Does the National Health Service Corps Help Underserved Areas?

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Background and Aims

Medically underserved areas are communities with a high levels of unmet healthcare needs, often secondary to insufficient access to primary care physicians (Shi et al., 2005; Starfield, Shi, & Macinko, 2005). Formal designations of underserved areas began in the late 1980s and is based on the Index of Medical Underservice (IMU), a weighted score of census or county-level infant mortality rate, primary care provider to population ratio, percent of population older than 65, and percent of population below the federal poverty line ("Development of the index of medical underservice," 1975). Although primary care recruitment to and subsequent health improvement in underserved areas are often cited targets for healthcare and physician workgroups, medically underserved areas are consistently faced with physician shortages. Determinants of shortages include lack of physician exposure to rural health in medical school, individual preference to work in urban centers, lower pay for primary care specialties, and hospital closures (Fagan et al., 2015; Parlier, Galvin, Thach, Kruidenier, & Fagan, 2018; Rabinowitz, Diamond, Markham, & Paynter, 2001).

To increase physician supply to underserved areas, several loan repayment and subsidized training programs for primary care practitioners have been instituted, including the National Health Service Corps (NHSC) through the U.S. Department of Health and Human Services (National Health Service Corps Scholarship Program, 2003). The NHSC grants primary care physicians up to $50,000 in medical school loan forgiveness in exchange for two years of service in a medically underserved area, although select states offer additional compensation. Early assessments of the NHSC have shown the program to be successful in recruiting physicians to areas of high need (Holmes, 2005); unfortunately, less than half of participating physicians remain in their initial area of service after completion of the program, leading to high rates of turnover and lack of continuity in the care of underserved community members (Heisler, 2017; Pathman, Konrad, Dann, & Koch, 2004). Further, despite the purported goal of primary care recruitment programs in improving population health, few evaluations have explored the effects of the NHSC on population health indicators.

The aim of this analysis is to determine whether participation in the NHSC reduces county-level all-cause and disease-specific mortality (herein, simply ‘mortality’).

Method

Data for this study come from three sources: one, the Area Health Resource Files (US Department of Health and Human Services, 2014) for the ratio of primary care physicians-to-population; two, the American Community Survey (ACS) (U.S. Census Bureau; American Community Survey, 2014) for population estimates, age demographics, and poverty and unemployment rates; three, the Centers for Disease Control Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) (Centers for Disease Control and Prevention, 1995) for infant mortality rates, low birthweight rates, and crude all-cause, cancer, and heart disease mortality rates. Briefly, the Area Health Resource Files are a compilation of 50 separate health service and economic datasets provided by the American Medical Association, American Hospital Association, and Bureau of Health Workforce. Files are updated annually to monitor health service worker supply, regional demand for specific medical procedures (e.g. elective surgery, orthodontia), and costs of care. Among the provided indicators is a census of all physicians licensed in the U.S., disaggregated by county of practice and medical specialty. The ACS is an ongoing, nationally representative, multistage probability sample conducted by the U.S. Census Bureau as a supplement to the decennial census. Roughly 0.6% of the U.S. population is sampled for the ACS in any given year, and, because the Census Bureau contacts respondents multiple time to encourage participation, the response rate in 2014 was 96.7% (Torrieri, 2014). The ACS includes census tract-level demographics including estimates of population by age group and race/ethnicity, poverty, unemployment, and educational attainment. Finally, CDC WONDER is an online query system maintained by the National Center for Health Statistics that allows users to generate area- and period-level natality and mortality data from linkage to birth records and the National Death Index ($>$ 90% of all deaths are accounted for in any given year) for all U.S. counties between 1999 and 2016. Area-level mortality rates disaggregated by age are provided for the 57 leading causes of death as determined by death certificate listed ICD-10 codes, although rates are suppressed for regions with fewer than 10 deaths from a specific cause. I used these cause-specific crude rates and county-level population estimates for each 10-year age stratum to standardize rates to the 2000 U.S. standard million (Anderson & Rosenberg, 1998).

Index of Medical Underservice Scoring

A county’s eligibility to participate in the NHSC is determined by the index of medical underservice score, which quantifies an area’s degree of physician shortage relative to healthcare needs. Scores are typically generated automatically by the Health Resource and Service Administration from Area Health Resource

Files, CDC WONDER, and Census data, with all scores of 62 or below eligible for NHSC participation. Although historic data on county eligibility are publicly available, actual index of medical underservice scores are only provided for counties currently eligible for the NHSC (i.e. in 2019; 2020 eligibility has not yet been determined). Thus, to obtain index of medical underservice scores for earlier years, I regenerate scores for each county in the U.S. using historic data and the Health Resource and Service Administration scoring guidelines (U.S. Department of Health and Human Services, 2015). Scores are calculated as the weighted sum of a county's primary care physician-to-population ratio, percentage of residents age 65 or older, percentage of population at or below the federal poverty level, and infant mortality rate or, in instances where infant mortality rates were suppressed due to small sample sizes, rates of low birthweight. All score subcomponents are based on five-year averages to prevent substantial annual variation in program eligibility for treated counties (i.e. the averages of 2009-2014 components were used to calculate 2014 scores), and counties with qualifying scores automatically retain eligibility for two years following designation, regardless of subsequent scores. Though the NHSC has been in operation since the late 1970s, the current index of medical underservice scoring criteria were first implemented in 2014 such that all potential carry-overs from 2012/2013 to 2014 were disallowed. Thus, unlike for earlier periods, a county's NHSC participation in 2014 is based strictly on its 2014 score rather than any one of its 2012, 2013, or 2014 scores. Table 1 provides a more detailed description of scoring criteria and weighting procedures.

Treatment Assignment

Let Z_i be a dichotomous variable denoting the eligibility of county i to participate in the NHSC in 2014 (with $0 =$ ineligible, $1 =$ eligible). Also let X_i denote the index of medical underservice score in 2014, and D_i ($1 =$ treated, $0 =$ control) denote actual participation in 2014. Z_i is a deterministic function of X_i such that:

$$E[Z_i|X_i] = \begin{cases} 1 \text{ if } X_i \leq 62 \\ 0 \text{ if } X_i > 62 \end{cases}$$

Due to budget constraints, not all eligible counties receive NHSC funding; however, no ineligible counties receive funding. Therefore, D_i is a probabilistic function of eligibility $f(Z_i)$ for counties below the cutoff, and deterministic for counties above such that:

$$E[D_i|Z_i] = \begin{cases} f(Z_i) & \text{if } Z_i = 1 \\ 0 & \text{if } Z_i = 0 \end{cases} \text{ where } f(Z_i) \neq 0$$

Because of this feature, monotonicity is guaranteed to hold, with the exception that state governors may grant exemptions for ineligible rural counties with demonstrated primary care shortages to receive funding for rural health clinics. However, the application process for exemption is long and requires extensive administrative oversight, with few requests ultimately being approved, so the population of defiers is both known and small (a total of five counties were exempted in 2014, all of which I exclude from further analyses). As shown in Table 2, derived treatment assignment according to simulated scores adhered to known participation and eligibility rules, with zero counties above the cutoff participating and approximately one-half of those below participating.

Model Specification

To recover the regression discontinuity effect τ of county NHSC participation D_i on 2015 mortality rate Y_i, I use a fuzzy regression discontinuity design and estimate τ with a two-stage least squares approach where D is instrumented by Z. I allow for possible heterogeneity in the treatment effect as a function of X_i by including interaction terms between the zero-centered transformation of X_i ($\tilde{X}_i$) and eligibility Z_i. The models for the first stages are represented by equations 1 and 2, where $f_1(\tilde{X}_i)$ is a given polynomial transformation of the centered running variable.

$$D_i = \alpha_i + \gamma_0 Z_i + \gamma_1(f_1(\tilde{X}_i)) + \epsilon_i \ (1)$$

$$f_1(\tilde{X}_i)D_i = \alpha_i + \gamma_0 Z_i + \gamma_1(f_1(\tilde{X}_i))Z_i + \epsilon_i \ (2)$$

The second stage is then estimated as follows, where $\hat{D}_i$ represents the fitted values of equation 1, and the various functions of $\tilde{X}_i\hat{D}_i$ represents fitted values from equation 2 where $f_1(\tilde{X}_i) = \tilde{X}_i^{\,p}$. $Y_i = \alpha + \tau\hat{D}_i + \beta_0\tilde{X}_i + \beta_1(\tilde{X}_i\hat{D}_i) + ...\beta_p(\tilde{X}_i^{\,p}\hat{D}_i)\mu_i$

To determine the appropriate functional form of the regression, I estimate local average treatment effects (LATEs) of program participation using both the full sample with first, second and third order polynomials (i.e. where a $f_1(\tilde{X}_i) = \tilde{X}_i; \tilde{X}_i^{\,2}; \tilde{X}_i^{\,3}$), and with local linear regression using a triangular kernel and observations within the robust bias-corrected (RBC) bandwidth (Calonico, Cattaneo, and Farrell, 2019).[1]

Sensitivity Analyses

To assess potential manipulation of the running variable X_i, I check for discontinuity in the density of observations just above and below the cutoff score, again using the optimal bandwidth to test for discontinuity (McCrary, 2008). I also perform placebo tests using a range of false cutoff values of X_i to estimate local

[1] An aside regarding weights and clustering: Though counties do differ substantially in population, weighting for size would typically acheive an effect estimate appropriate for individual, rather than population inference. Additionally, although there is clear geographic clustering (e.g. counties within states), treatment (score) is not randomized at this level. Further, some clusters (namely, Delaware and Rhode Island) contain only two participating counties, leading not only to highly imbalanced cluster sizes and a substantial reduction in power.

average treatment effects at different points along the running variable. To assess balance in covariates around the cutoff, I estimate the LATE of program participation on 2014 county-level median household income, percentage of residents who live in rural areas and who are White, Black, or Hispanic, and rates of unemployment, high school graduation, uninsurance, obesity, smoking, and insufficient physical activity using the same model specifications as above. As a final robustness check, I assess the effect of 2014 NHSC participation on placebo outcomes of 1999, 2005, and 2009 age-standardized mortality rates.

Fixed Effects It is important to acknowledge the possibility that because the NHSC existed prior to 2014, albeit using different eligibilty criteria, some ineligible counties in 2014 may have participated in the NHSC as recently as 2013. Indeed, This presents a challenge to the identification of τ as

Results

A total of 851 counties were eligible for the NHSC in 2014, 406 (47.7%) of which ultimately received a physician recruit. In general, even restricting to counties within the median estimated RBC bandwidth, eligible counties differed significantly from ineligible counties by simple difference-in-means tests. On average, counties with IMU scores below the cutoff were less populous, had greater percentages of residents living in rural areas, lower percentages of non-Hispanic White residents, and performed worse on socioeconomic and health indicators, although in most instances differences were slight and less pronounced than in the full sample (Table 2).

```
##
## Call:
## ivreg(formula = age_adjusted_rate_2015a ~ treatment | x_tilde *
##     eligible, data = merge.mortb)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -654.458  -95.295   -9.468   88.125  820.528
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  795.437      3.443  231.00   <2e-16 ***
## treatment    190.456     11.641   16.36   <2e-16 ***
```

Table 1: Description of index of medical underservice score subcomponents and weighting

Infant Mortality		Percent Over 65		Primary Care Ratio		Percent in Poverty	
Value	Score	Value	Score	Value	Score	Value	Score
<= 8	26.0	<= 7	20.2	<= 0.05	0.0	<= 0.1	25.1
<= 9	25.6	<= 8	20.1	<= 0.1	0.5	<= 1	24.6
<= 10	24.8	<= 9	19.9	<= 0.15	1.5	<= 4	23.7
<= 11	24.0	<= 10	19.8	<= 0.2	2.8	<= 6	22.8
<= 12	23.2	<= 11	19.6	<= 0.25	4.1	<= 8	21.9
<= 13	22.4	<= 12	19.4	<= 0.3	5.7	<= 10	21.0
<= 14	20.5	<= 13	19.1	<= 0.35	7.3	<= 12	20.0
<= 15	20.5	<= 14	18.9	<= 0.4	9.0	<= 14	18.7
<= 16	19.5	<= 15	18.7	<= 0.45	10.7	<= 16	17.4
<= 17	18.5	<= 16	17.8	<= 0.5	12.6	<= 18	16.2
<= 18	17.5	<= 17	16.1	<= 0.55	14.8	<= 20	14.9
<= 19	16.4	<= 18	14.4	<= 0.6	16.9	<= 22	13.6
<= 20	15.3	<= 19	12.8	<= 0.65	19.1	<= 24	12.2
<= 21	14.2	<= 20	11.2	<= 0.7	20.7	<= 26	10.9
<= 22	13.1	<= 21	9.8	<= 0.75	21.9	<= 28	9.3
<= 23	11.9	<= 22	8.9	<= 0.8	23.1	<= 30	7.8
<= 24	10.8	<= 23	8.0	<= 0.85	24.3	<= 32	6.6
<= 25	9.6	<= 24	7.0	<= 0.9	25.3	<= 34	5.6
<= 26	8.5	<= 25	6.1	<= 0.95	25.9	<= 36	4.7
<= 27	7.3	<= 26	5.1	<= 1	26.6	<= 38	3.4
<= 28	6.1	<= 27	4.0	<= 1.05	27.2	<= 40	2.1
<= 29	5.4	<= 28	2.8	<= 1.1	27.7	<= 42	1.3
<= 30	5.0	<= 29	1.7	<= 1.15	28.0	<= 44	1.0
<= 31	4.7	<= 30	0.6	<= 1.2	28.3	<= 46	0.7
<= 32	4.3	>30	0.0	<= 1.25	28.6	<= 48	0.4
<= 33	4.0	–	–	>1.25	28.7	>48	0.1
<= 34	3.6	–	–	–	–	–	–
<= 35	3.3	–	–	–	–	–	–
<= 36	3.0	–	–	–	–	–	–
<= 37	2.6	–	–	–	–	–	–
<= 39	2.0	–	–	–	–	–	–
<= 41	1.4	–	–	–	–	–	–
<= 43	0.8	–	–	–	–	–	–
>43	0.2	–	–	–	–	–	–

[1] Infant Mortality Rate = Infant Deaths per 1000 Live Births
[2] PCP Ratio = Total FTE Non-federal Primary Care Providers per 1000 Population
[3] Poverty = At or Below Federal Poverty Level

Table 2: Sample characteristics of counties with Index of Medical Underservice (IMU) scores within the median RBC bandwidth. All characteristics are based on 2014 data or, for IMU components, the five-year average of 2009-2014 data and are shown as Mean (SD). Except for total population, infant health index, and primary care ratio, all values represent proportions of county residents with given characteristic.

	IMU > 51.88 and <= 62	IMU > 62 and <= 72.11	P-value
N	620	690	–
Enrolled in NHSC	290 (47.90)	0 (0.00)	–
IMU Components			
Poverty[1]	0.17 (0.03)	0.14 (0.05)	< 0.001
Older Than 65 Years	0.13 (0.05)	0.14 (0.05)	< 0.001
Infant Health Index[2]	25.67 (1.70)	24.76 (0.74)	< 0.001
Primary Care Ratio[3]	0.81 (0.57)	1.36 (0.60)	< 0.001
County Characteristics			
Total Population	29,304 (55,339)	54,822 (129,421)	< 0.001
Rural	0.75 (0.24)	0.60 (0.26)	< 0.001
Non-Hispanic White	0.76 (0.20)	0.81 (0.18)	< 0.001
Non-Hispanic Black	0.12 (0.17)	0.07 (0.11)	< 0.001
Hispanic	0.08 (0.14)	0.09 (0.14)	0.001
Health Indicators			
Current Smokers	0.24 (0.06)	0.22 (0.06)	< 0.001
Obese	0.33 (0.04)	0.32 (0.04)	< 0.001
Physically Inactive	0.30 (0.05)	0.26 (0.04)	< 0.001
Uninsured	0.16 (0.04)	0.14 (0.04)	< 0.001

[1] Poverty = At or Below Federal Poverty Level
[2] Infant Mortality Rate = Infant Deaths per 1000 Live Births
[3] PCP Ratio = Total FTE Non-federal Primary Care Providers per 1000 Population

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 153.2 on 2789 degrees of freedom
## Multiple R-Squared: 0.01445, Adjusted R-squared: 0.01409
## Wald test: 267.7 on 1 and 2789 DF,  p-value: < 2.2e-16
```

```
##
## Call:
## ivreg(formula = age_adjusted_rate_2015a ~ treatment | x_tilde +
##     x_tilde:eligible, data = merge.mortb)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -686.681  -97.094   -9.646   90.120  826.640
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  789.325      3.631  217.37   <2e-16 ***
## treatment    228.790     13.121   17.44   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 156.8 on 2789 degrees of freedom
## Multiple R-Squared: -0.03202,    Adjusted R-squared: -0.03239
## Wald test:   304 on 1 and 2789 DF,  p-value: < 2.2e-16
```

Table 3: Effect of NHSC Participation on County-Level Mortality

				95% Confidence Interval	
Outcome	Order	BW	Estimate	Conventional	Robust
Age Adjusted Rate					
All Cause	1	9.39	171.75	**76.46 - 267.04**	**63.04 - 280.47**
	2	11.67	160.85	**37.51 - 284.18**	**22.05 - 299.65**
	3	10.24	79.32	-15.97 - 174.61	-29.39 - 188.04
Heart Disease	1	7.26	51.99	**4.64 - 99.33**	-4.17 - 108.14
	2	12.75	55.33	**2.03 - 108.64**	-4.82 - 115.49
	3	11.36	37.06	-10.28 - 84.41	-19.09 - 93.22
Cancer	1	8.50	39.78	**13.39 - 66.17**	**9.01 - 70.55**
	2	9.96	38.31	**3.34 - 73.29**	-1.22 - 77.85
	3	11.84	30.58	**4.18 - 56.97**	-0.19 - 61.35
Crude Rate					
All Cause	1	7.38	61.29	-99.44 - 222.01	-129.59 - 252.16
	2	8.36	-22.01	-230.84 - 186.82	-253.77 - 209.75
	3	12.55	-51.68	-212.41 - 109.04	-242.56 - 139.2
Heart Disease	1	9.75	23.94	-35.06 - 82.94	-46.21 - 94.09
	2	10.01	7.50	-76.17 - 91.18	-86.8 - 101.81
	3	14.92	9.81	-49.19 - 68.81	-60.34 - 79.96
Cancer	1	8.47	31.70	-11.25 - 74.65	-19.66 - 83.06
	2	11.34	31.50	-23.38 - 86.37	-30.67 - 93.67
	3	10.67	12.60	-30.34 - 55.55	-38.76 - 63.97

Note:
Estimates represent tau FRD using a local regression with a triangular kernel
[a] Bold face denotes statistical significance ($p < 0.05$)

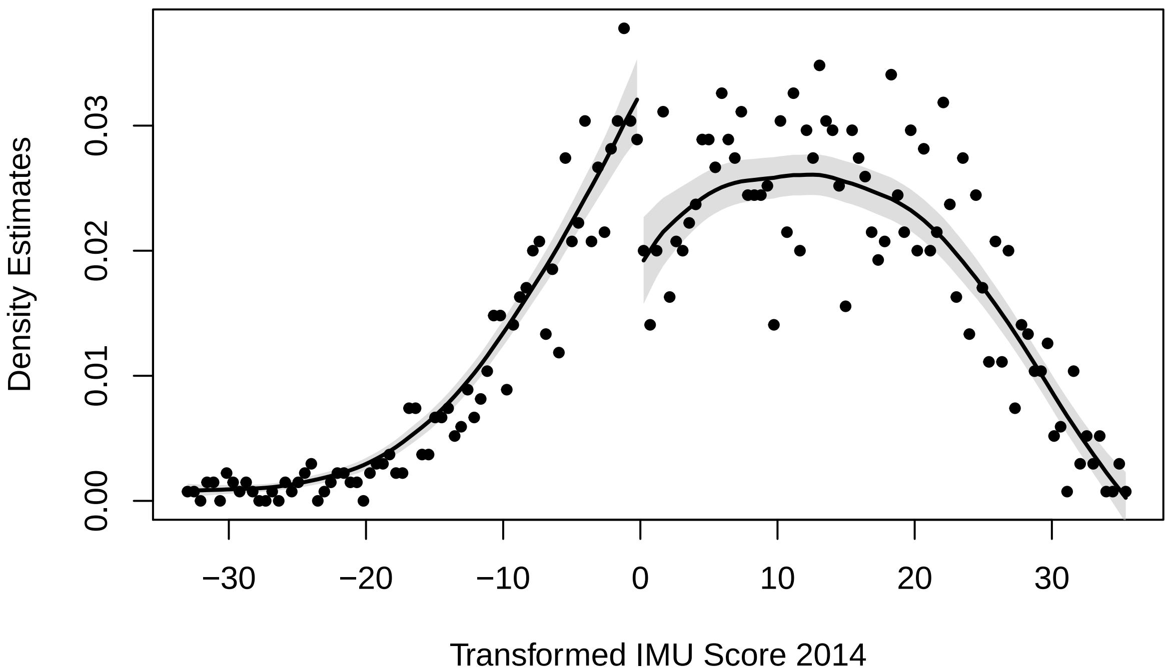
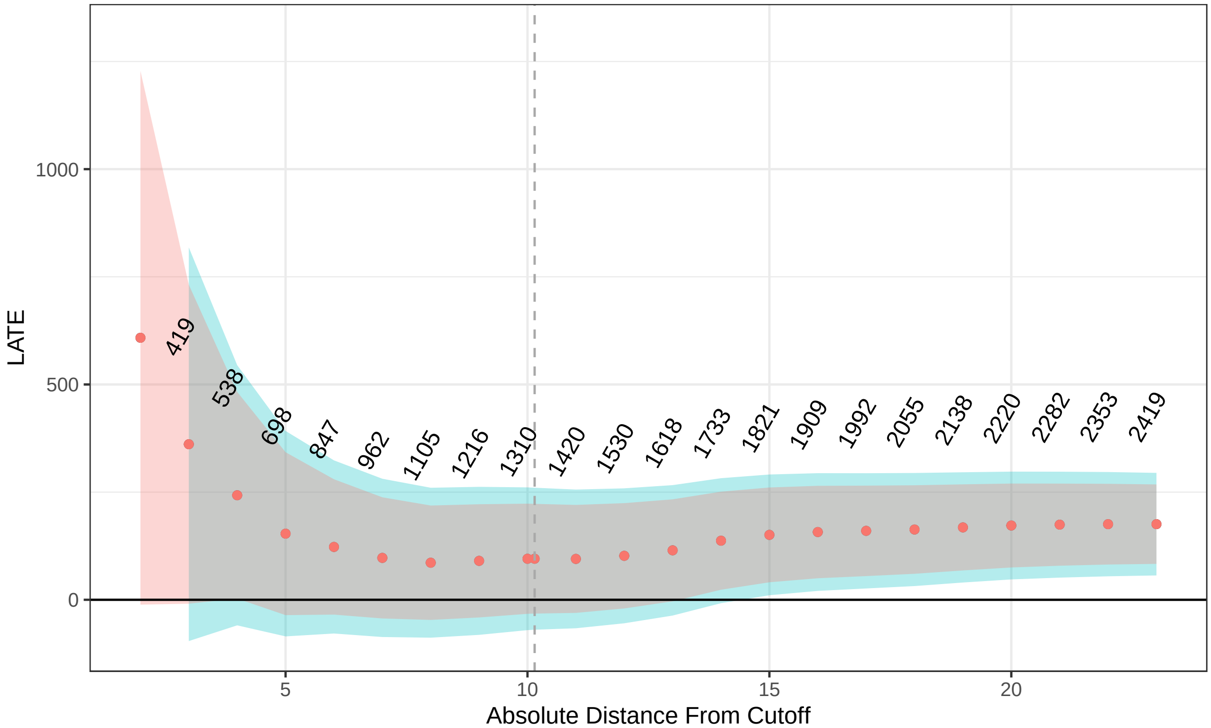


Figure 1: McCrary Density Test shows no evidence of sorting at the cutoff (p = 0.68)

Effect of NHSC on All−Cause Mortality Rate



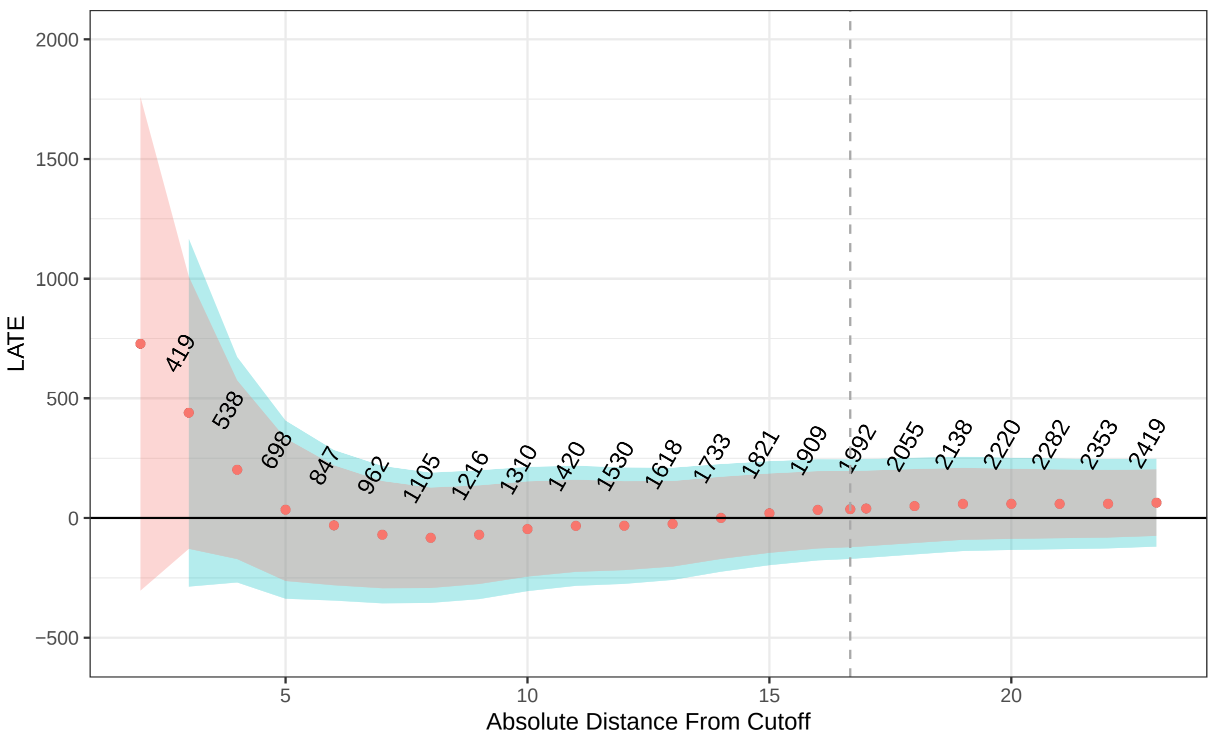


Figure 2: Age-standardized (top) LATE estimates for all-cause mortality are robust against choice of bandwidht, while crude (bottom) effect estimates are not. LATE is estimated as a local fuzzy RDD with a triangular kernel and second-order polynomial. Dashed line indicates IK bandwidth, numbers reflect number of observations within a given bandwidth, blue ribbon represents robust 95% CI, and dark ribbon represents bias-corrected 95% CI

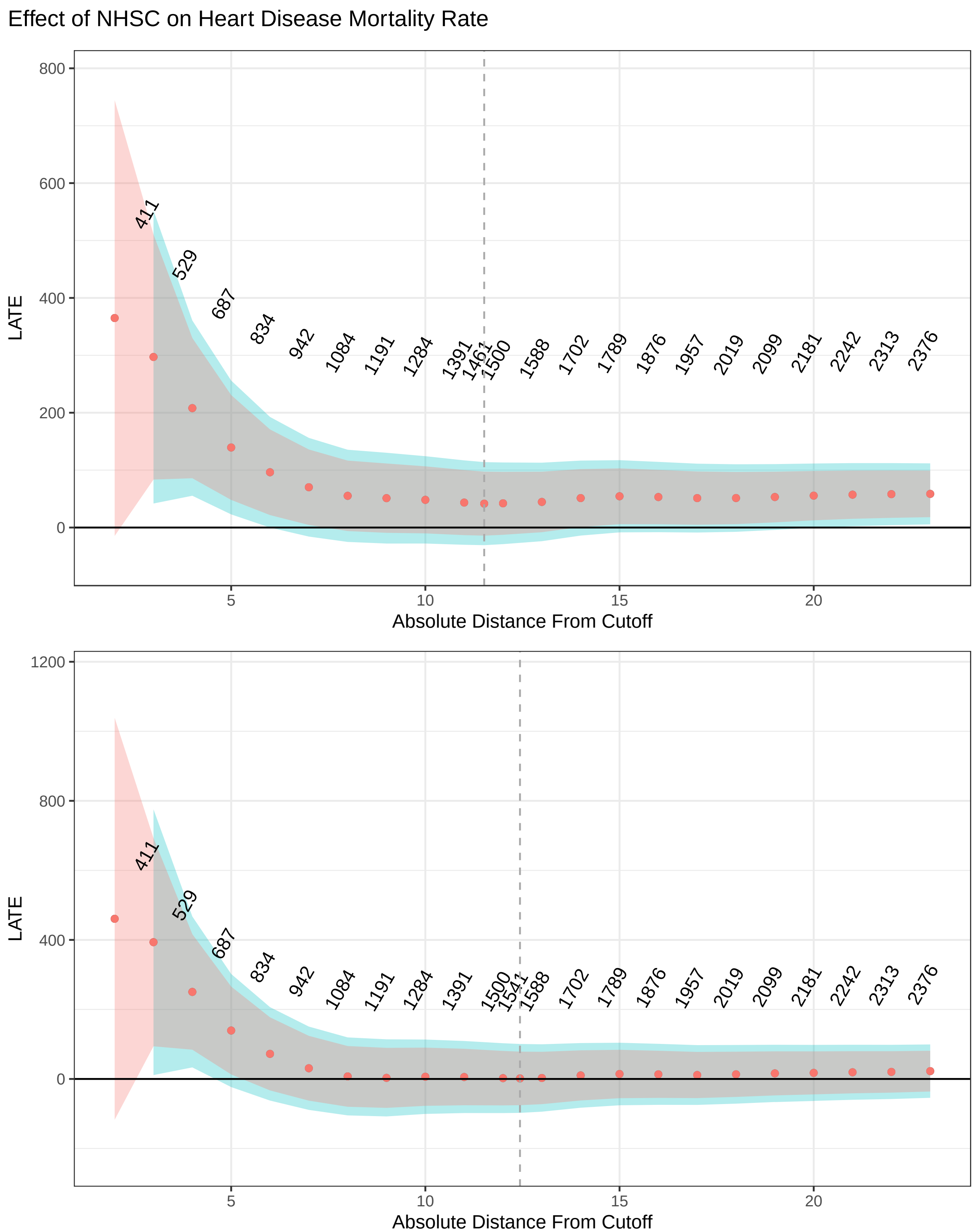


Figure 3: Age-standardized (top) and crude (bottom) effect estimates for heart disease mortality are robust against choice of bandwidth. LATE is estimated as a local fuzzy RDD with a triangular kernel and second-order polynomial. Dashed line indicates IK bandwidth, numbers reflect number of observations within a given bandwidth, blue ribbon represents robust 95% CI, and dark ribbon represents bias-corrected 95% CI

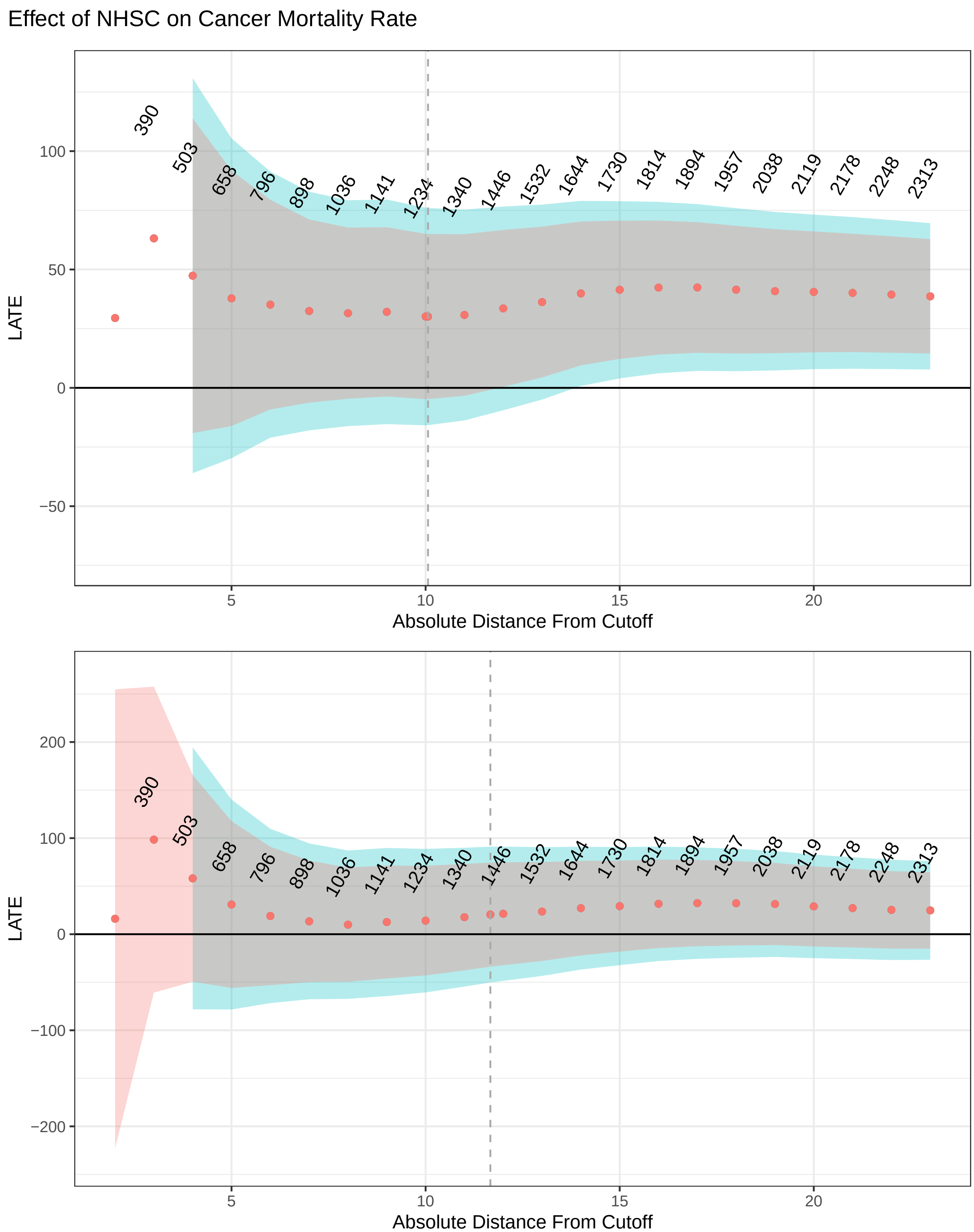
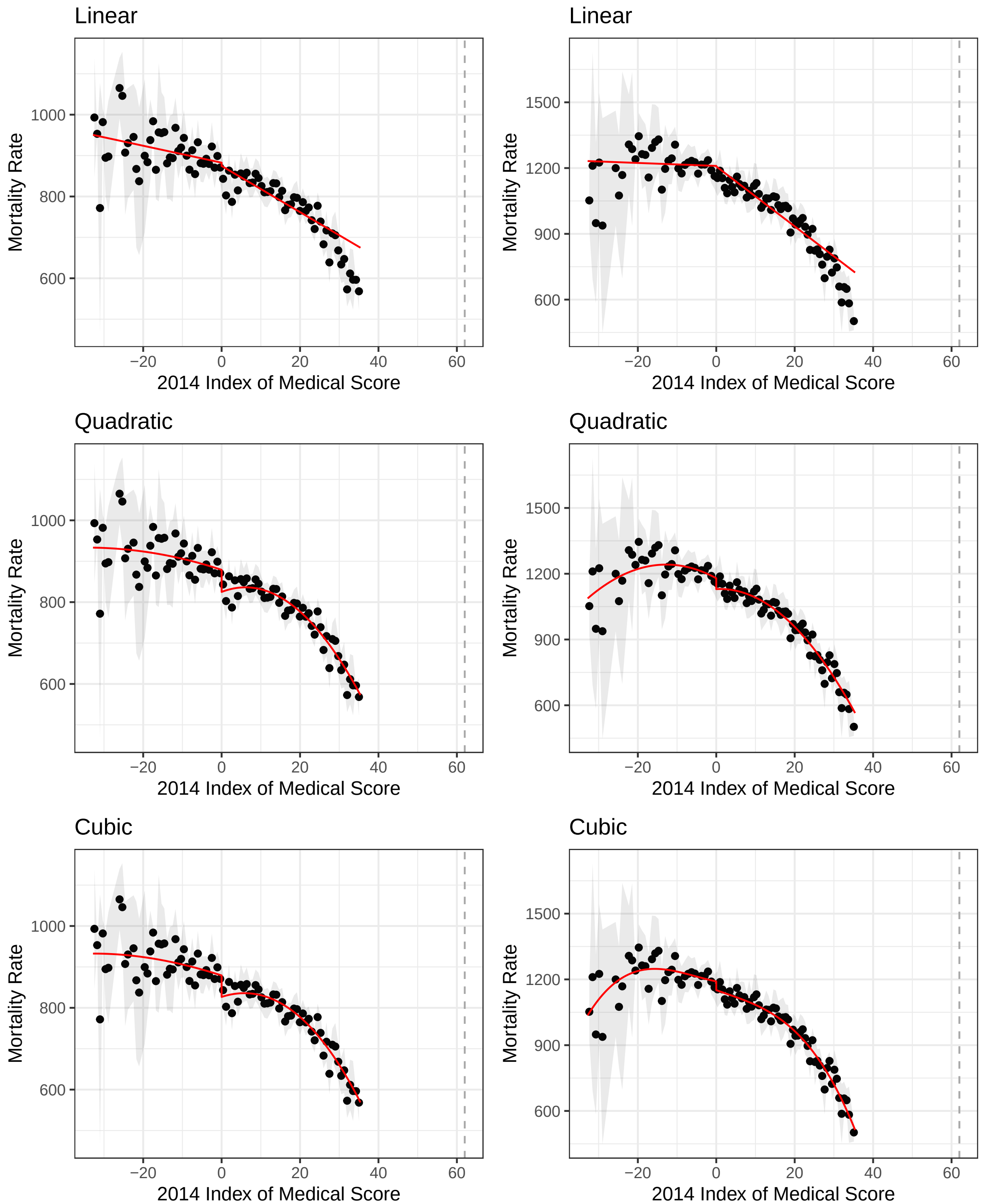


Figure 4: Age-standardized (top) and crude (bottom) effect estimates for cancer mortality are robust against choice of bandwidth. LATE is estimated as a local fuzzy RDD with a triangular kernel and second-order polynomial. Dashed line indicates IK bandwidth, numbers reflect number of observations within a given bandwidth, blue ribbon represents robust 95% CI, and dark ribbon represents bias-corrected 95% CI

Supplementary Material and Sensitivity Analyses

FRDD Specifications



Lines represent predicted mortality rate for binned observations, and grey ribbons show 95% confidence intervals

Figure 5: Age-Standardized (Left) and Crude (Right) All Cause Mortality FRDD Fits

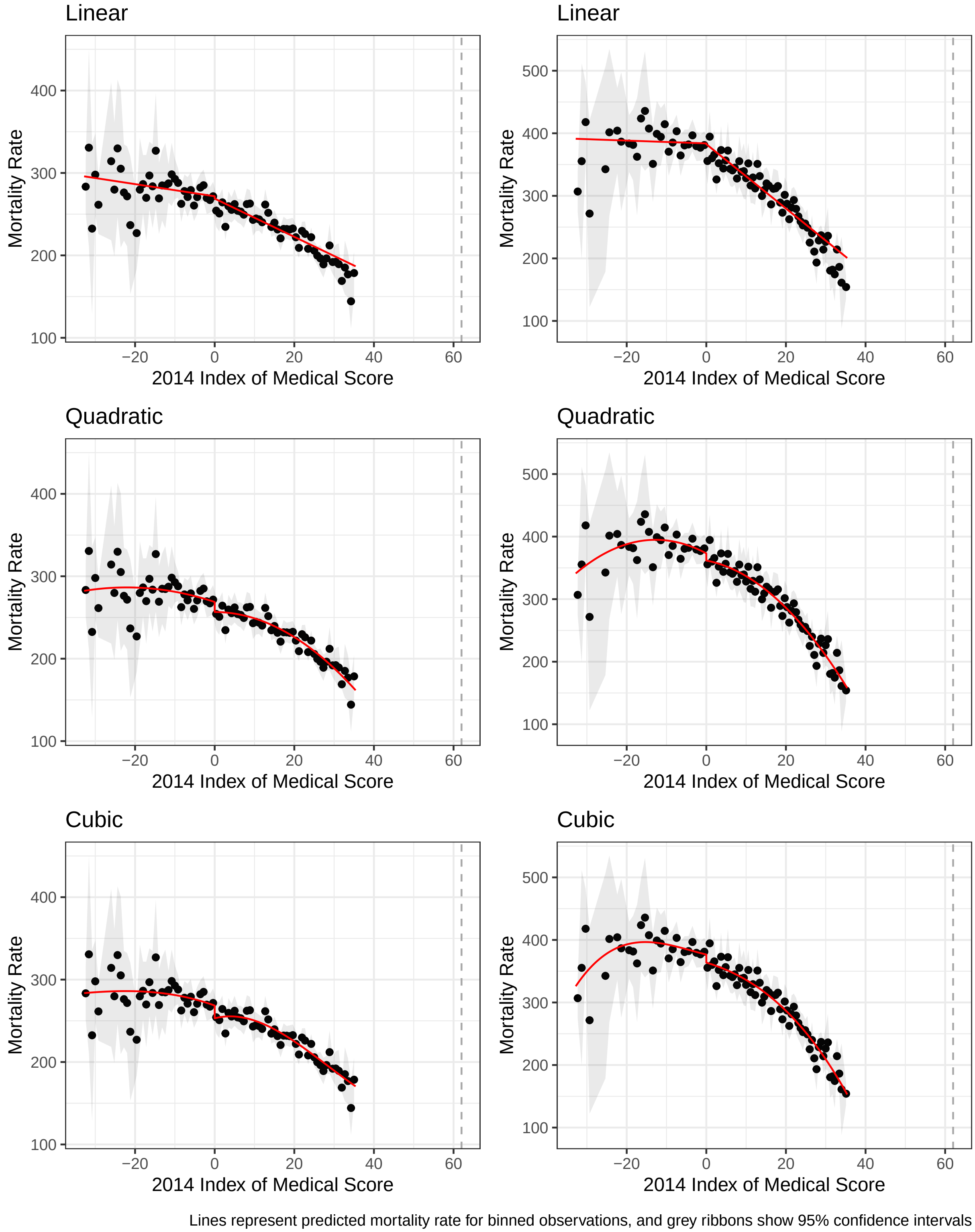


Figure 6: Age-Standardized (Left) and Crude (Right) Heart Disease Mortality FRDD Fits

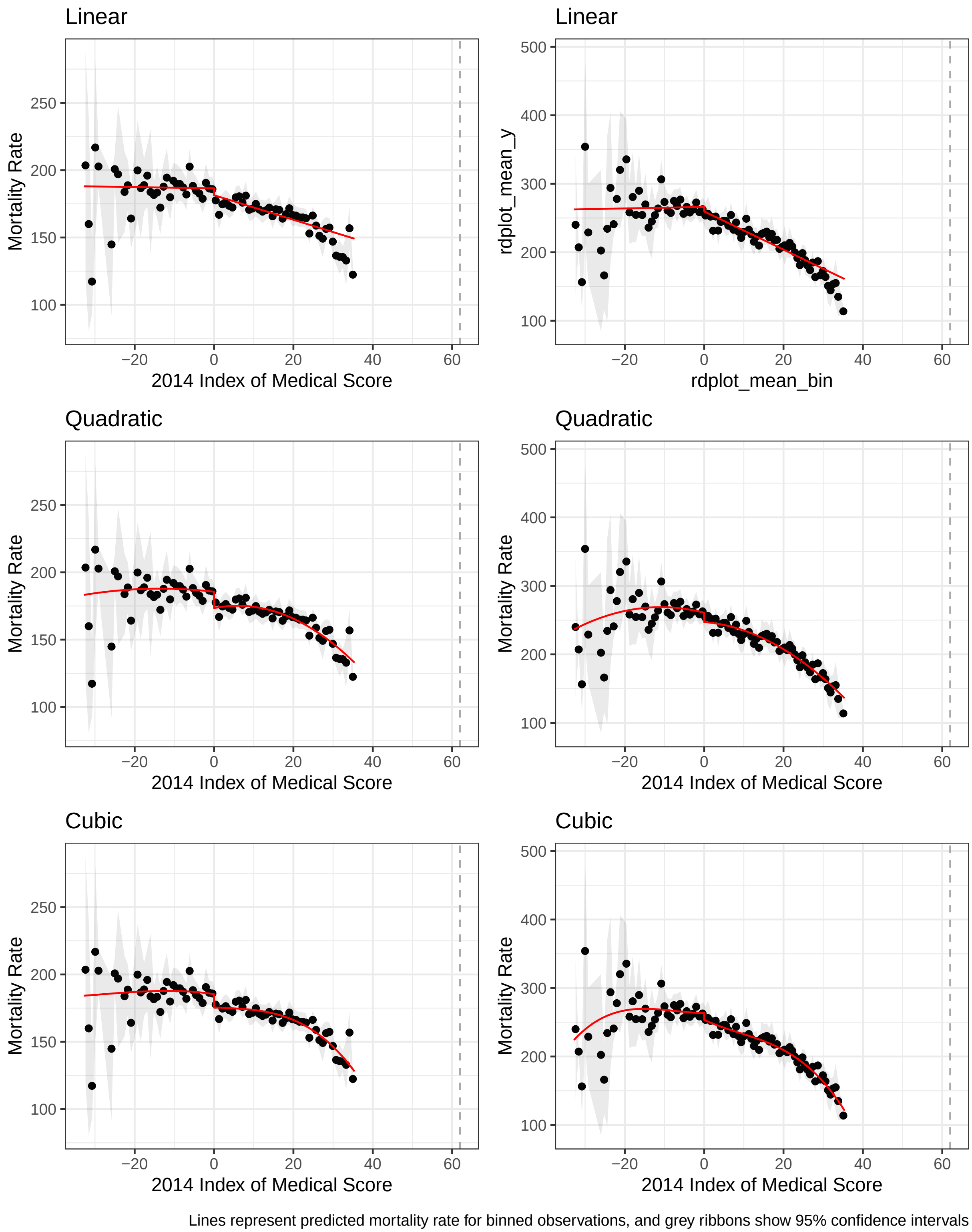


Figure 7: Age-Standardized (Left) and Crude (Right) Cancer Mortality FRDD Fits

Table 4: Placebo Effects of NHSC Participation

Outcome	Estimate	Robust
Median HH Income	-3333.39	-9933.05 - 3266.28
Unemployment	-0.01	-0.03 - 0.01
High School Graduation	0.00	-0.09 - 0.09
Uninsured	0.04	-0.01 - 0.08
Adult Obesity	0.01	-0.03 - 0.05
Smoking	0.06	-0.02 - 0.13
Physical Inactivity	0.02	-0.02 - 0.06
Percent White	-0.09	-0.28 - 0.1
Percent Black	0.05	-0.08 - 0.18
Percent Hispanic	0.05	-0.1 - 0.21
Percent Rural	-0.03	-0.27 - 0.2
1999 All Cause Mortality	119.04	**5.29 - 232.8**
2004 All Cause Mortality	41.44	-92.28 - 175.15
2009 All Cause Mortality	89.28	-37.14 - 215.69
1999 Heart Disease Mortality	29.42	-36.77 - 95.61
2004 Heart Disease Mortality	16.81	-45.45 - 79.07
2009 Heart Disease Mortality	-3.20	-65.86 - 59.46
1999 Cancer Mortality	32.86	-0.97 - 66.7
2004 Cancer Mortality	5.20	-36.35 - 46.74
2009 Cancer Mortality	89.28	**10.23 - 85.08**

Note:
Estimates represent tau FRD using a local regression with a triangular kernel
[a] Bold face denotes statistical significance ($p < 0.05$)
[a] All Cause Mortality is Age-Standardized

Placebo Tests : Balance on Covariates

Placebo Tests: Using Alternate Cutoffs