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Supplementary appendix

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Supplement to: Trickey KS, Chen Z, Sanghavi P. Hospitalisations for cardiovascular and respiratory disease among older adults living near unconventional natural gas development: a difference-in-differences analysis. *Lancet Planet Health* 2023; **7:** e187–96.

Supplementary Appendix: "Hospitalizations for cardiovascular and respiratory disease among older adults living near unconventional natural gas development"

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A. Details of study regions

Each of the exposed and two control regions are defined by the ZIP codes they encompass, along with the counties that the study regions approximately overlap with (ZIP code–county borders do not align naturally). We listed all ZIP codes included in the study and provided a brief description of ZIP code selection criteria in Supplementary Table 1. Most of the ZIP codes (36 in total) in the exposed region started UNGD between 2008 and 2010, the rest were thinly spread across other years between 2005 and 2014. Therefore, we further subset the exposed region in the main analysis to these 36 ZIP codes.

B. Details of ICD codes

We studied the association between UNGD and five health outcomes: AMI (acute myocardial infarction), COPD (chronic obstructive pulmonary disease) and bronchiectasis, heart failure, IHD (ischemic heart disease), and stroke. We used ICD-9-CM and ICD-10-CM codes taken from the Chronic Conditions Warehouse algorithms to identify these conditions in MedPAR. All ICD codes are listed in Supplementary Table 2.

C. Total count of MedPAR data

Supplementary Table 3 provides counts of observations in the final analysis sample by study region, health outcome, and by the number of diagnosis codes used to identify each health outcome.

D. Sensitivity analysis: Difference-in-differences analysis using New York (alt. control) as the control region

We chose two control regions in this study: New York (main control) was the middle area in New York state and was the main control region, and New York (alt. control), which shared the border with the treated region in Pennsylvania and was the alternate control region. New York (alt. control) was used as the alternative control region because although there was no UNGD in the area, it might have been exposed to UNGD effects given its proximity to the treated area. This could result in a violation of the parallel trends assumption because the trend of hospitalizations in this control region might be impacted by the treatment. Therefore, the estimates could be biased toward zero.

Nonetheless, as a secondary analysis, we repeated the same statistical analysis in the main manuscript but using New York (alt. control) as the control region. Supplementary Table 4 provides estimates from the difference-in-differences analysis. The effects of UNGD on AMI identified using primary diagnoses, which were significant and increasing from 2013 - 2015, were slightly smaller but shared a similar path as results from our main analysis in Table 2. The estimates for other health outcomes were mostly not statistically significant. Therefore, even though New York (alt. control) was possibly impacted by UNGD as well, we still observed significantly negative associations between UNGD and AMI hospitalizations for the Medicare population in Pennsylvania.

E. Sensitivity analysis: Using negative binomial models to estimate associations with UNGD

Since hospitalizations could also be specified with a count variable and a population offset instead of a percentage as in the main analysis, we used a negative binomial model to estimate the association of UNGD with health outcomes as a sensitivity analysis. In this model, we estimated the differences between the change of relative risk of hospitalization in Pennsylvania between each post-treatment period (2010 – 2015) and 2009 (the pre-period) versus the change of relative risk of hospitalization in New York over the same time period, as denoted by the following equation:

$$\mu_{zt} = \exp(ln(n_{zt}) + treated_z + post_t + \beta(treated_z * post_t) + \epsilon_{zt})$$

where μ_{zt} is the number of hospitalization in ZIP code z at time t, n_{zt} is the number of Medicare beneficiaries in ZIP code z at time t; $treated_z$ was a binary indicator of UNGD activity in the ZIP code, $post_t$ was an indicator for whether the year was in the pre-period (2009) or post-period (2010, 2011, 2012, 2013, 2014, or 2015), and ϵ_{zt} was the error term.

Supplementary Table 5 shows estimated risk ratios that indicate the estimated risk associated with UNGD in Pennsylvania. For instance, in 2014, Pennsylvania was associated with a 56% higher risk of AMI hospitalization (based on primary diagnosis codes) compared with 2009 than would be expected in the absence of UNGD. The sign and statistical significance of most estimates is similar to the main results in Table 2, except for IHD, which was not statistically significant for 2012, 2014 and 2015 (any diagnosis), as well as COPD and bronchiectasis in 2012 (any diagnosis).

F. Sensitivity analysis: Difference-in-differences analysis with estimates adjusted for multiple testing

In Table 2, we reported estimates with pointwise 95% confidence intervals, i.e., the critical value is 1.96. Callaway and Sant'Anna recommend using uniform confidence intervals that adjust for multiple testing[1]. In Supplementary Table 5, we presented results from the same statistical analysis as in the main text but adjusted for multiple testing using a simple multiplier bootstrap procedure, which was done by setting the options bstrap=TRUE, cband=TRUE to the att_gt() function in the *did* package. Therefore, while the point estimates would be the same, we would expect the 95% confidence interval to generally be larger. These estimates were also clustered at the ZIP code level.

Compared with Table 2, estimates in Supplementary Table 6 for heart failure and IHD are not statistically significant in 2015 for primary diagnoses after calculating a uniform confidence interval. For any diagnosis, estimates for COPD and bronchiectasis are not statistically significant in 2014; heart failure is not statistically significant only in 2012, and IHD in 2011, 2012 and 2014. Estimates for AMI were still significantly different from zero between 2012 – 2015.

G. Sensitivity analysis: Group-time average treatment effects by separating ZIP codes based on first UNGD in 2008, 2009, and 2010

ZIP codes that first got UNGD in 2008, 2009, and 2010 could follow different trends in hospitalizations and ZIP codes that got UNGD before 2010 could already be impacted in

2009 and thus influence our estimates. However, we would assume that such differences would be minimal because there were only a limited number of wells developed before 2010 and thus exposure to UNGD would be small. In this sensitivity analysis, we treated these ZIP codes (marked with * in Supplementary Table 1) as three different groups based on the year they first started well development and estimated their group-time average treatment effects to address any potential bias in the main analysis.

The group-time analysis estimates a treatment effect for units categorized as group g based on their time of treatment, at different time points t ($t \geq g$) after the treatment. The pre-period for each group is specified as time g-1, the year right before the treatment starts. This analysis shows the dynamics of treatment effects over time specific for group g. In Supplementary Table 7, we presented all estimates for group-time average treatment effects, where the Group column corresponds to g and the Year column corresponds to t. This table shows all estimates from the model including those before the time of treatment, which can be used as a pre-period parallel trends analysis. For example, the treatment effects for the group treated in 2008 start at the sixth row where Group=2008 and Year=2008. The interpretation of the estimate for AMI in this row is as follows: The change in hospitalization rates for AMI in Pennsylvania between 2008 and 2007 was 0.14 lower than what it would have been in the absence of UNGD. The estimates for hospitalization rates for AMI for group 2008 become positive and statistically significant and increase steadily after 2012.

As shown in the table, there were in total $3 \times 13 = 39$ average treatment effects estimated for each health outcome. The large number of estimates and the limited sample size used to estimate them impede meaningful interpretation of the results, so we further aggregated these estimates based on calendar year (Supplementary Table 8) and based on the years of exposure to UNGD (Supplementary Table 9, similar to event-study design). All estimates from Supplementary Tables 8 and 9 were similar in magnitude and significance to our main results. Each aggregated treatment effect is a weighted average of the group-time average effects.

H. Sensitivity analysis: Pre-period parallel trends analysis, using varying base periods

The (unconditional) parallel trends assumption of difference-in-differences for multiple time periods developed by Callaway and Sant'Anna is denoted as the following.

$$E\left[Y_t(0) - Y_{t-1}(0) \middle| G_g = 1\right] = E[Y_t(0) - Y_{t-1}(0) | C = 1] \; for \; t \geq g$$

Where g refers to group g as assigned by the time when units are first treated. It requires that the average outcomes for the treated in absence of the treatment would have followed a parallel path to those of the untreated in post-treatment periods. Although it is impossible to test this assumption because we cannot observe outcomes for the treated without treatment in the post-period, we can test for parallel trends before treatment, which provides more credibility for the assumption to hold after treatment.

A common practice to test for the assumption is an event-study design where researchers estimate the effect of the policy intervention with respect to the length of exposure to the policy. However, there are some drawbacks associated with this method[2]. Callaway and

Sant'Anna propose two tests[3] to avoid these drawbacks. In the main analysis, we presented one of these which was to use the latest year before treatment (2009 in our study) as the base period and compare it to each year in the pre-treatment period (2002 – 2008) between treated and main control regions. Another way was to compare each year in the pre-treatment period to its prior year between treated and control regions, i.e., comparing 2003 to 2002, 2004 to 2003. The method we used in the main analysis might put too much emphasis on 2009 data, so we also performed this second test to assess whether the pre-period parallel trends hold with varying base periods.

Supplementary Figure 1 plots the results of the pre-period parallel trends analysis with varying base periods. Estimates are not statistically significant except for AMI in 2004 (for primary) and 2005 (for primary diagnosis and any diagnosis), and heart failure in 2003 (for any diagnosis) and 2008 (for primary diagnoses).

Supplementary Table 1: ZIP codes and region definitions included in analysis.

Study Region Name	Approx. County Overlap	Description	ZIP Codes Included
Exposed region (PA (exposed region))	Bradford, Susquehanna, Tioga	Exposed study region with ZIP codes selected for UNGD activity during 2002–2015	16901*, 16912*, 16914, 16917*, 16920*, 16925, 16926*, 16928*, 16929*, 16930*, 16932*, 16933*, 16935*, 16936*, 16942*, 16946*, 16947*, 17724*, 17765*, 18623*, 18630*, 18801, 18810*, 18812, 18817, 18818*, 18821, 18822*, 18823, 18824*, 18825, 18826*, 18828*, 18829*, 18830, 18831*, 18832*, 18833*, 18834, 18837*, 18840, 18842, 18844, 18845*, 18846, 18847*, 18848*, 18850*, 18851, 18853*, 18854*
Main control region (New York (main control))	Chenango, Cortland, Schuyler, Tompkins	A control region with no UNGD, selected further removed geographically from the exposed PA (exposed region) region to minimize uncaptured effects of UNGD from across the border (e.g. spread of pollution)	13040, 13045, 13053, 13062, 13068, 13073, 13077, 13087, 13101, 13102, 13124, 13136, 13141, 13155, 13158, 13460, 13733, 13778, 13780, 13784, 13801, 13803, 13809, 13815, 13830, 13832, 13835, 13841, 13843, 13844, 13863, 14437, 14529, 14572, 14805, 14807, 14808, 14809, 14815, 14817, 14818, 14826, 14837, 14840, 14841, 14850, 14853, 14854, 14856, 14865, 14867, 14869, 14873, 14874, 14878, 14881, 14882, 14886, 14891, 14893
Alternate control region (New York (alt. control))	Broome, Chemung, Steuben, Tioga	An alternate control region with no UNGD, selected to approximately mirror (and immediately border) PA (exposed region) region to maximize similarity with the exposed ZIP codes	13730, 13732, 13734, 13736, 13743, 13744, 13746, 13748, 13754, 13760, 13787, 13790, 13795, 13797, 13802, 13811, 13812, 13813, 13826, 13827, 13833, 13845, 13850, 13862, 13864, 13865, 13901, 13902, 13903, 13904, 13905, 14801, 14810, 14812, 14814, 14816, 14819, 14820, 14821, 14823, 14824, 14825, 14827, 14830, 14838, 14839, 14843, 14845, 14855, 14858, 14859, 14861, 14864, 14870, 14871, 14872, 14877, 14879, 14883, 14885, 14889, 14892, 14894, 14898, 14901, 14903, 14904, 14905

*ZIP codes with stars are the 36 ZIP codes selected as the exposed areas in the main analysis because the beginning date of UNGD in these areas is between 2008 and 2010.

Supplementary Table 2: ICD-9-CM and ICD-10-CM codes used to identify outcomes in Medicare claims

Outcome	Description	ICD-9-CM codes	ICD-10-CM codes
Acute myocardial infarction (AMI)	Blockage of the coronary artery	41001 41011 41021 41031 41041 41051 41061 41071 41081 41091	I2101 I2102 I2109 I2111 I2119 I2121 I2129 I213 I214 I219 I21A1 I21A9 I220 I221 I222 I228 I229
Chronic obstructive pulmonary disease (COPD) **and bronchiectasis**	Lung diseases blocking airflow and impeding breath	490 4910 4911 4918 4919 4920 4928 49120 49121 49122 4940 4941 496	J40 J410 J411 J418 J42 J430 J431 J432 J438 J439 J440 J441 J449 J470 J471 J479
Heart failure	Inability of heart to pump blood sufficiently	39891 40201 40211 40291 40401 40403 40411 40413 40491 40493 4280 4281 42820 42821 42822 42823 42830 42831 42832 42833 42840 42841 42842 42843 4289	I0981 I110 I130 I132 I501 I5020 I5021 I5022 I5023 I5030 I5031 I5032 I5033 I5040 I5041 I5042 I5043 I50810 I50811 I50812 I50813 I50814 I5082 I5083 I5084 I5089 I509
Ischemic heart disease (IHD, including AMI)	Damage to the coronary arteries, restricting blood flow to the heart	41000 41001 41002 41010 41011 41012 41020 41021 41022 41030 41031 41032 41040 41041 41042 41050 41051 41052 41060 41061 41062 41070 41071 41072 41080 41081 41082 41090 41091 41092 4110 4111 41181 41189 412 4130 4131 4139 41400 41401 41402 41403 41404 41405 41406 41407 41412 4142 4143 4144 4148 4149	I200 I201 I208 I209 I2101 I2102 I2109 I2111 I2119 I2121 I2129 I213 I214 I21A1 I21A9 I220 I221 I222 I228 I229 I230 I231 I232 I233 I234 I235 I236 I237 I238 I240 I241 I248 I249 I2510 I25110 I25111 I25118 I25119 I252 I253 I2541 I2542 I255 I256 I25700 I25701 I25708 I25709 I25710 I25711 I25718 I25719 I25720 I25721 I25728 I25729 I25730 I25731 I25738 I25739 I25750 I25751 I25758 I25759 I25760 I25761 I25768 I25769 I25790 I25791 I25798 I25799 I25810 I25811 I25812 I2582 I2583 I2584 I2589 I259

Outcome	Description	ICD-9-CM codes	ICD-10-CM codes
Stroke	Interruption of blood supply to brain	430 431 43301 43311 43321 43331 43381 43391 43400 43401 43410 43411 43490 43491 4350 4351 4353 4358 4359 436 99702	G450 G451 G452 G458 G459 G460 G461 G462 G463 G464 G465 G466 G467 G468 G9731 G9732 I6000 I6001 I6002 I6010 I6011 I6012 I6020 I6021 I6022 I6030 I6031 I6032 I604 I6050 I6051 I6052 I606 I607 I608 I609 I610 I611 I612 I613 I614 I615 I616 I618 I619 I6300 I63011 I63012 I63013 I63019 I6302 I63031 I63032 I63039 I6309 I6310 I63111 I63112 I63113 I63119 I6312 I63131 I63132 I63133 I63139 I6319 I6320 I63211 I63212 I63213 I63219 I6322 I63231 I63232 I63233 I63239 I6329 I6330 I63311 I63312 I63313 I63319 I63321 I63322 I63323 I63329 I63331 I63332 I63333 I63339 I63341 I63342 I63343 I63349 I6339 I6340 I63411 I63412 I63413 I63419 I63421 I63422 I63423 I63429 I63431 I63432 I63433 I63439 I63441 I63442 I63443 I63449 I6349 I6350 I63511 I63512 I63513 I63519 I63521 I63522 I63523 I63529 I63531 I63532 I63533 I63539 I63541 I63542 I63543 I63549 I6359 I636 I638 I6381 I6389 I639 I6601 I6602 I6603 I6609 I6611 I6612 I6613 I6619 I6621 I6622 I6623 I6629 I663 I668 I669 I67841 I67848 I6789 I97810 I97811 I97820 I97821
		Excluding claims with any diagnosis code 800 ≤ *DX* ≤ 804.9 or 850 ≤ *DX* ≤ 854.1 or *DX* V57xx	EXCLUSION: If any of the qualifying claims have any of the following codes in any DX position then EXCLUDE: S01.90XA, S02.0XXA, S02.0XXB, S02.101A, S02.101B, S02.102A, S02.102B, S02.109A, S02.109B, S02.10XA, S02.10XB, S02.110A, S02.110B, S02.111A, S02.111B, S02.112A, S02.112B, S02.113A, S02.113B, S02.118A, S02.118B, S02.119A, S02.119B, S02.11GA, S02.11GB, S02.11HA, S02.11HB, S02.121A, S02.121B, S02.121D, S02.121G, S02.121K, S02.121S, S02.122A, S02.122B, S02.122D, S02.122G, S02.122K, S02.122S, S02.129A, S02.129B, S02.129D, S02.129G, S02.129K, S02.129S, S02.19XA, S02.19XB, S02.2XXA, S02.2XXB, S02.30XA, S02.30XB, S02.31XA, S02.31XB, S02.32XA, S02.32XB, S02.3XXA, S02.3XXB, S02.400A, S02.400B, S02.401A, S02.401B, S02.402A, S02.402B, S02.40AA, S02.40AB, S02.40BA, S02.40BB, S02.40CA, S02.40CB, S02.40DA, S02.40DB, S02.40EA, S02.40EB, S02.40FA, S02.40FB, S02.411A, S02.411B, S02.412A, S02.412B, S02.413A, S02.413B, S02.42XA, S02.42XB, S02.600A, S02.600B, S02.601A, S02.601B, S02.602A, S02.602B, S02.609A, S02.609B, S02.610A, S02.610B, S02.611A, S02.611B, S02.612A, S02.612B, S02.61XA, S02.61XB, S02.620A, S02.620B, S02.621A, S02.621B, S02.622A, S02.622B, S02.62XA, S02.62XB, S02.630A, S02.630B, S02.631A, S02.631B, S02.632A, S02.632B, S02.63XA, S02.63XB, S02.640A, S02.640B, S02.641A, S02.641B, S02.642A, S02.642B, S02.64XA, S02.64XB, S02.650A, S02.650B, S02.651A, S02.651B, S02.652A, S02.652B, S02.65XA, S02.65XB, S02.66XA, S02.66XB, S02.670A, S02.670B, S02.671A, S02.671B, S02.672A, S02.672B, S02.67XA, S02.67XB, S02.69XA, S02.69XB, S02.80XA, S02.80XB, S02.81XA, S02.81XB, S02.82XA, S02.82XB, S02.831A, S02.831B, S02.831D, S02.831G, S02.831K, S02.831S, S02.832A, S02.832B, S02.832D, S02.832G, S02.832K, S02.832S, S02.839A, S02.839B, S02.839D, S02.839G, S02.839K, S02.839S, S02.841A, S02.841B, S02.841D, S02.841G, S02.841K, S02.841S, S02.842A, S02.842B, S02.842D, S02.842G, S02.842K, S02.842S, S02.849A, S02.849B, S02.849D, S02.849G, S02.849K, S02.849S, S02.85XA, S02.85XB, S02.85XD, S02.85XG, S02.85XK ,S02.85XS, S02.8XXA, S02.8XXB, S02.91XA, S02.91XB, S02.92XA, S02.92XB, S06.0X0A, S06.0X1A, S06.0X2A, S06.0X3A, S06.0X4A, S06.0X5A, S06.0X6A, S06.0X7A, S06.0X8A, S06.0X9A, S06.1X0A, S06.1X1A, S06.1X2A, S06.1X3A, S06.1X4A, S06.1X5A, S06.1X6A, S06.1X7A, S06.1X8A, S06.1X9A, S06.2X0A, S06.2X1A, S06.2X2A, S06.2X3A, S06.2X4A, S06.2X5A, S06.2X6A, S06.2X7A, S06.2X8A, S06.2X9A, S06.300A, S06.301A, S06.302A, S06.303A, S06.304A, S06.305A, S06.306A, S06.307A, S06.308A, S06.309A, S06.310A, S06.311A, S06.312A, S06.313A, S06.314A, S06.315A, S06.316A, S06.317A, S06.318A, S06.319A, S06.320A, S06.321A, S06.322A, S06.323A, S06.324A, S06.325A, S06.326A, S06.327A, S06.328A, S06.329A, S06.330A, S06.331A, S06.332A, S06.333A, S06.334A, S06.335A, S06.336A, S06.337A, S06.338A, S06.339A, S06.340A, S06.341A, S06.342A, S06.343A, S06.344A, S06.345A, S06.346A, S06.347A, S06.348A, S06.349A, S06.350A, S06.351A, S06.352A, S06.353A, S06.354A, S06.355A, S06.356A, S06.357A, S06.358A, S06.359A, S06.360A, S06.361A, S06.362A, S06.363A, S06.364A, S06.365A, S06.366A, S06.367A, S06.368A, S06.369A, S06.370A, S06.371A, S06.372A, S06.373A, S06.374A, S06.375A, S06.376A, S06.377A, S06.378A, S06.379A, S06.380A, S06.381A, S06.382A, S06.383A, S06.384A, S06.385A, S06.386A, S06.387A, S06.388A, S06.389A, S06.4X0A, S06.4X1A, S06.4X2A, S06.4X3A, S06.4X4A, S06.4X5A, S06.4X6A, S06.4X7A, S06.4X8A, S06.4X9A, S06.5X0A, S06.5X1A, S06.5X2A, S06.5X3A, S06.5X4A, S06.5X5A, S06.5X6A, S06.5X7A, S06.5X8A, S06.5X9A, S06.6X0A, S06.6X1A, S06.6X2A, S06.6X3A, S06.6X4A, S06.6X5A, S06.6X6A, S06.6X7A, S06.6X8A, S06.6X9A, S06.810A, S06.811A, S06.812A, S06.813A, S06.814A, S06.815A, S06.816A, S06.817A, S06.818A, S06.819A, S06.820A, S06.821A, S06.822A, S06.823A, S06.824A, S06.825A, S06.826A, S06.827A, S06.828A, S06.829A, S06.890A, S06.891A, S06.892A, S06.893A, S06.894A, S06.895A, S06.896A, S06.897A, S06.898A, S06.899A, S06.9X0A, S06.9X1A, S06.9X2A, S06.9X3A, S06.9X4A, S06.9X5A, S06.9X6A, S06.9X7A, S06.9X8A, S06.9X9A, OR Z51.89 as the principal DX Code then EXCLUDE.

Supplementary Table 3: The total number of MedPAR hospitalizations by health outcomes and study regions, 2002 – 2015

Study Region	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke
			Primary diagnoses[a]		
New York (alt. control)	11575	26770	39144	26921	11031
New York (main control)	5119	11593	14377	13362	4920
PA (exposed region)	3015	7088	10142	7735	2994
			Any diagnosis[b]		
New York (alt. control)	13505	71718	76996	103550	12942
New York (main control)	5977	29770	29070	42920	5820
PA (exposed region)	3668	17454	18394	26845	3638

[a]Health outcomes were determined by the first two diagnosis codes in MedPAR hospital admission data.
[b]Health outcomes were determined by all diagnosis codes in MedPAR hospital admission data.

Supplementary Table 4: Difference-in-differences analysis: Associations between hospitalization rates and UNGD in Pennsylvania, in each post-treatment year compared with 2009, relative to changes over the same time period in New York (alt. control)

Year	Primary diagnoses[a]					Any diagnosis[b]				
	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke
2010	0·00 [-0·27, 0·28]	0·05 [-0·29, 0·39]	0·09 [-0·43, 0·60]	0·21 [-0·28, 0·70]	0·15 [-0·09, 0·39]	-0·02 [-0·30, 0·25]	-0·12 [-0·62, 0·38]	0·20 [-0·52, 0·93]	0·72 [-0·03, 1·47]	0·11 [-0·16, 0·38]
2011	-0·04 [-0·35, 0·27]	-0·06 [-0·52, 0·40]	0·03 [-0·63, 0·69]	-0·27 [-0·78, 0·23]	0·31* [0·02, 0·60]	-0·03 [-0·34, 0·27]	0·25 [-0·58, 1·09]	0·45 [-0·43, 1·33]	-0·10 [-1·02, 0·82]	0·32* [0·04, 0·60]
2012	0·27 [-0·03, 0·57]	0·59* [0·18, 1·01]	0·07 [-0·75, 0·88]	0·06 [-0·62, 0·74]	0·15 [-0·08, 0·38]	0·34* [0·02, 0·66]	0·48 [-0·18, 1·14]	0·61 [-0·40, 1·63]	0·51 [-0·72, 1·73]	0·16 [-0·12, 0·44]
2013	0·32* [0·07, 0·57]	0·45 [-0·06, 0·96]	-0·10 [-0·85, 0·65]	0·00 [-0·58, 0·58]	0·13 [-0·12, 0·37]	0·57* [0·26, 0·88]	0·95 [-0·09, 1·98]	0·91 [-0·17, 1·99]	0·56 [-0·83, 1·96]	0·12 [-0·13, 0·37]
2014	0·45* [0·16, 0·74]	0·40 [-0·05, 0·84]	0·03 [-0·81, 0·87]	0·24 [-0·29, 0·76]	0·10 [-0·17, 0·38]	0·75* [0·39, 1·12]	0·56 [-0·45, 1·58]	0·69 [-0·37, 1·76]	-0·35 [-1·39, 0·68]	0·10 [-0·20, 0·39]
2015[c]	0·46* [0·15, 0·78]	0·30 [-0·18, 0·77]	-0·03 [-0·74, 0·67]	0·30 [-0·29, 0·89]	-0·02 [-0·29, 0·25]	0·80* [0·43, 1·17]	0·13 [-0·82, 1·07]	0·56 [-0·43, 1·54]	0·25 [-0·63, 1·13]	-0·04 [-0·29, 0·21]

Note: 95% pointwise confidence interval are presented in brackets. The model was weighted by the Medicare population of each zip code.
*Estimates are statistically significant at an alpha level of 0.05.
[a]Health outcomes were determined by the first two diagnosis codes in MedPAR hospital admission data.
[b]Health outcomes were determined by all diagnosis codes in MedPAR hospital admission data.
[c]The outcome values in 2015 were determined by both ICD-9-CM and ICD-10-CM codes.

Supplementary Table 5: Difference-in-differences analysis: Relative risk of hospitalization for UNGD in Pennsylvania

Year	Primary diagnoses[a]					Any diagnosis[b]				
	Acute myocardial infarction (AMI)	**Chronic obstructive pulmonary disease (COPD) and bronchiectasis**	**Heart Failure**	**Ischemic heart disease (including AMI)**	**Stroke**	**Acute myocardial infarction (AMI)**	**Chronic obstructive pulmonary disease (COPD) and bronchiectasis**	**Heart Failure**	**Ischemic heart disease (including AMI)**	**Stroke**
2010	1·04 [0·76, 1·42]	1·06 [0·78, 1·43]	1·12 [0·87, 1·43]	1·04 [0·83, 1·31]	1·06 [0·76, 1·47]	1·01 [0·75, 1·35]	1·13 [0·89, 1·42]	1·12 [0·90, 1·39]	1·05 [0·89, 1·24]	1·07 [0·79, 1·44]
2011	1·08 [0·77, 1·52]	0·99 [0·73, 1·35]	1·09 [0·85, 1·40]	0·96 [0·76, 1·21]	1·16 [0·86, 1·56]	1·11 [0·82, 1·51]	1·12 [0·88, 1·41]	1·11 [0·90, 1·37]	1·09 [0·92, 1·30]	1·13 [0·86, 1·50]
2012	1·42* [1·05, 1·92]	1·20 [0·87, 1·65]	1·16 [0·90, 1·49]	1·16 [0·91, 1·48]	1·18 [0·87, 1·60]	1·42* [1·07, 1·88]	1·18 [0·93, 1·48]	1·24* [1·01, 1·52]	1·18 [0·98, 1·42]	1·18 [0·88, 1·58]
2013	1·57* [1·18, 2·09]	1·17 [0·84, 1·63]	1·19 [0·93, 1·53]	1·10 [0·85, 1·42]	1·20 [0·89, 1·60]	1·89* [1·47, 2·43]	1·34* [1·07, 1·68]	1·40* [1·13, 1·74]	1·21* [1·00, 1·46]	1·14 [0·87, 1·51]
2014	1·56* [1·10, 2·22]	1·32 [0·96, 1·81]	1·29* [1·00, 1·66]	1·26 [0·97, 1·63]	1·06 [0·79, 1·41]	1·80* [1·30, 2·48]	1·29* [1·01, 1·65]	1·33* [1·07, 1·65]	1·11 [0·94, 1·31]	1·09 [0·83, 1·43]
2015	1·80* [1·32, 2·47]	1·35 [0·99, 1·84]	1·36* [1·06, 1·74]	1·36* [1·05, 1·76]	1·07 [0·78, 1·47]	2·10* [1·58, 2·79]	1·22 [0·97, 1·52]	1·43* [1·15, 1·77]	1·17 [0·98, 1·40]	1·08 [0·80, 1·44]

Notes: Risk ratio estimates are presented in the table and 95% confidence intervals are in the brackets.
*Estimates are statistically significant at an alpha level of 0.05.
[a]Health outcomes were determined by the first two diagnosis codes in MedPAR hospital admission data.
[b]Health outcomes were determined by all diagnosis codes in MedPAR hospital admission data.

Supplementary Table 6: Difference-in-differences analysis with adjustment for multiple testing: Associations between hospitalization rates and UNGD in Pennsylvania[a], in each post-treatment year compared with 2009, relative to changes over the same time period in New York (main control)

Year	Primary diagnoses[b]					Any diagnosis[c]				
	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke
2010	0·06 [-0·34, 0·46]	-0·05 [-0·60, 0·51]	0·26 [-0·44, 0·96]	0·18 [-0·55, 0·91]	0·09 [-0·28, 0·46]	0·03 [-0·39, 0·45]	0·23 [-0·61, 1·07]	0·37 [-0·79, 1·54]	0·60 [-0·61, 1·82]	0·11 [-0·29, 0·51]
2011	0·14 [-0·35, 0·64]	0·03 [-0·64, 0·70]	0·41 [-0·42, 1·23]	-0·09 [-0·83, 0·66]	0·26 [-0·17, 0·68]	0·19 [-0·33, 0·71]	0·78 [-0·49, 2·06]	0·73 [-0·65, 2·12]	1·31 [-0·27, 2·89]	0·26 [-0·10, 0·62]
2012	0·44* [0·00, 0·89]	0·44 [-0·21, 1·08]	0·48 [-0·63, 1·60]	0·35 [-0·66, 1·36]	0·20 [-0·14, 0·55]	0·53* [0·03, 1·03]	1·23* [0·04, 2·42]	1·37 [-0·13, 2·88]	1·90 [-0·02, 3·83]	0·23 [-0·19, 0·64]
2013	0·49* [0·13, 0·85]	0·37 [-0·39, 1·13]	0·45 [-0·63, 1·53]	0·27 [-0·54, 1·09]	0·20 [-0·19, 0·59]	0·80* [0·37, 1·24]	1·89* [0·34, 3·44]	1·91* [0·29, 3·53]	2·20* [0·09, 4·31]	0·18 [-0·20, 0·56]
2014	0·61* [0·15, 1·07]	0·38 [-0·29, 1·04]	0·63 [-0·57, 1·84]	0·55 [-0·25, 1·35]	0·10 [-0·28, 0·49]	0·91* [0·40, 1·42]	1·24 [-0·33, 2·81]	1·74* [0·14, 3·34]	1·19 [-0·31, 2·68]	0·16 [-0·26, 0·57]
2015[d]	0·77* [0·28, 1·27]	0·23 [-0·47, 0·94]	0·88 [-0·08, 1·84]	0·77 [-0·10, 1·64]	0·11 [-0·31, 0·53]	1·18* [0·67, 1·69]	0·78 [-0·61, 2·17]	2·16* [0·74, 3·58]	2·04* [0·80, 3·28]	0·12 [-0·32, 0·56]

Note: 95% uniform confidence intervals are presented in the brackets.
*Estimates are statistically significant at an alpha level of 0.05.
[a]Each health outcome was measured by the number of hospitalizations divided by the total Medicare fee-for-service population within the ZIP code and multiplied by 100. The control region was New York (main control) in this table. The model was weighted by the Medicare population of each zip code.
[b]Health outcomes were determined by the first two diagnosis codes in MedPAR hospital admission data.
[c]Health outcomes were determined by all diagnosis codes in MedPAR hospital admission data.
[d]The outcome values in 2015 were determined by both ICD-9-CM and ICD-10-CM codes.

Supplementary Table 7: Group-time average treatment effects estimates for associations between hospitalization rates and UNGD in Pennsylvania[a]

Group	Year	Primary diagnoses[b]					Any diagnosis[c]				
		Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke
2008	2003	-0·17 [-0·62, 0·28]	0·31 [-0·28, 0·91]	0·29 [-0·48, 1·07]	-0·08 [-0·84, 0·68]	-0·01 [-0·33, 0·30]	-0·15 [-0·59, 0·28]	0·45 [-0·57, 1·47]	0·51 [-0·51, 1·54]	0·61 [-0·57, 1·80]	-0·15 [-0·48, 0·18]
2008	2004	-0·27 [-0·77, 0·23]	0·26 [-0·30, 0·83]	0·57 [-0·32, 1·46]	-0·18 [-1·07, 0·72]	-0·03 [-0·37, 0·30]	-0·39 [-0·90, 0·12]	-0·14 [-1·14, 0·85]	0·62 [-0·70, 1·94]	-0·58 [-1·91, 0·74]	0·04 [-0·37, 0·45]
2008	2005	0·22 [-0·13, 0·57]	0·27 [-0·34, 0·87]	-0·21 [-1·03, 0·61]	0·49 [-0·11, 1·10]	0·27 [-0·04, 0·57]	0·25 [-0·11, 0·61]	0·30 [-0·90, 1·50]	-0·67 [-1·74, 0·39]	0·26 [-1·00, 1·52]	0·18 [-0·19, 0·55]
2008	2006	0·02 [-0·23, 0·27]	-0·17 [-0·76, 0·42]	0·15 [-0·79, 1·08]	0·17 [-0·44, 0·79]	-0·10 [-0·39, 0·18]	0·07 [-0·21, 0·36]	-0·12 [-1·32, 1·08]	0·47 [-0·79, 1·72]	0·84 [-0·57, 2·26]	0·02 [-0·30, 0·35]
2008	2007	0·11 [-0·17, 0·40]	-0·39 [-1·04, 0·26]	-0·13 [-0·88, 0·63]	0·04 [-0·56, 0·64]	0·26 [-0·10, 0·63]	0·08 [-0·20, 0·36]	-0·29 [-1·59, 1·02]	-0·18 [-1·31, 0·94]	0·03 [-1·01, 1·08]	0·21 [-0·21, 0·64]
2008	2008	-0·14 [-0·44, 0·16]	0·31 [-0·13, 0·75]	0·83* [0·00, 1·67]	0·22 [-0·18, 0·62]	0·02 [-0·31, 0·35]	-0·14 [-0·44, 0·15]	0·29 [-0·47, 1·05]	0·88 [-0·17, 1·94]	-0·49 [-1·44, 0·46]	0·04 [-0·33, 0·41]
2008	2009	-0·18 [-0·47, 0·12]	0·16 [-0·51, 0·82]	0·41 [-0·59, 1·42]	0·23 [-0·40, 0·86]	-0·33 [-0·60, -0·05]	-0·19 [-0·51, 0·13]	0·25 [-0·96, 1·45]	0·28 [-1·13, 1·69]	0·54 [-0·61, 1·69]	-0·27 [-0·57, 0·03]
2008	2010	-0·07 [-0·44, 0·29]	0·09 [-0·55, 0·74]	0·53 [-0·16, 1·21]	0·60 [-0·05, 1·24]	-0·03 [-0·42, 0·37]	-0·09 [-0·44, 0·26]	0·44 [-0·86, 1·75]	0·55 [-0·59, 1·69]	1·38* [0·28, 2·48]	0·05 [-0·35, 0·45]
2008	2011	0·02 [-0·42, 0·46]	0·34 [-0·14, 0·82]	0·93* [0·25, 1·60]	0·21 [-0·39, 0·82]	0·15 [-0·11, 0·41]	0·07 [-0·35, 0·49]	1·35* [0·27, 2·42]	1·32* [0·13, 2·51]	2·34* [0·80, 3·88]	0·24 [-0·03, 0·52]
2008	2012	0·42* [0·08, 0·76]	0·59 [-0·09, 1·28]	1·06* [0·31, 1·81]	0·81* [0·03, 1·60]	-0·03 [-0·34, 0·28]	0·53* [0·20, 0·86]	1·55* [0·19, 2·91]	2·00* [0·95, 3·06]	2·55* [0·97, 4·13]	0·11 [-0·31, 0·52]

Group	Year	Primary diagnoses[b]					Any diagnosis[c]				
		Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke
2008	2013	0·44* [0·15, 0·72]	0·41 [-0·31, 1·12]	0·71 [-0·04, 1·46]	0·75* [0·24, 1·26]	-0·01 [-0·34, 0·33]	0·70* [0·42, 0·98]	1·72* [0·73, 2·71]	1·79* [0·89, 2·68]	2·87* [1·50, 4·24]	0·02 [-0·38, 0·42]
2008	2014	0·51* [0·12, 0·90]	0·45 [-0·38, 1·28]	0·79* [0·12, 1·45]	0·93* [0·33, 1·53]	0·00 [-0·33, 0·33]	0·86* [0·43, 1·29]	0·93 [-0·14, 2·00]	1·72* [0·59, 2·86]	1·79* [0·43, 3·15]	0·09 [-0·30, 0·49]
2008	2015	0·63* [0·28, 0·97]	0·49 [-0·30, 1·29]	1·27* [0·63, 1·91]	1·17* [0·57, 1·76]	-0·11 [-0·42, 0·20]	1·06* [0·68, 1·44]	0·90* [0·00, 1·80]	2·48* [1·52, 3·45]	2·77* [1·60, 3·94]	-0·01 [-0·36, 0·33]
2009	2003	0·23 [-0·48, 0·94]	-0·51 [-1·51, 0·50]	1·23 [0·18, 2·29]	0·13 [-0·86, 1·12]	0·17 [-0·29, 0·63]	0·23 [-0·58, 1·04]	-0·14 [-1·81, 1·54]	2·25* [0·60, 3·89]	1·39 [-0·56, 3·35]	0·15 [-0·38, 0·69]
2009	2004	-1·06 [-1·64, -0·48]	0·47 [-0·41, 1·35]	-0·08 [-1·39, 1·22]	-1·21 [-2·60, 0·18]	0·25 [-0·30, 0·81]	-1·05 [-1·54, -0·56]	1·02 [-0·31, 2·34]	-0·21 [-1·63, 1·21]	-0·86 [-2·55, 0·83]	0·37 [-0·42, 1·16]
2009	2005	0·90 [0·50, 1·30]	-0·21 [-1·04, 0·62]	-0·97 [-2·21, 0·26]	0·67 [-0·37, 1·72]	-0·32 [-0·94, 0·30]	0·76* [0·29, 1·23]	-1·72* [-3·35, -0·08]	-1·85 [-3·84, 0·14]	-1·47* [-2·92, -0·03]	-0·62 [-1·34, 0·11]
2009	2006	-0·05 [-0·51, 0·41]	0·88 [-0·14, 1·91]	0·40 [-0·50, 1·29]	-0·34 [-1·17, 0·48]	0·45 [-0·36, 1·26]	0·01 [-0·52, 0·54]	2·08 [0·17, 3·99]	0·69 [-0·42, 1·80]	0·27 [-0·74, 1·28]	0·70 [-0·48, 1·88]
2009	2007	-0·05 [-0·66, 0·56]	-1·65 [-2·33, -0·98]	-0·49 [-1·38, 0·40]	0·08 [-1·06, 1·22]	-0·31 [-0·85, 0·23]	-0·17 [-0·77, 0·42]	-2·12 [-3·85, -0·39]	-0·43 [-2·09, 1·23]	-0·45 [-1·93, 1·03]	-0·45 [-1·20, 0·29]
2009	2008	0·11 [-0·48, 0·71]	0·57 [-0·52, 1·66]	0·93* [0·22, 1·65]	0·06 [-0·85, 0·98]	-0·26 [-0·62, 0·11]	0·32 [-0·25, 0·90]	0·43 [-0·88, 1·73]	0·99 [-0·76, 2·73]	1·28 [-0·36, 2·93]	-0·27 [-0·65, 0·11]
2009	2009	0·01 [-0·39, 0·41]	0·24 [-0·33, 0·82]	-0·53 [-1·40, 0·33]	0·21 [-0·29, 0·70]	0·26 [-0·32, 0·84]	-0·03 [-0·41, 0·36]	-0·17 [-1·67, 1·34]	-0·69 [-2·09, 0·72]	-0·09 [-2·68, 2·51]	0·23 [-0·42, 0·89]
2009	2010	-0·16 [-0·52, 0·21]	0·06 [-1·06, 1·17]	0·05 [-0·68, 0·78]	-0·44 [-1·29, 0·41]	0·08 [-0·46, 0·61]	-0·28 [-0·67, 0·11]	0·07 [-1·46, 1·61]	0·21 [-1·18, 1·60]	-0·47 [-2·84, 1·91]	0·13 [-0·48, 0·73]

Group	Year	Primary diagnoses[b]					Any diagnosis[c]				
		Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke
2009	2011	-0·32 [-0·76, 0·12]	-0·17 [-1·24, 0·91]	-0·57 [-1·29, 0·15]	-0·62 [-1·61, 0·36]	0·37 [-0·14, 0·88]	-0·34 [-0·79, 0·10]	0·09 [-1·85, 2·03]	-0·67 [-1·95, 0·62]	-0·73 [-3·38, 1·92]	0·30 [-0·31, 0·92]
2009	2012	-0·16 [-0·48, 0·17]	1·03 [-0·26, 2·33]	-0·61 [-1·42, 0·20]	-0·63 [-1·50, 0·25]	0·56 [-0·04, 1·16]	-0·23 [-0·63, 0·18]	1·37 [-0·49, 3·22]	-0·03 [-0·93, 0·86]	1·16 [-1·58, 3·90]	0·54 [-0·22, 1·30]
2009	2013	-0·11 [-0·57, 0·35]	0·64 [-0·77, 2·06]	-0·28 [-0·83, 0·26]	-0·68 [-1·74, 0·38]	0·30 [-0·07, 0·67]	0·11 [-0·43, 0·65]	2·42* [0·50, 4·34]	1·34 [-0·07, 2·75]	0·43 [-1·98, 2·85]	0·32 [-0·18, 0·82]
2009	2014	0·24 [-0·30, 0·78]	0·87 [-0·45, 2·19]	0·37 [-0·22, 0·96]	0·09 [-0·93, 1·11]	0·05 [-0·31, 0·41]	0·37 [-0·35, 1·08]	2·17* [0·28, 4·07]	1·64* [0·55, 2·74]	0·57 [-2·75, 3·90]	0·08 [-0·27, 0·44]
2009	2015	0·56* [0·08, 1·05]	0·29 [-1·09, 1·67]	0·27 [-0·43, 0·96]	0·22 [-0·78, 1·22]	0·28* [0·04, 0·52]	0·79* [0·26, 1·32]	1·09 [-1·47, 3·65]	1·08 [-0·08, 2·25]	1·33 [-1·52, 4·17]	0·23 [-0·21, 0·67]
2010	2003	-0·51 [-1·33, 0·31]	0·78 [-0·09, 1·65]	0·90 [-0·01, 1·82]	1·20 [-0·47, 2·87]	0·44 [-0·28, 1·16]	-0·49 [-1·25, 0·27]	1·80* [0·64, 2·96]	1·29 [-0·77, 3·35]	1·45 [-0·81, 3·71]	0·62 [-0·14, 1·38]
2010	2004	-0·01 [-0·58, 0·56]	-0·56 [-1·75, 0·63]	-0·68 [-1·91, 0·56]	-1·19 [-2·40, 0·03]	-0·28 [-1·20, 0·63]	-0·32 [-0·90, 0·27]	-1·11 [-2·93, 0·72]	-1·69* [-3·30, -0·08]	-2·29 [-4·76, 0·18]	-0·63 [-1·48, 0·22]
2010	2005	0·77 [-0·01, 1·55]	0·02 [-1·04, 1·08]	0·58 [-0·77, 1·92]	0·21 [-1·74, 2·17]	-0·13 [-0·88, 0·62]	0·75 [-0·03, 1·53]	-0·47 [-1·73, 0·79]	1·06 [-0·88, 3·00]	-0·93 [-3·82, 1·96]	0·15 [-0·69, 0·99]
2010	2006	-0·51 [-1·05, 0·03]	0·30 [-0·72, 1·32]	-0·50 [-1·65, 0·64]	0·00 [-0·79, 0·79]	-0·24 [-0·64, 0·17]	-0·39 [-1·01, 0·23]	0·35 [-0·89, 1·58]	-1·44 [-3·19, 0·31]	-0·38 [-1·93, 1·17]	-0·38 [-0·82, 0·07]
2010	2007	0·20 [-0·17, 0·57]	0·24 [-1·22, 1·69]	0·63 [-0·98, 2·23]	0·61 [-0·31, 1·53]	-0·32* [-0·60, -0·04]	0·37* [0·01, 0·72]	0·05 [-1·56, 1·67]	1·79* [0·08, 3·49]	3·42* [1·59, 5·26]	-0·33 [-0·70, 0·05]
2010	2008	-0·14 [-0·96, 0·67]	-0·56 [-1·57, 0·46]	0·48 [-1·01, 1·98]	-0·90 [-2·43, 0·64]	0·31 [-0·39, 1·00]	-0·28 [-1·17, 0·61]	0·08 [-1·65, 1·80]	-0·34 [-1·96, 1·29]	-2·09 [-4·24, 0·05]	0·40 [-0·30, 1·09]

Group	Year	Primary diagnoses[b]					Any diagnosis[c]				
		Acute myocardial infarction (AMI)	**Chronic obstructive pulmonary disease (COPD) and bronchiectasis**	**Heart Failure**	**Ischemic heart disease (including AMI)**	**Stroke**	**Acute myocardial infarction (AMI)**	**Chronic obstructive pulmonary disease (COPD) and bronchiectasis**	**Heart Failure**	**Ischemic heart disease (including AMI)**	**Stroke**
2010	2009	-0·52 [-1·15, 0·10]	0·54 [-0·18, 1·26]	-0·37 [-1·45, 0·72]	-0·16 [-1·22, 0·89]	0·45 [-0·35, 1·25]	-0·42 [-1·15, 0·31]	0·48 [-1·37, 2·32]	0·16 [-1·91, 2·23]	0·30 [-1·73, 2·33]	0·52 [-0·36, 1·41]
2010	2010	0·25 [-0·22, 0·72]	0·26 [-0·59, 1·12]	0·37 [-0·63, 1·36]	0·80* [0·02, 1·57]	-0·40 [-0·91, 0·11]	0·21 [-0·26, 0·67]	0·39 [-1·43, 2·21]	-0·11 [-1·89, 1·68]	1·23 [-0·10, 2·55]	-0·46 [-1·05, 0·13]
2010	2011	0·67* [0·30, 1·04]	-0·02 [-1·00, 0·96]	0·58 [-1·03, 2·19]	0·85* [0·18, 1·51]	-0·52 [-0·99, -0·05]	0·66* [0·17, 1·16]	0·13 [-2·57, 2·84]	0·43 [-1·90, 2·76]	2·35* [0·21, 4·50]	-0·59 [-1·08, -0·11]
2010	2012	0·77* [0·25, 1·29]	-0·21 [-0·90, 0·48]	0·65 [-1·17, 2·46]	1·25* [0·62, 1·87]	-0·39 [-1·08, 0·30]	0·88* [0·25, 1·51]	0·33 [-1·42, 2·08]	0·95 [-1·83, 3·74]	2·47 [-0·26, 5·20]	-0·57 [-1·36, 0·23]
2010	2013	0·91* [0·48, 1·34]	0·84 [-0·90, 2·57]	1·50 [-0·22, 3·22]	1·13* [-0·21, 2·46]	-0·08 [-0·80, 0·64]	1·49* [0·74, 2·25]	2·63* [0·18, 5·08]	3·60* [1·27, 5·94]	4·55* [1·99, 7·10]	-0·13 [-0·93, 0·66]
2010	2014	0·93* [0·30, 1·56]	0·32 [-0·29, 0·92]	1·31 [-0·51, 3·12]	1·01* [0·37, 1·65]	-0·39 [-1·19, 0·42]	1·14* [0·50, 1·78]	1·94 [-1·02, 4·90]	2·11 [-0·21, 4·43]	1·90* [0·23, 3·56]	-0·28 [-1·34, 0·78]
2010	2015[d]	1·02* [0·35, 1·69]	0·04 [-0·46, 0·54]	1·09 [-0·03, 2·21]	1·31* [0·20, 2·43]	-0·20 [-0·94, 0·53]	1·45* [0·77, 2·12]	0·51 [-1·21, 2·22]	2·66* [1·19, 4·12]	2·26* [0·61, 3·91]	-0·27 [-1·03, 0·49]

Notes: 95% pointwise confidence interval are presented in the brackets.
*Estimates are statistically significant at an alpha level of 0.05.
[a]Each health outcome was measured by the number of hospitalizations divided by the total Medicare fee-for-service population within the zip code and multiplied by 100. The control region was New York (main control) in this table. The model was weighted by the Medicare population of each zip code.
[b]Health outcomes were determined by the first two diagnosis codes in MedPAR hospital admission data.
[c]Health outcomes were determined by all diagnosis codes in MedPAR hospital admission data.
[d]The outcome values in 2015 were determined by both ICD-9-CM and ICD-10-CM codes.

Supplementary Table 8: Calendar-time average treatment effects

Year	Primary diagnoses[b]					Any diagnosis[c]				
	Acute myocardial infarction (AMI)	**Chronic obstructive pulmonary disease (COPD) and bronchiectasis**	**Heart Failure**	**Ischemic heart disease (including AMI)**	**Stroke**	**Acute myocardial infarction (AMI)**	**Chronic obstructive pulmonary disease (COPD) and bronchiectasis**	**Heart Failure**	**Ischemic heart disease (including AMI)**	**Stroke**
2008	-0·14 [-0·44, 0·16]	0·31 [-0·13, 0·75]	0·83* [0·00, 1·67]	0·22 [-0·18, 0·62]	0·02 [-0·31, 0·35]	-0·14 [-0·44, 0·15]	0·29 [-0·47, 1·05]	0·88 [-0·17, 1·94]	-0·49 [-1·44, 0·46]	0·04 [-0·33, 0·41]
2009	-0·13 [-0·38, 0·12]	0·18 [-0·35, 0·71]	0·17 [-0·66, 1·00]	0·22 [-0·28, 0·72]	-0·18 [-0·45, 0·10]	-0·15 [-0·42, 0·12]	0·14 [-0·87, 1·15]	0·03 [-1·15, 1·21]	0·38 [-0·75, 1·51]	-0·14 [-0·44, 0·15]
2010	-0·05 [-0·33, 0·23]	0·11 [-0·42, 0·63]	0·40 [-0·13, 0·92]	0·39 [-0·15, 0·94]	-0·05 [-0·35, 0·25]	-0·10 [-0·37, 0·18]	0·35 [-0·65, 1·35]	0·39 [-0·51, 1·29]	0·95 [-0·11, 2·01]	0·00 [-0·33, 0·32]
2011	0·03 [-0·32, 0·38]	0·18 [-0·28, 0·64]	0·55 [-0·07, 1·16]	0·11 [-0·42, 0·64]	0·11 [-0·14, 0·35]	0·06 [-0·28, 0·41]	0·90 [-0·13, 1·94]	0·75 [-0·33, 1·84]	1·66* [0·15, 3·16]	0·14 [-0·12, 0·41]
2012	0·34* [0·06, 0·61]	0·58* [0·03, 1·13]	0·63 [-0·05, 1·31]	0·55 [-0·07, 1·17]	0·05 [-0·23, 0·33]	0·41* [0·12, 0·70]	1·35* [0·28, 2·41]	1·41* [0·42, 2·39]	2·23* [0·80, 3·66]	0·11 [-0·24, 0·46]
2013	0·38* [0·13, 0·63]	0·52 [-0·12, 1·15]	0·59 [-0·03, 1·22]	0·48 [-0·06, 1·02]	0·05 [-0·22, 0·33]	0·68* [0·40, 0·95]	2·00* [1·13, 2·87]	1·93* [1·10, 2·76]	2·55* [1·26, 3·85]	0·07 [-0·25, 0·39]
2014	0·50* [0·18, 0·83]	0·52 [-0·13, 1·18]	0·76* [0·20, 1·33]	0·76* [0·23, 1·28]	-0·04 [-0·31, 0·22]	0·79* [0·41, 1·17]	1·34* [0·37, 2·32]	1·76* [0·83, 2·68]	1·53* [0·28, 2·79]	0·04 [-0·28, 0·36]
2015[d]	0·66* [0·39, 0·94]	0·39 [-0·23, 1·00]	1·02* [0·49, 1·56]	0·97* [0·44, 1·51]	-0·04 [-0·29, 0·22]	1·05* [0·75, 1·36]	0·89* [0·02, 1·76]	2·19* [1·39, 3·00]	2·38* [1·24, 3·52]	0·01 [-0·29, 0·30]

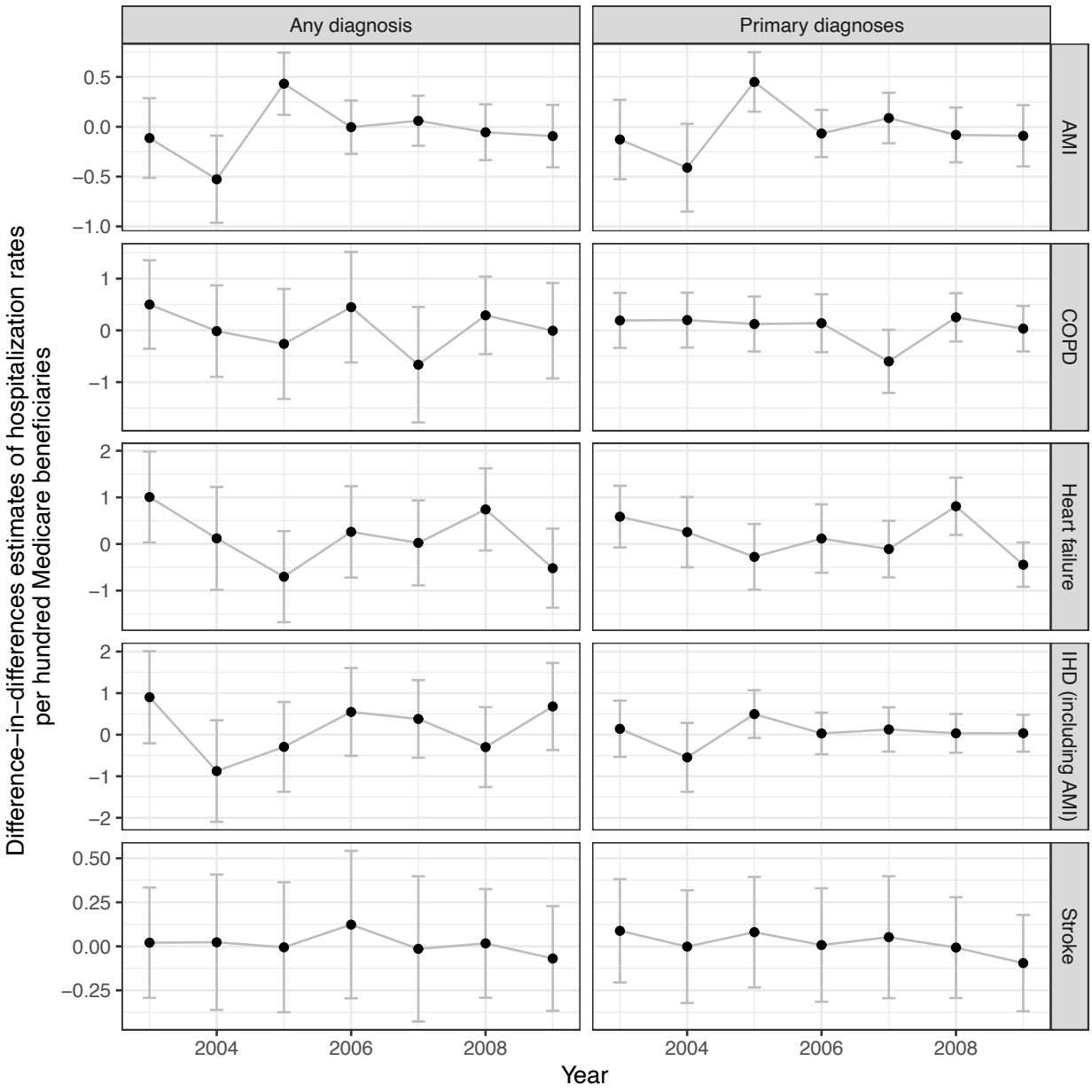
Notes: 95% pointwise confidence interval are presented in the brackets.
*95% confidence interval of estimate does not include zero.
[a]The estimates were aggregated from the group-time average treatment effects in Supplementary Table 7 across each calendar year since the first UNGD in the exposed region.
[b]Health outcomes were determined by the first two diagnosis codes in MedPAR hospital admission data.
[c]Health outcomes were determined by all diagnosis codes in MedPAR hospital admission data.
[d]The outcome values in 2015 were determined by both ICD-9-CM and ICD-10-CM codes.

Supplementary Table 9: Event-time average treatment effects

Number of years to the first well development	Primary diagnoses[b]					Any diagnosis[c]				
	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke	Acute myocardial infarction (AMI)	Chronic obstructive pulmonary disease (COPD) and bronchiectasis	Heart Failure	Ischemic heart disease (including AMI)	Stroke
0	-0·05 [-0·27, 0·16]	0·29 [-0·02, 0·60]	0·47 [-0·17, 1·10]	0·30 [0·00, 0·60]	0·02 [-0·23, 0·27]	-0·07 [-0·28, 0·14]	0·20 [-0·42, 0·82]	0·40 [-0·44, 1·24]	-0·17 [-0·99, 0·66]	0·01 [-0·27, 0·30]
1	-0·06 [-0·29, 0·17]	0·11 [-0·40, 0·62]	0·35 [-0·36, 1·06]	0·16 [-0·33, 0·65]	-0·26 [-0·49, -0·04]	-0·10 [-0·35, 0·15]	0·19 [-0·75, 1·14]	0·28 [-0·73, 1·30]	0·56 [-0·48, 1·60]	-0·23 [-0·48, 0·02]
2	-0·02 [-0·31, 0·28]	-0·01 [-0·51, 0·49]	0·30 [-0·30, 0·90]	0·41 [-0·14, 0·96]	0·01 [-0·29, 0·32]	-0·02 [-0·31, 0·27]	0·35 [-0·66, 1·36]	0·33 [-0·64, 1·31]	1·06 [-0·13, 2·24]	0·02 [-0·30, 0·34]
3	0·10 [-0·22, 0·42]	0·56* [0·07, 1·05]	0·66* [0·04, 1·28]	0·15 [-0·38, 0·68]	0·21 [-0·04, 0·46]	0·20 [-0·14, 0·54]	1·52* [0·62, 2·43]	1·33* [0·34, 2·31]	2·38* [0·99, 3·76]	0·26 [-0·02, 0·54]
4	0·37* [0·09, 0·65]	0·57* [0·01, 1·13]	0·79* [0·16, 1·43]	0·51 [-0·12, 1·13]	0·00 [-0·26, 0·25]	0·52* [0·24, 0·80]	1·80* [0·75, 2·84]	1·87* [0·99, 2·75]	1·99* [0·69, 3·29]	0·10 [-0·23, 0·43]
5	0·47* [0·22, 0·72]	0·46 [-0·11, 1·03]	0·68* [0·13, 1·23]	0·68* [0·21, 1·15]	-0·02 [-0·28, 0·24]	0·73* [0·44, 1·01]	1·66* [0·84, 2·48]	1·87* [1·16, 2·59]	2·27* [0·97, 3·58]	0·00 [-0·30, 0·30]
6	0·52* [0·20, 0·84]	0·41 [-0·31, 1·13]	0·65* [0·11, 1·20]	0·75* [0·18, 1·32]	0·07 [-0·19, 0·33]	0·84* [0·48, 1·20]	0·97 [-0·06, 2·01]	1·56* [0·63, 2·49]	1·67* [0·40, 2·95]	0·13 [-0·19, 0·44]
7	0·63* [0·28, 0·97]	0·49 [-0·30, 1·29]	1·27* [0·63, 1·91]	1·17* [0·57, 1·76]	-0·11 [-0·42, 0·20]	1·06* [0·68, 1·44]	0·90* [0·00, 1·80]	2·48* [1·52, 3·45]	2·77* [1·60, 3·94]	-0·01 [-0·36, 0·33]

Notes: 95% pointwise confidence interval are presented in the brackets.
*95% confidence interval of estimate does not include zero.
[a]The estimates were aggregated from the group-time average treatment effects in Supplementary Table 7 based on the length of exposure to UNGD.
[b]Health outcomes were determined by the first two diagnosis codes in MedPAR hospital admission data.
[c]Health outcomes were determined by all diagnosis codes in MedPAR hospital admission data.

Supplementary Figure 1: Pre-period parallel trends analysis, using difference-in-differences of hospitalization rates in New York vs Pennsylvania, year-to-year analysis



Code and data availability

All code and certain de-identified datasets are currently available at https://github.com/sanghavi-lab/medicare_claims_and_pennsylvania_UNGD-. The outline below walks through the code used to analyze data and generate visualizations and model output.

Below is a table of code descriptions including the input and output from the code.

Steps	Script	Description	Input	Output
1	FIN-count-cases-with-mbsf.py	Merge MedPAR and MBSF data, filter to those with Parts A and B coverage, and count the number of cases per outcome group per zip code per year.	**Outcomes to study and corresponding ICD-9 and ICD-10 codes** FIN-outcomes-groups.csv FIN-outcome-group-ICD10s.csv FIN-outcome-group-ICD10s-exclusion.csv **List of included ZIP codes in Pennsylvania & New York study regions** included-zipcodes-list.csv **MedPAR files (inpatient claims), one CSV file per year, each CSV contains all records from entire PA & NY states in one year** THES-DID-INP-REF-whole-state-filtered-medpar-{year}.csv **MBSF files (all Medicare beneficiaries), one CSV per year, each CSV filtered to all beneficiaries from just the ZIP codes of study** THES-DID-INP-REF-ZIP-mbsf-zipcode-subset-{year}.csv	**Two CSV files per year: one counting cases using 2 diagnosis columns only, one using all 25 diagnosis columns. CSVs contain columns for the outcome (e.g. "AMI"), the ZIP code, and the number of cases.** FIN-icd-counts-per-zipcode-with-mbsf-{year}-using-{num}-dgns-columns.csv

Steps	Script	Description	Input	Output
2	FIN-join-zipcodes-mbsf.py	Aggregate MBSF subset data into zip code-level bins, recording total populations and some average statistics, and merge with aggregated ICD codes.	**Counted cases per ZIP code, per year, per # of diagnosis columns (Output from (1))** PUB-ZIP-icd-counts-per-zipcode-with-mbsf-{year}-using-2-dgns-columns.csv **MBSF files (all Medicare beneficiaries), one CSV per year, each CSV filtered to all beneficiaries from just the ZIP codes of study** THES-DID-INP-REF-ZIP-mbsf-zipcode-subset-{year}.csv **List of included ZIP codes in Pennsylvania & New York study regions** included-zipcodes-list.csv	**Aggregate statistics per ZIP code of beneficiary demographics (age distributions, sex, race, duals, etc.) from MBSF file, for each year** FIN-mbsf-agg-statistics-{year}.csv **Merged CSV file for each year, each number of diagnosis columns, with hospitalization counts AND MBSF aggregate statistics (i.e. denominators) together** FIN-icd-rates-per-zipcode-{year}-using-{num}-dgns-columns.csv
3	FIN-plot-raw-rates.R	Plot time series of raw incidence rates, aggregated over study regions (New York (main control), New York (alt. control), PA (exposed region)).	**Hospitalization counts and aggregate statistics (Output from (2))** FIN-icd-rates-per-zipcode-{year}-using-{num}-dgns-columns.csv **List of included ZIP codes in Pennsylvania & New York study regions** included-zipcodes-list.csv **UNGD spuds aggregated over ZIP codes** THES-DID-INP-REF-ZIP-zipcode-aggregated-spuds.csv **Outcomes to study and corresponding ICD-9 codes** FIN-outcomes-groups.csv	**"Master dataframe" containing all ZIP code data (hospitalization counts per outcome per year, etc) in one table** MASTER-DF.csv (this was changed to MASTER-DF-UPDATE.csv after adding the last three month of data in 2015) **Data frame of demographic trends (age, race, sex, total benes) over time** DEMOGRAPHICS-DF.csv **Final, publishable plot with time-series of hospitalization rates stacked on top of UNGD development over time** publishable_plot_column.eps

Steps	Script	Description	Input	Output
4	CALLAWAY_DID.R	Run difference-in-difference anlaysis on our panel dataset usind the did package developed by Callaway et al.	**UNGD spuds aggregated over ZIP codes** THES-DID-INP-REF-ZIP-zipcode-aggregated-spuds.csv **Cleaned MedPAR/MBSF data with health outcomes (Output from (3))** MASTER-DF-UPDATE.csv **Outcomes to study and corresponding ICD-9 codes** FIN-outcomes-groups.csv	**Spreadsheet with one row of model output for each model specification (outcome, # diagnosis cols used, which control region) and plots for pre-trend analysis** CALLAWAY_FINAL_DID_RESULTS_0810ONLY.csv CALLAWAY_FINAL_DID_RESULTS_0810ONLY_preperiod2009_BOOTSTRAPPED.csv CALLAWAY_FINAL_DID_RESULTS_0810ONLY_preperiodVARYING.csv pretrend_NYMid_basedperiod2009.eps pretrend_NYMid_basedperiodVARYING.eps