between local public health spending per capita and adjusted Medicare spending per person while controlling for the effects of other characteristics likely to influence Medicare resource use. Because we use longitudinal data, it is important to account for autocorrelation that exists between multiple observations taken on the same community over time. We first use a fixed-effects model that includes community-specific coefficients that control implicitly for all time-invariant community characteristics that are correlated with area-level Medicare spending. This specification allows us to estimate what happens to Medicare spending in an individual community as local public health spending changes over time. We estimate all models using a logarithmic specification in order to reduce skewness and the influence of outlier observations in both public health and Medicare spending variables.

Table 1: Characteristics of the Study Communities

	1993		*2013*	
Variable	*Mean*	*SD*	*Mean*	*SD*
Local public health agency expenditures per capita ($2013)[1]	35.24	33.32	55.47	100.93
Residual state public health expenditures per capita ($2013)[2]	19.73	22.41	26.19	31.68
Residual federal public health expenditures per capita ($2013)[3]	14.82	28.93	27.33	61.27
Public health political economy structures				
Local board of health exists (0,1)[1]	0.74	0.44	0.78	0.42
Local agency is a centralized unit of state agency (0,1)[1]	0.10	0.30	0.08	0.26
State agency hires local agency director (0,1)[1]	0.23	0.42	0.23	0.42
Local government approves agency budget (0,1)[1]	0.51	0.50	0.49	0.50
State agency approves local agency budget (0,1)[1]	0.18	0.38	0.18	0.38
Local government sets public health fees (0,1)[1]	0.44	0.50	0.42	0.49
Local government imposes public health taxes (0,1)[1]	0.63	0.48	0.60	0.49
Local board of health can request public health tax levy (0,1)[1]	0.28	0.45	0.27	0.44
Demand-side community characteristics				
Population size (1000s)[4]	114.70	415.62	122.23	369.79
Population per square mile[4]	475.08	1841.46	559.89	1920.17
Medicare beneficiaries (#)[5]	3990.10	7586.58	7607.28	12936.54
Jurisdiction included within a metropolitan area designation (0,1)[4]	0.51	0.50	0.52	0.50
Jurisdiction included within a micropolitan area designation (0,1)[4]	0.21	0.40	0.18	0.39
Percent population nonwhite (%)[4]	14.33	17.93	13.09	13.60
Percent population over 65 years of age (%)[4]	14.39	3.91	14.86	3.87
Percent of population below federal poverty level (%)[4]	15.65	7.04	13.11	5.11
Income per capita ($1,000s)[4]	16.40	4.70	34.42	11.71
Unemployment rate (%)[4]	6.21	2.42	5.76	1.80
Percent population with college degree (%)[4]	15.85	8.25	19.98	9.99
Percent population without health insurance coverage (%)[4]	13.66	4.65	16.10	5.59
Supply-side community characteristics				
Active nonfederal physicians per 100,000 residents[4]	138.04	133.83	182.77	179.48
Hospital beds per 100,000 residents[4]	384.16	320.51	351.25	392.21
Federally qualified health center operates in jurisdiction (0,1)[4]	0.48	0.50	0.55	0.50
CMS wage index[4]	0.86	0.26	0.97	0.14

Continued

Table 1. *Continued*

	1993		*2013*	
Variable	*Mean*	*SD*	*Mean*	*SD*
Adjusted Medicare expenditures per person ($2013)[5]	5,484.41	1,378.15	9,541.42	1,517.61
N	1,894		1,517	

Note. The measures derive from the data sources listed in the following references: 1. (NACCHO 2014); 2. (U.S. Census Bureau 2016); 3. (GSA 2016); 4. (HRSA 2016); 5. (Dartmouth Institute 2016).

An important methodological complication arises in this analysis due to the possibility that public health spending levels are endogenously determined based on unobserved community characteristics that also influence Medicare spending. For example, local economic conditions and health risks that change over time within communities may simultaneously influence the resources allocated to public health and the medical services used by Medicare beneficiaries. To address this possible source of bias, we use instrumental-variables (IV) methods to model the relationship between public health and Medicare spending while controlling for the effects of unmeasured characteristics that simultaneously influence both levels of spending (Angrist, Imbens, and Rubin 1996; Newhouse and McClellan 1998). To implement the IV analysis, we first estimate an ancillary multivariate model that expresses the public health spending level in a community as a function of public health agency characteristics along with the community characteristics used in the Medicare spending model. Estimates from this first-stage model are used to generate predicted values of local public health spending that are then used in place of the actual spending values to estimate the Medicare spending model. This two-stage method effectively removes the influence of unobservable characteristics on local public health spending levels, thereby allowing an unbiased estimate of the association between public health and Medicare spending. We interpret this estimate as the Medicare spending offset attributable to public health spending.

Identification of the two-equation IV model requires the use of one or more variables that are correlated with local public health spending and therefore included in the first-stage model, but uncorrelated with area-level Medicare spending and therefore excluded from the second-stage model. We use several local public health agency characteristics for this purpose that reflect the political economy of local public health resource decision making, particularly the degree to which decisions about public health resources and activities are controlled by local agencies, local governing boards, or state agencies. These IVs include the following: (1) whether the agency is governed by a local board of health with policy making authority; (2) whether the agency operates as a centralized unit of state government; (3) whether the state or the local government has the authority to approve the local public health agency budget; and (4) whether the local government and/or local board of health has the authority to establish public health fees and/or dedicated tax levies. Local governing boards of health are hypothesized to generate enhanced public and political support for allocating resources to public health, because their membership frequently includes individuals who have political access, professional credibility, and/or technical expertise that can be used to attract and maintain resources. Several prior studies have found evidence of higher levels of spending and performance among local public health agencies that are governed by local boards of health (Mays and Smith 2011; Mays, Mamaril, and Timsina 2016). Conversely, spending is expected to be lower among public health agencies that operate under the centralized control of state government. These agencies are hypothesized to have less autonomy and administrative flexibility to seek outside sources of support, and less ability to tap local sources of funding, than their counterparts that operate as decentralized units of local government (DeFriese et al. 1981). Specification tests (Staiger and Stock 1997) indicate that the governance and decision making variables are strongly associated with local public health spending levels ($F = 28.6$, $p < .01$). Furthermore, tests of the over-identifying restrictions provide strong evidence that the IVs are excludable from the Medicare spending equations.

One important limitation of the two-equation IV model is that it produces estimates with considerably larger standard errors than those produced by a standard, single-equation regression models. These standard errors are particularly large when the IV model is estimated with a fixed-effects specification, because the instrumental variables exhibit relatively little change over time within communities. To address this problem, we estimated the IV model using a random-effects specification that assumes the community-specific correlation coefficients are randomly distributed and uncorrelated with other characteristics included in the model. Specification tests confirm that when the Medicare spending equation is estimated using the IV methodology, the random-effects assumption is reasonable and produces estimates similar to the fixed-effects estimator but with smaller standard errors. In this specification, the instrumental variables control for unobserved heterogeneity that might otherwise cause independent variables to be correlated with the model's random effects. For this reason, we report estimates from the IV model using the random-effects specification and compare these results with estimates from the single-equation model using a fixed-effects specification.

A final methodological issue arising in this study concerns possible time lags between public health expenditures and their effects on Medicare resource use. Public health outlays support the implementation of a broad array of prevention programs and policies in the community, some of which may have near-term effects on health risks and medical costs (e.g., influenza vaccination, tobacco control) while others require longer time horizons (e.g., nutrition and physical activity interventions). For this reason, we include model specifications that test various lag structures between public health and Medicare spending. Our base model uses a one-year lag, allowing us to use all of the available panels of observations on local public health agency spending during 1993–2013, linked with observations on Medicare spending 1 year later. To test the sensitivity of results to alternative specifications, we also test five-year lag and 10-year lag structures, which reduce the total available sample size by excluding data points on public health spending from 2013 and 2008, respectively, because they cannot be linked to future (2018) Medicare spending data.

RESULTS

Local Public Health Spending

Local public health spending reached more than $55 per capita for the average community in 2013, up from $32 in 1993 (Table 1). The average rate of growth in local public health spending during the 1993–2013 period was less than 1.2 percent per year in constant dollars. Overall, 65 percent of communities experienced positive growth in per capita public health spending over the 1993–2013 period, with an average increase of $3.73 per capita. However, 35 percent of communities experienced reductions in spending during this period, with the average loss of more than $11 per capita. Spending levels varied widely across communities, ranging from a low of less than $1 per capita to more than $400 per capita in 2013. The Gini coefficient of 0.45 indicated a relatively high degree of inequality in local public health spending among communities in 2013, closely mirroring the level of income inequality observed among U.S. households.

Estimates from the multivariate model of local public health spending indicate that spending was more than 14 percent higher in communities served by a local governing board of health compared with communities without such boards ($p < .01$), after controlling for other characteristics in the model (Table 2). Other measures of public health agency governance and decision making structures also show strong associations with public health spending levels. Spending levels were significantly higher among agencies where the local government has the authority to hire agency leadership, establish fees for public health services, and impose dedicated taxes for public health. Spending was significantly lower in communities where local elected officials rather than local boards of health approve agency budgets, and spending was higher where state governments held some budget approval authority. Collectively, the seven measures of public health political economy explain approximately one-third of the total variation in local public health spending over the study period. Several community characteristics were positively associated with public health spending levels, including nonwhite racial composition, percent of population over 65 years of age, physician supply, and nonmetropolitan area designation.

Medicare Spending Offsets

Estimates from both fixed-effects and instrumental-variables models indicate that growth in local public health spending is associated with reductions in area-level Medicare spending, consistent with a spending offset effect (Table 3). In the fixed-effects model, a 10 percent increase in public health spending was associated with a 0.1 percent decrease in Medicare spending ($p < .01$) after controlling for other variables. The instrumental-variables estimate of this offset was more than eight times larger than the fixed-effect estimate, indicating a 10 percent increase in public health spending was associated with a 0.8 percent decrease in area-level Medicare spending ($p < .01$). Several other community characteristics were positively associated with Medicare spending in both models, including poverty, unemployment, lack of health insurance coverage, less than college educational attainment, population over 65 years of age, and metropolitan area designation. Physician supply and hospital bed supply were not independently associated with Medicare spending after controlling for other variables in the model, nor were measures of residual state and federal public health spending.

The Medicare spending offsets were larger in magnitude when we restricted the sample to communities with lower socioeconomic status and

Table 2: Determinants of Local Public Health Spending: First-Stage Regression Estimates

Variable	*Coefficient*	*SE*
Political economy variables (instrumental variables)		
Local agency governed by board of health (0,1)	0.151	0.038***
State agency hires local agency director (0,1)	−0.129	0.058**
Local government approves agency budget (0,1)†	−0.304	0.066***
State agency approves local agency budget (0,1)†	0.291	0.051***
Local government approves public health regulations (0,1)	0.225	0.055***
Local government sets public health fees (0,1)	0.199	0.040***
Local government imposes public health taxes (0,1)	0.165	0.050***
Demand-side community characteristics		
Population size (log)	−0.001	0.013
Population per square mile (1,000s)	0.012	0.008
Medicare beneficiaries (log)	0.048	0.014***
Metropolitan area designation (reference: nonmetropolitan)		
Metropolitan area	−0.364	0.045***
Micropolitan area	−0.148	0.041***
Percent population nonwhite	0.0055	0.0012***
Percent with college degree	−0.0020	0.0028
Percent 65+ years old	0.0151	0.0043***
Percent population below poverty	0.0073	0.0047
Unemployment	0.0090	0.0066
Income per capita (log)	−0.120	0.111
Percent residents uninsured	0.0052	0.0037**
Residual state public health spending	−0.0062	0.0081
Residual federal public health spending	0.0031	0.0068
Supply-side community characteristics		
Active physicians per 100,000 population	0.0033	0.0013**
Hospital beds per 100,000 population	−0.006	0.011
Federally Qualified Health Center located in area (0,1)	−0.03	0.03
Year (reference: 1993)		
1997	0.156	0.035***
2005	0.192	0.055***
2008	0.316	0.076***
2013	0.373	0.081***
Constant	3.561	1.070***
N (community-years)	8,532	

Note. Coefficients are from a logarithmic regression model that controls for community-level random effects. Standard errors are adjusted for clustering within states.
†As compared to local board of health.
$^{***}p < .01$, $^{**}p < .05$, $^{*}p < .10$.

lower health resource availability (Table 4). The offset was 51 percent larger when estimated among communities where more than 9.3 percent of the population fell below the federal poverty level (the 25th percentile of the sample),

Table 3: Determinants of Area-Level Medicare Spending: Second-Stage Regression Estimates

	Fixed-Effects Model		*Random-Effects IV Model*	
Variable	*Coefficient*	*SE*	*Coefficient*	*SE*
Local public health spending/capita (log)†	−0.0105	0.0024***	−0.083	0.013***
Residual state public health spending (log)†	0.008	0.054	−0.006	0.076
Residual federal public health spending† (log)	−0.003	0.018	−0.014	0.054
Population size (log)	−0.0089	0.0028***	−0.0040	0.0032
Population per square mile (1,000s)	0.101	0.020***	0.65	0.18***
Medicare beneficiaries (log)	0.0085	0.0034**	0.0066	0.0035*
Metropolitan designation (reference = Nonmetropolitan)				
Metropolitan area	0.087	0.011***	0.054	0.013***
Micropolitan area	0.0041	0.0010	−0.013	0.011
Percent population nonwhite	0.010	0.026	0.080	0.030***
Percent with college degree	−0.134	0.065**	−0.003	0.070***
Percent 65+ years old	−0.58	0.10***	−0.45	0.11***
Percent population below poverty	0.620	0.098***	0.71	0.11***
Unemployment rate	0.82	0.14***	0.91	0.16***
Income per capita (log)	0.230	0.024***	0.255	0.028***
Percent residents uninsured	0.14	0.08*	0.37	0.091***
Active physicians per 100,000	−0.020	0.032	0.027	0.033
Hospital beds per 100,000	−0.021	0.025	−0.049	0.028*
Federally Qualified Health Center located in area	0.03721	0.0069***	0.0276	0.0076***
Year (1993 = reference)				
1997	0.3159	0.0066***	0.3262	0.0091***
2005	0.633	0.011***	0.641	0.014***
2008	0.666	0.016***	0.670	0.020***
2013	0.714	0.022***	0.724	0.031***
Constant	5.91	0.23***	6.43	0.276***
σ_u	0.134		0.101	
σ_e	0.170		0.237	
ρ	0.385		0.155	

Note. Coefficients are from logarithmic regression models that control for community-level fixed effects (column 1) and random effects (column 2). Standard errors are adjusted for clustering within states.
†One-year lagged values are used.
***$p < .01$, **$p < .05$, *$p < .10$.

compared to communities with lower poverty rates. Similarly, the offset was 88 percent larger among communities, where more than 10.2 percent of the nonelderly population lacked health insurance coverage, compared to communities with higher coverage rates. Communities designated as Health

Table 4: Sensitivity Analysis of Medicare Spending Offset Estimates: Alternative Subgroups and Lag Periods

Model and Subgroup	*N*	*Coefficient*	*SE*
One-year lag models			
Full sample of all communities	8,532	−0.083	0.013***
Communities with poverty rate <9.3%	2,731	−0.053	0.016***
Communities with poverty rate >9.3%	5,801	−0.080	0.017***
Communities with uninsured rate <10.2%	1,850	−0.041	0.022*
Communities with uninsured rate >10.2%	6,682	−0.077	0.014***
Communities with HPSA designation			
FQHCs located in community	3,742	−0.093	0.016***
FQHCs not located in community	2,877	0.005	0.023
Communities without HPSA designation	1,913	−0.050	0.020**
Five-year lag model, full sample	6,492	−0.112	0.053**
Ten-year lag model, full sample	4,387	−0.179	0.112

Note. Coefficients are from logarithmic regression models with instrumental-variables estimation that control for community-level random effects. Standard errors are adjusted for clustering within states.
***$p < .01$, **$p < .05$, *$p < .10$.

Professions Shortage Areas (HPSAs) had Medicare spending offsets that were 46 percent larger than the offsets estimated among non-HPSA communities, and this difference was almost entirely driven by HPSA communities that had FQHCs located within them. Among HPSA communities without FQHCs, the estimated Medicare spending offset due to public health spending was not significantly different from zero.

Allowing for multiyear lag periods between public health and Medicare spending resulted in estimated offsets that were significantly larger in magnitude but less precisely estimated than the models using one-year lag periods (Table 4). Using a five-year lag resulted in a 35 percent increase in the estimated offset, indicating that a 10 percent increase in public health spending was associated with a 1.1 percent decrease in Medicare spending ($p < .05$). Using a 10-year lag resulted in a 116 percent increase in the offset estimate, but this estimate was not statistically significant due to the loss in sample size and power imposed by the lag.

DISCUSSION

This study is to our knowledge the first to find evidence that geographic variation in Medicare resource use is driven partly by differences in public health spending at the local level. Communities that increased local public health spending experienced significantly lower Medicare expenditures in subsequent years, compared to communities where public health spending remained flat or declined. The size of the Medicare spending offset is particularly large when instrumental-variables methods are used to adjust for unobserved heterogeneity that jointly influences public health and medical care spending. For an average U.S. community and year in our study, a 10 percent increase in per capita public health spending required $594,291 in additional outlays, yielding an estimated reduction in Medicare spending of $515,114 after 1 year and $656,449 after 5 years. These results suggest Medicare could recover an average of $1.10 for each dollar invested in public health activities after 5 years. If the spending offsets we estimate in this study apply to other populations beyond Medicare, the societal return on investment could be even larger.

Our results indicate that Medicare spending offsets are more pronounced in low-resource communities, such as areas with higher poverty, lower health insurance coverage, and substantial health professional shortages. One plausible explanation for these findings is that low-income populations benefit disproportionately from health promotion and disease prevention interventions supported through public health expenditures (Danaei et al. 2010). The offsets are especially large in underserved communities where FQHCs are located, suggesting that productive collaborations between public health and primary care providers may contribute to lower Medicare resource use in these settings (Landon, Grumbach, and Wallace 2012).

Collectively, these findings imply that public health agencies and their programs are well positioned to play important roles in the delivery system innovations and alternative payment models that Medicare is now testing as strategies for health improvement and cost control. Historically, federal rules have precluded Medicare reimbursement for community-wide public health interventions that extend beyond the individual medical needs of eligible program beneficiaries. New models such as accountable care organizations (ACOs), shared-savings arrangements, and value-based payment schemes offer providers and health plans greater latitude in incorporating community-wide public health programs into their Medicare strategies, and more options for financing these programs. CMS's new Accountable Health Community Demonstration Program and Million Hearts Cardiovascular Risk Reduction Model, both launched in 2017, and the Medicare Diabetes Prevention Program scheduled to begin in 2018, offer additional opportunities for integrating public health approaches into Medicare (Sanghavi and Conway 2015; Alley et al. 2016; Alva et al. 2017). For hospitals, medical practices, health plans, and other providers operating under Medicare's value-based payment models, our findings suggest that these stakeholders carefully consider how public health agencies may help to achieve the improved outcomes and reduced costs necessary for financial success under these models.

Several limitations of this study are important to bear in mind. First, the Medicare spending offsets estimated in this study represent average effects across all U.S. local public health agencies and across all categories of public health and Medicare spending. Our results do not reveal how public health resources should be allocated across the many possible programs and activities maintained at the local level in order to reduce Medicare spending. The aggregate nature of this analysis may underestimate the impact of public health spending on Medicare resource use, because not all public health programs target Medicare and near-Medicare age cohorts. For example, public health agencies devote considerable resources to maternal, child, and adolescent health programs that may have limited impact on older cohorts.

Second, this study employs strong statistical controls to address possible sources of bias, but it remains possible that factors distinct from, but closely correlated with, public health spending may explain some of the observed associations between public health and Medicare spending. To cause estimation bias, any unmeasured factors must be highly correlated with the public health governance and decision making measures that we use as instrumental variables in this analysis. We are unaware of factors that could cause such bias in this study.

Finally, this study's 20-year time frame and its lag periods of 1–10 years may not be sufficient for observing the full effects of public health spending on Medicare resource use. Many chronic diseases develop and progress over decades, and the protective effects of public health activities may accumulate over similarly long periods (Doll and Peto 1981; Rose 1982; Law and Wald 1999). Further research will be needed to clarify the long-term impact of public health spending across the lifespan.

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Supporting Information

Additional supporting information may be found online in the supporting information tab for this article:

Appendix SA1: Author Matrix.