

Regression Discontinuity Design

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Regression discontinuity designs in healthcare research

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Research

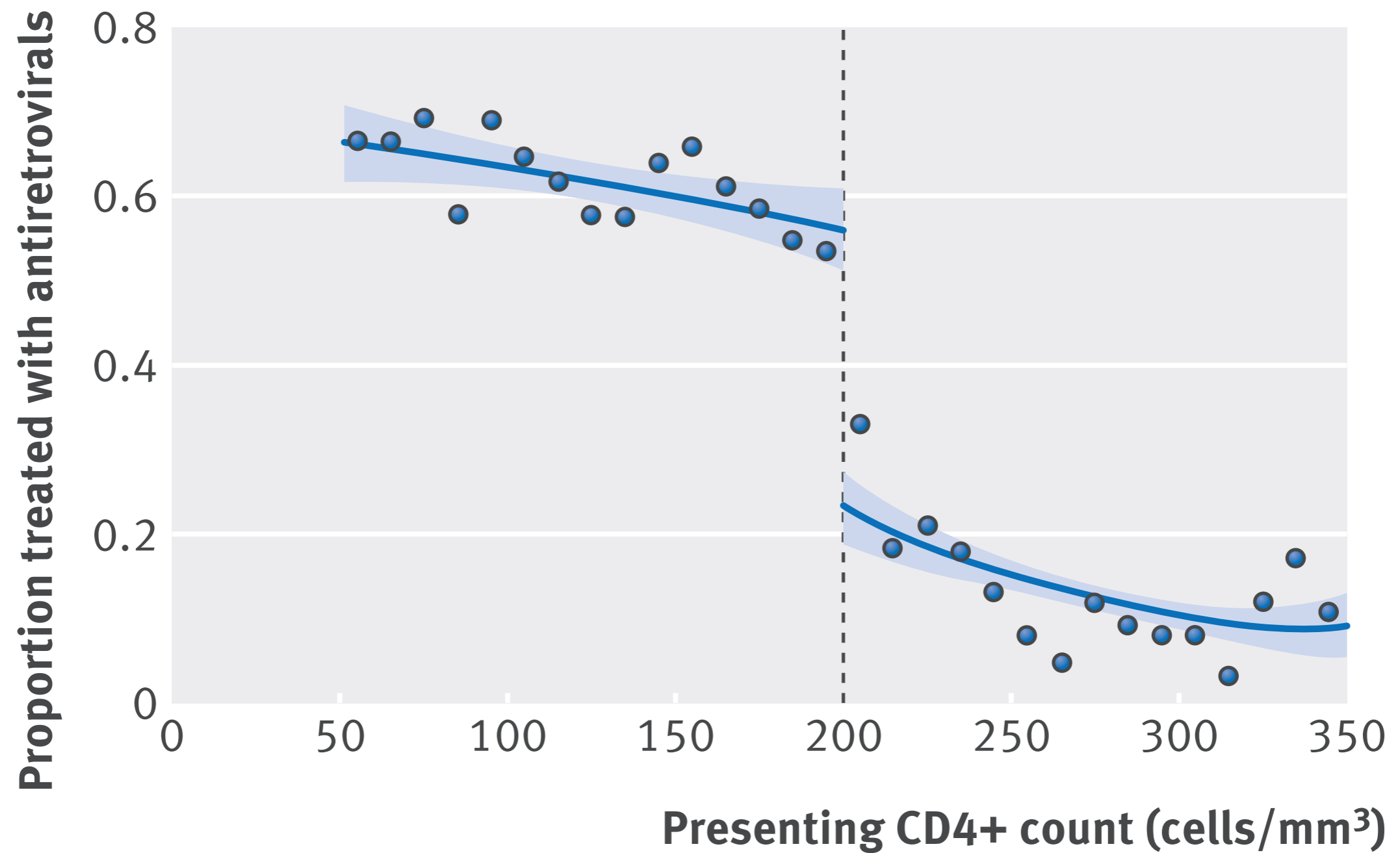
JAMA Internal Medicine | [Original Investigation](#) | HEALTH CARE REFORM

Changes in Racial and Ethnic Disparities in Access to Care and Health Among US Adults at Age 65 Years

Jacob Wallace, PhD; Karen Jiang, BA; Paul Goldsmith-Pinkham, PhD; Zirui Song, MD, PhD

Regression discontinuity design (RDD)

- A statistical approach that utilizes threshold based decision making to derive compelling causal estimates of different interventions
- Quasi-experimental method
- Takes advantage of clinical or policy decision rules in which people are differentially assigned to a treatment or intervention if they fall above or below an arbitrary cut-off for a continuous variable

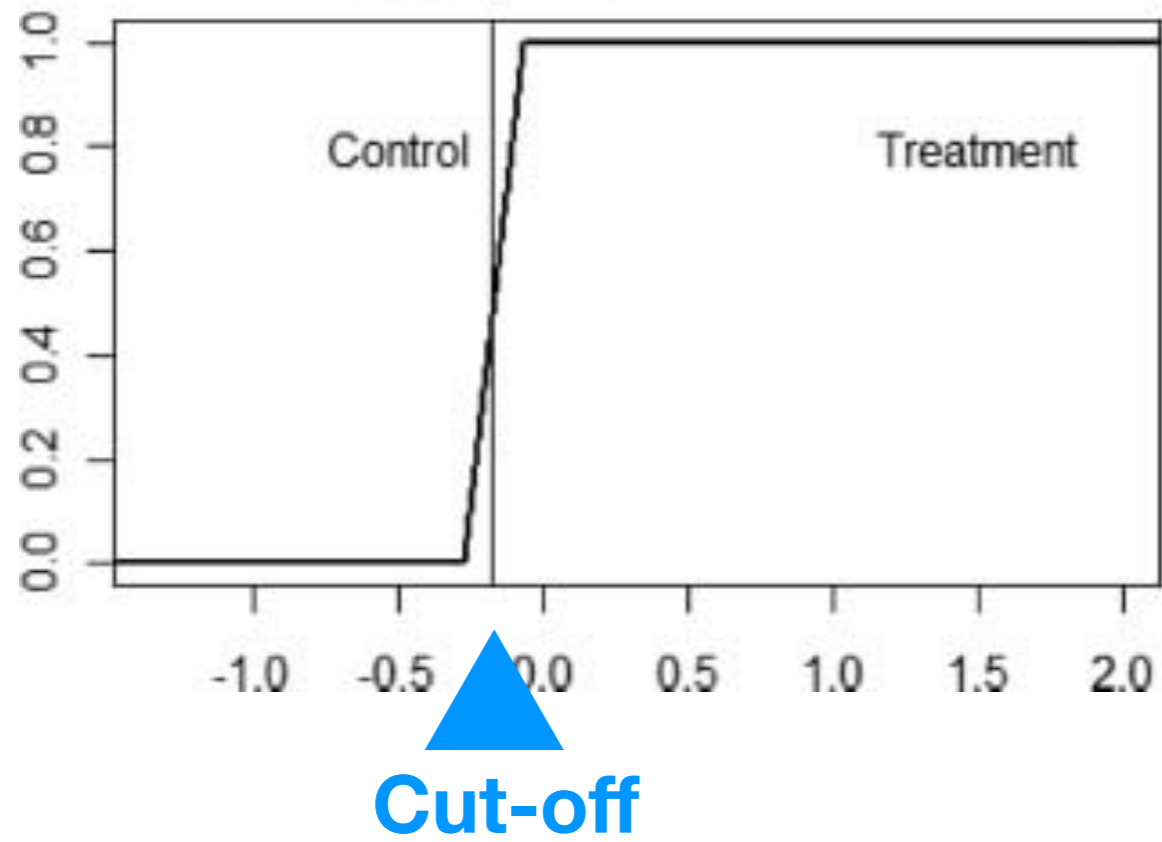


Initiation of **ARV treatment** in HIV patients
at **CD4 200 cells/mm³**

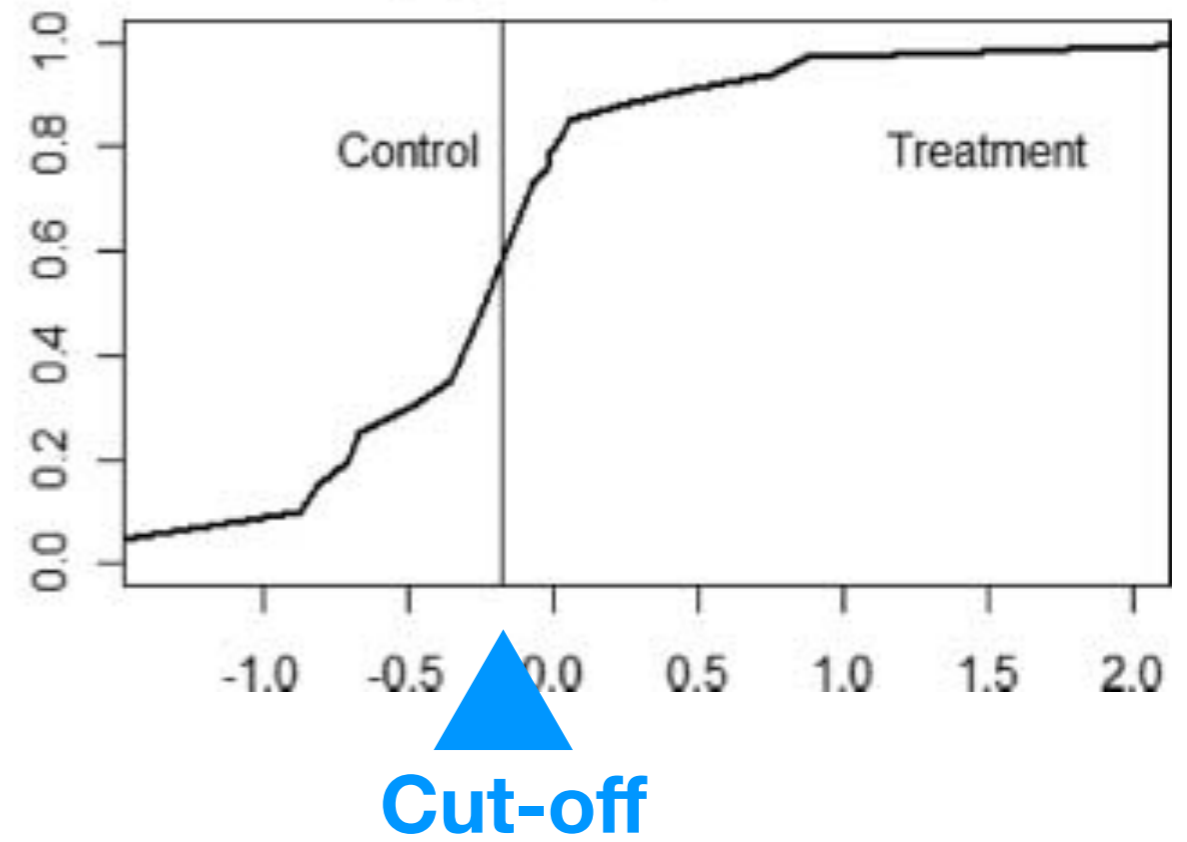
Treatment assignment and analysis

- Assignment to treatment by an arbitrary cutoff can be 'sharp' or 'fuzzy'
- **Sharp RD**
 - The probability of receiving treatment jumps deterministically from 0 to 1 at the cutoff
 - Treatment effect is estimated by comparing outcomes for those 'just above' the cutoff to those 'just below' it
- **Fuzzy RD**
 - The probability of treatment increases at the cutoff but is not deterministic
 - Allow crossover into or out of treatment
 - Comparison captures the effect of assignment to treatment by the threshold rule
 - Estimate effect of treatment by instrument variable method

(a) Sharp RD



(b) Fuzzy RD



Strengths

- Provide **transparent** method to estimate causal effects of treatments or policies, when RCT are not possible
- Non-random attrition and crossover
- Reflect '**real-world**' effects, incorporate important behavioral phenomena such as poor adherence and loss to follow up

Limitations

- External validity – estimates are only interpretable as causal effects for those **near the specific cutoff** interest
- May be threaten by **non-random manipulation** around the treatment cutoff
- Require **large datasets** to generate precise estimates

Examples of RD studies

Table 1 | Examples of regression discontinuity designs in clinical, prevention and public health, and health policy studies

Studies	Exposures	Type of assignment variables	Threshold rules	Outcomes
Clinical:				
Bor et al 2014, 2015 ⁷¹⁶	HIV antiretroviral therapy	Therapeutic	Patients with CD4 counts <200 cells/mm ³ eligible to initiate early antiretroviral treatment in South Africa	Mortality, immune recovery, retention in clinical care
Almond et al 2010 ¹³	Neonatal intensive care	Therapeutic	Infants with birth weights <1500 g (designated very low birth weight) recommended for intensive care in United States	Infant mortality
Bharadwaj et al 2013 ¹⁴	Neonatal intensive care	Therapeutic	Infants with birth weights <1500 g (designated very low birth weight) recommended for intensive care in Chile and Norway	Child cognitive development, academic achievement
Geneletti et al 2015 ¹⁵	Statins	Therapeutic	10 year cardiovascular risk >20% as a guideline to initiate statins	Low density lipoprotein cholesterol
Jensen and Wust 2015 ¹⁹	Caesarean section	Calendar time	Changes in information and guidelines about efficacy of caesarean section starting 21 October 2000 in Denmark	Apgar score, physician visits, hospital admissions for neonates
Prevention and public health:				
Smith et al 2015 ²⁰	HPV vaccine	Calendar time	Vaccines were available for select age groups after 1 January 1994	Cervical dysplasia and anogenital warts
Callaghan 2013 ²¹	Minimum drinking age	Age	Adults aged 21 or older can legally purchase and consume alcohol in United States	Mortality
Ludwig and Miller 2007 ²²	Head Start program	Program eligibility	Counties ranked <300 based on historic poverty rates were eligible to receive federal Head Start	Child mortality
Chen et al 2013 ²³	Air pollution	Geographic	Households north of China's Huai River received subsidies for high emission coal to heat homes	Mortality
Health policy:				
De La Mata et al 2012 ²⁴	Health insurance	Program eligibility	People in households below a specific income threshold were eligible for Medicaid	Healthcare utilization among children
Wherry et al 2015 ²⁵	Health insurance	Calendar time	People born after 1 October 1983 were eligible for more years of Medicaid coverage owing to rule changes	Hospital admissions among adolescents
Sood et al 2014 ²⁶	Health insurance	Geographic	People living in predesignated districts were eligible to receive insurance, whereas those in neighboring districts were not	Mortality
Almond et al 2011 ²⁷	Length of hospital stay	Clock time	Patients admitted after 12 am were allowed longer hospital stays based on insurance rules	Maternal and newborn health

Clinical research

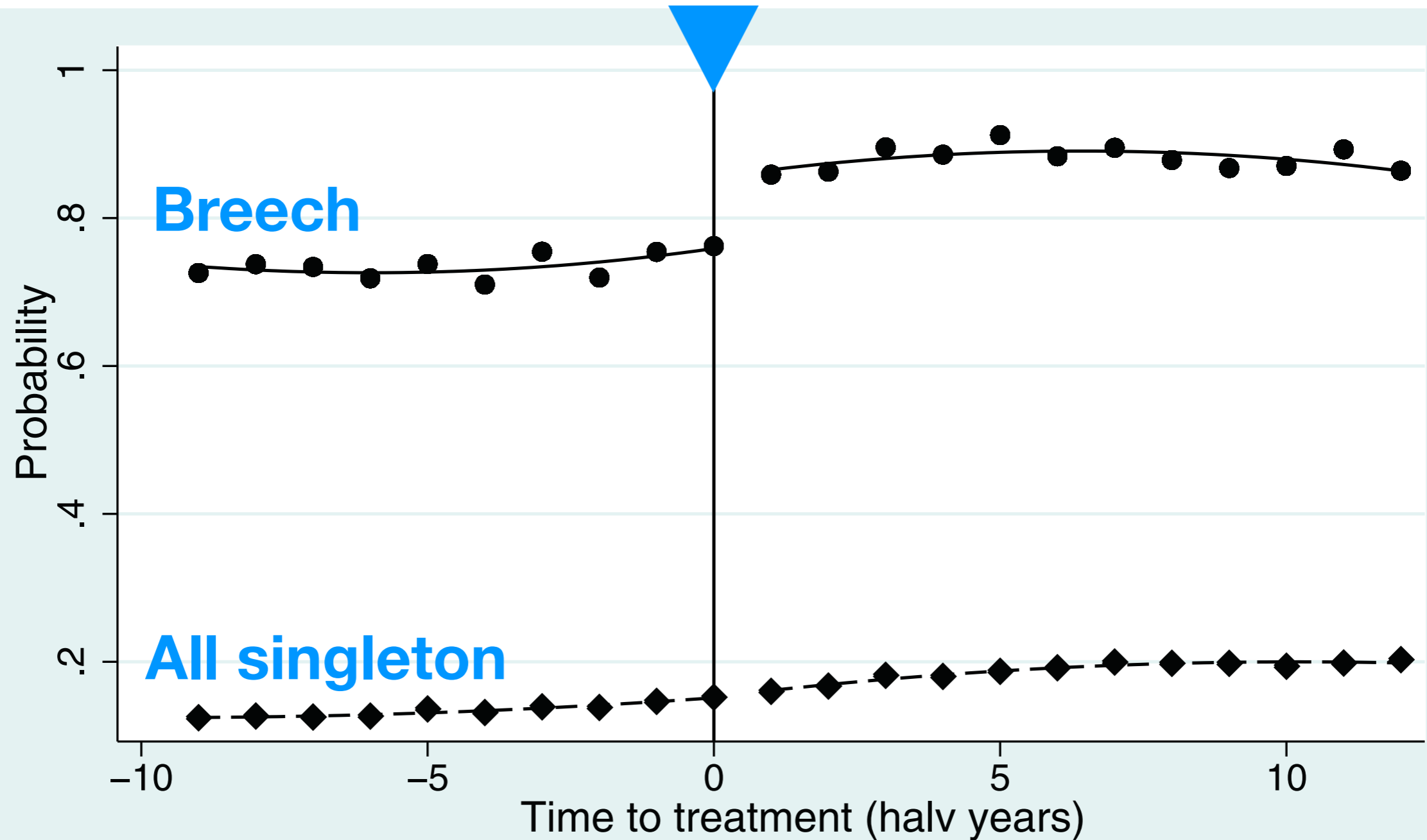
Health outcome of infants born just before and just after a announcement the result from clinical trial in Denmark

"Caesarean section conferred better health outcome than vagina delivery for term breech infants"



Caesarean rates increased markedly after announcement of the trial & **higher apgar scores** and **lower rates of hospitalization** in the first year of life than those born just before the announcement

Trial announcement



--- Fitted values



Probability CS, all singletons



Fitted values

--- Fitted values



Fitted values



Probability CS, breeches

Prevention and public health

Geographic boundaries: Impact of air pollution on health
using data from China

Variation in pollution generated by a national policy
"Provided free coal based winter heating for
those living in north of Huai River"



Statistically **higher levels of pollution** just north of the river
vs just south & **life expectancies were 5.5 years lower**
in north of the river

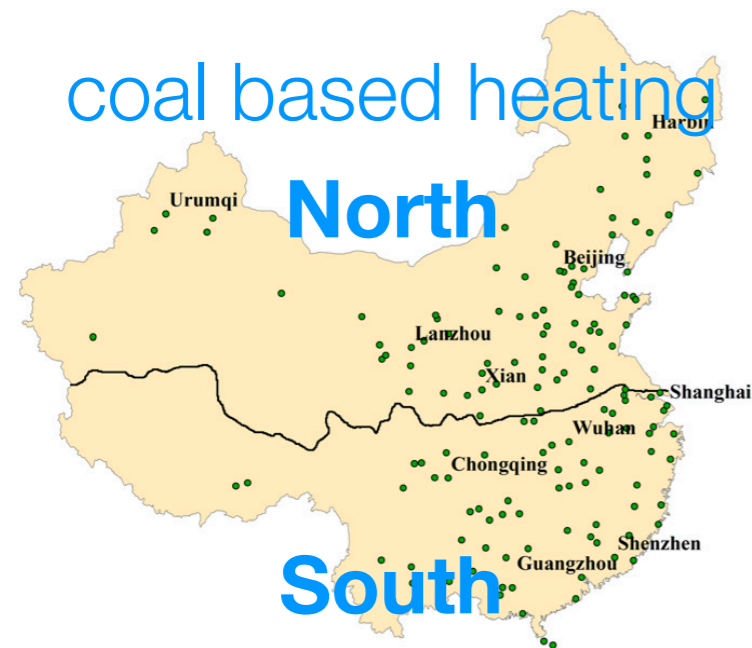
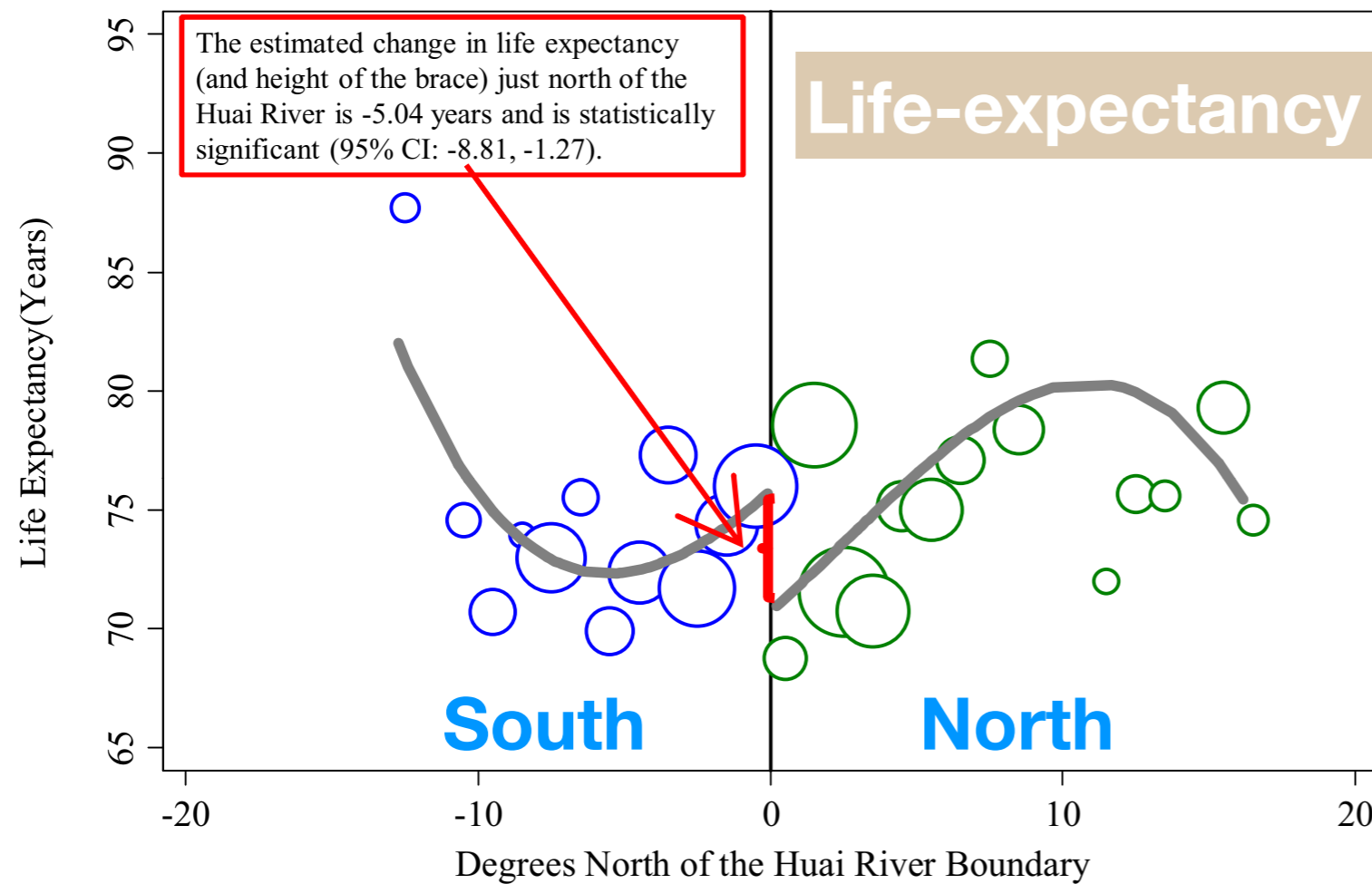
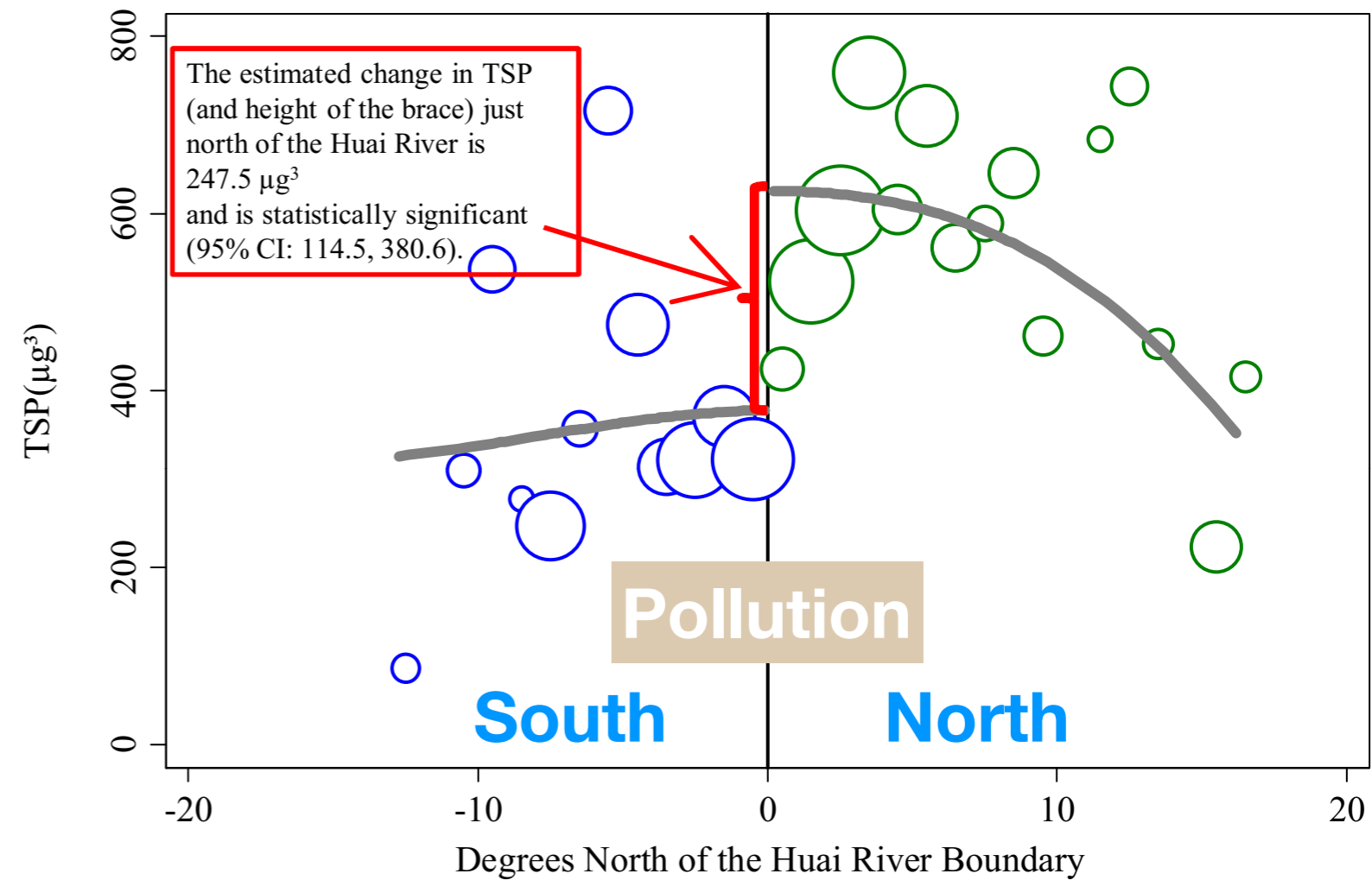


Fig. 1. The cities shown are the locations of the Disease Surveillance Points. Cities north of the solid line were covered by the home heating policy.



Health policy research

Research

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Changes in Racial and Ethnic Disparities in Access to Care and Health Among US Adults at Age 65 Years

Jacob Wallace, PhD; Karen Jiang, BA; Paul Goldsmith-Pinkham, PhD; Zirui Song, MD, PhD

- **Research question:** Is Medicare eligibility associated with reductions in racial and ethnic disparities in access to care and health? (in US)
- Using "natural experiment"
 - Eligibility for Medicare at age 65 yrs
 - Using RDD comparing individuals just before and after age 65
 - Estimate effect sizes for the associations between **Medicare eligibility** with **coverage**, **access to care**, and **health** by race and ethnicity and state

Behavioral Risk Factor Surveillance
System

BRFSS

- Annual health survey across 50 states
- Estimates of Medicare's effects at age 65 yrs at the national and state levels

The Wide-Ranging Online Data
for Epidemiologic Research

WONDER

- Cause of death from US death certificates

Eligibility

- US citizens
- Age 51 – 79 yrs
- From 2008 – 2018
- 50 States and Washington DC
- Removed observations with missing values

Outcomes

- Insurance coverage
- Access to care
 - Access to regular source of care
 - Cost-related barriers to seeing a physician during the past year
 - Receiving influenza vaccine during the past year
- Self-reported health and mortality
 - **BRFSS**: being in poor/fair/good or better health
 - **WONDER**: all-cause mortality

Results

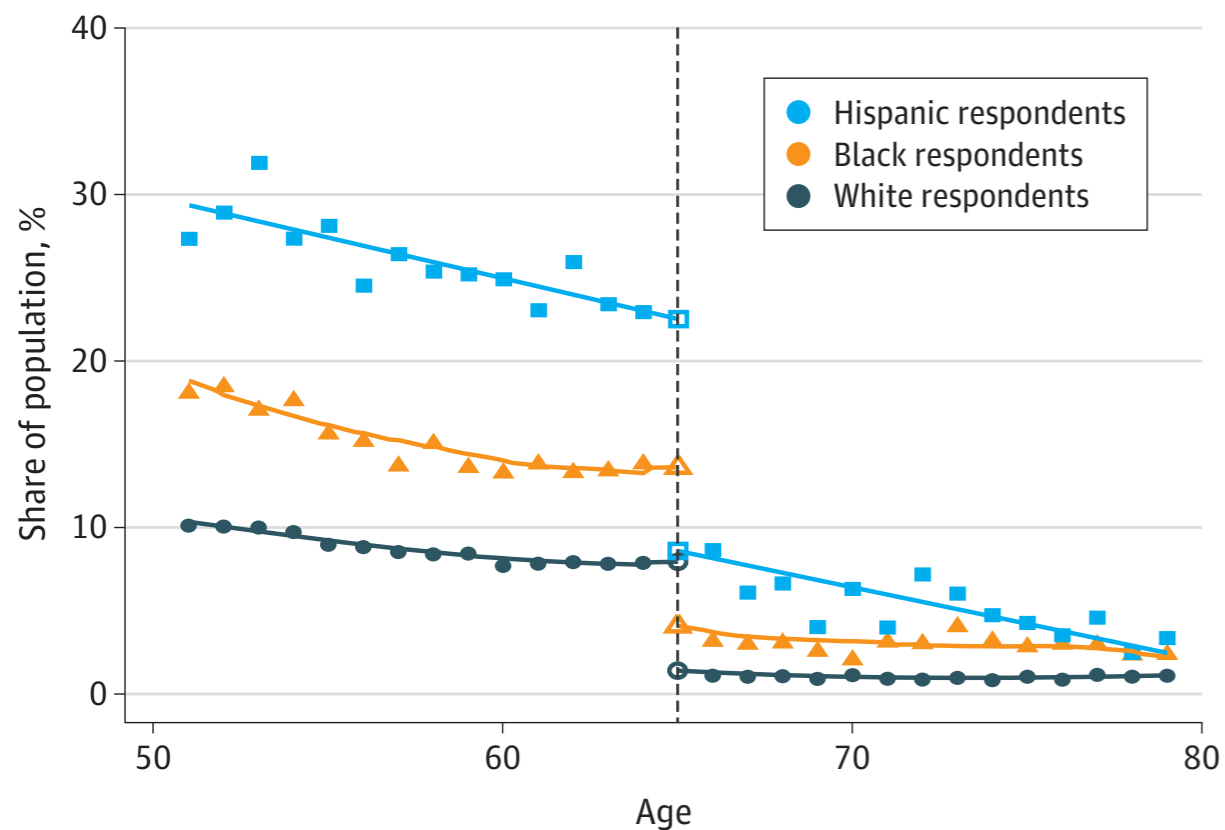
Table 1. Characteristics of the Study Population

Characteristic	Sample means, No. (%) ^a		Change at age 65 years	
	Age, 51-64 y	Age, 65-79 y	Expected mean, % ^b	Adjusted discontinuity, pp (95% CI) ^c
Race				
Black	115 779 (12)	76 567 (9)	10.1	0.5 (−0.2 to 1.2)
Hispanic	66 748 (11)	37 546 (8)	9.3	−0.2 (−1.0 to 0.6)
White	1 137 239 (77)	1 000 441 (83)	80.6	−0.3 (−1.3 to 0.7)
Women	820 598 (56)	721 545 (60)	57.0	0.7 (0.1 to 1.3)
Men	499 168 (44)	393 009 (40)	43.0	−0.7 (−1.3 to −0.1)
Married	804 334 (65)	602 405 (61)	65.9	−0.7 (−1.5 to 0.0)
Employed	813 908 (62)	210 094 (18)	35.0	−2.8 (−4.6 to −1.1)
Education				
Less than high school	82 165 (11)	94 521 (14)	10.9	0.3 (−0.2 to 1.0)
High school	369 632 (28)	351 306 (31)	27.2	0.8 (0.3 to 1.3)
Some college	369 447 (30)	291 358 (29)	31.4	−0.6 (−1.1 to −0.2)
College graduate	495 160 (30)	374 196 (26)	29.9	0.0 (−0.6 to 0.7)
Income, \$				
<10 000	56 826 (5)	34 326 (3)	3.2	0.3 (−0.1 to 0.8)
10 000-24 999	214 648 (16)	251 030 (22)	18.4	0.0 (−0.4 to 0.5)
25 000-49 999	274 724 (20)	296 758 (26)	24.6	−0.8 (−1.6 to 0.1)
50 000-74 999	207 894 (15)	144 777 (13)	15.4	−0.0 (−0.4 to 0.3)
>75 000	412 265 (33)	190 585 (18)	23.7	−0.4 (−1.3 to 0.5)

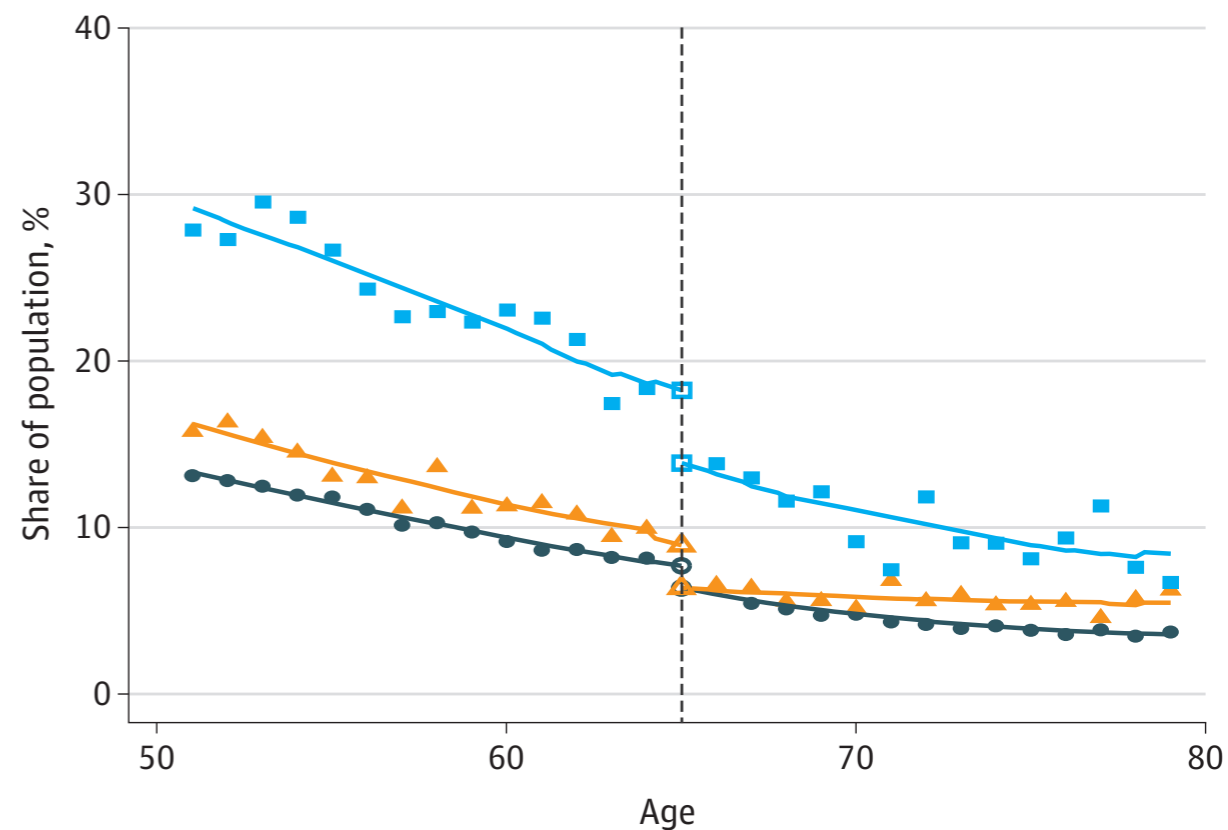
2 434 320
respondents

44 587
state-age-year
observations

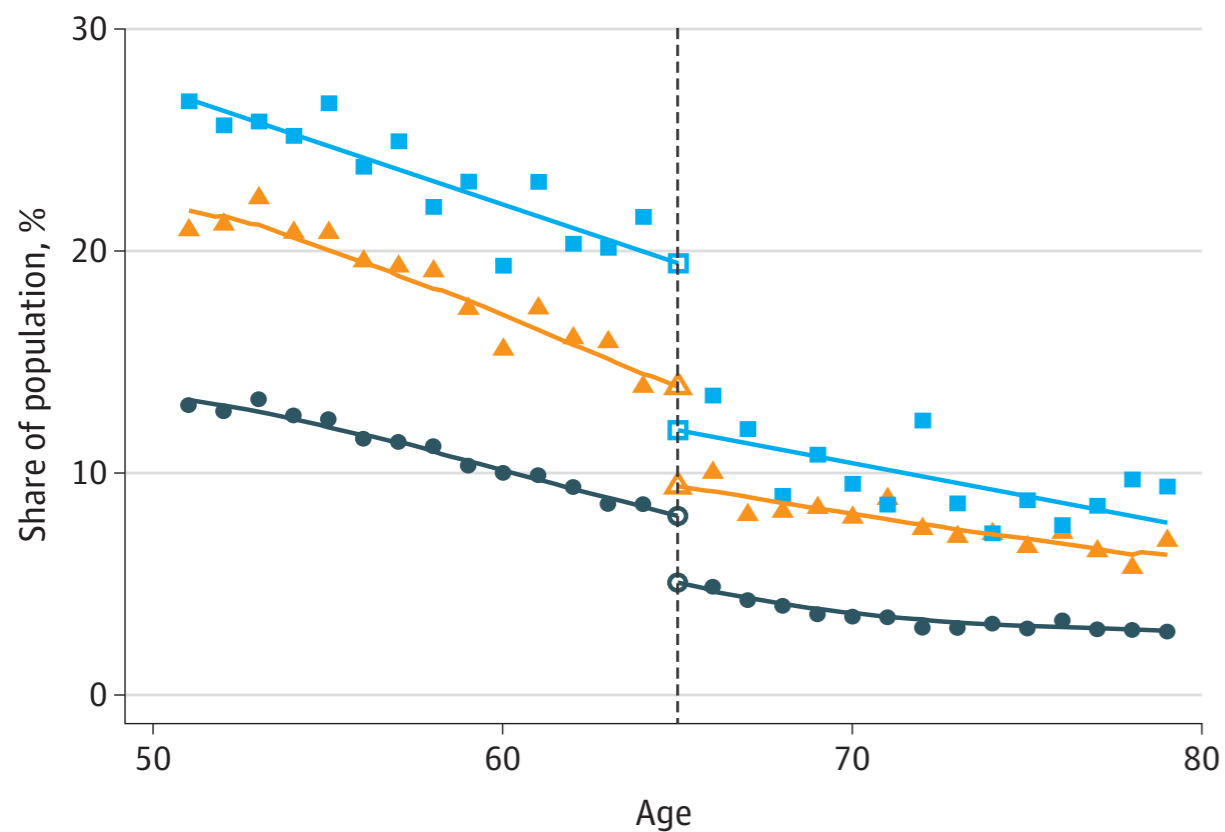
A Share uninsured



B Share without a usual source of care



C Share unable to see physician in the past year due to cost



D Share in poor self-reported health

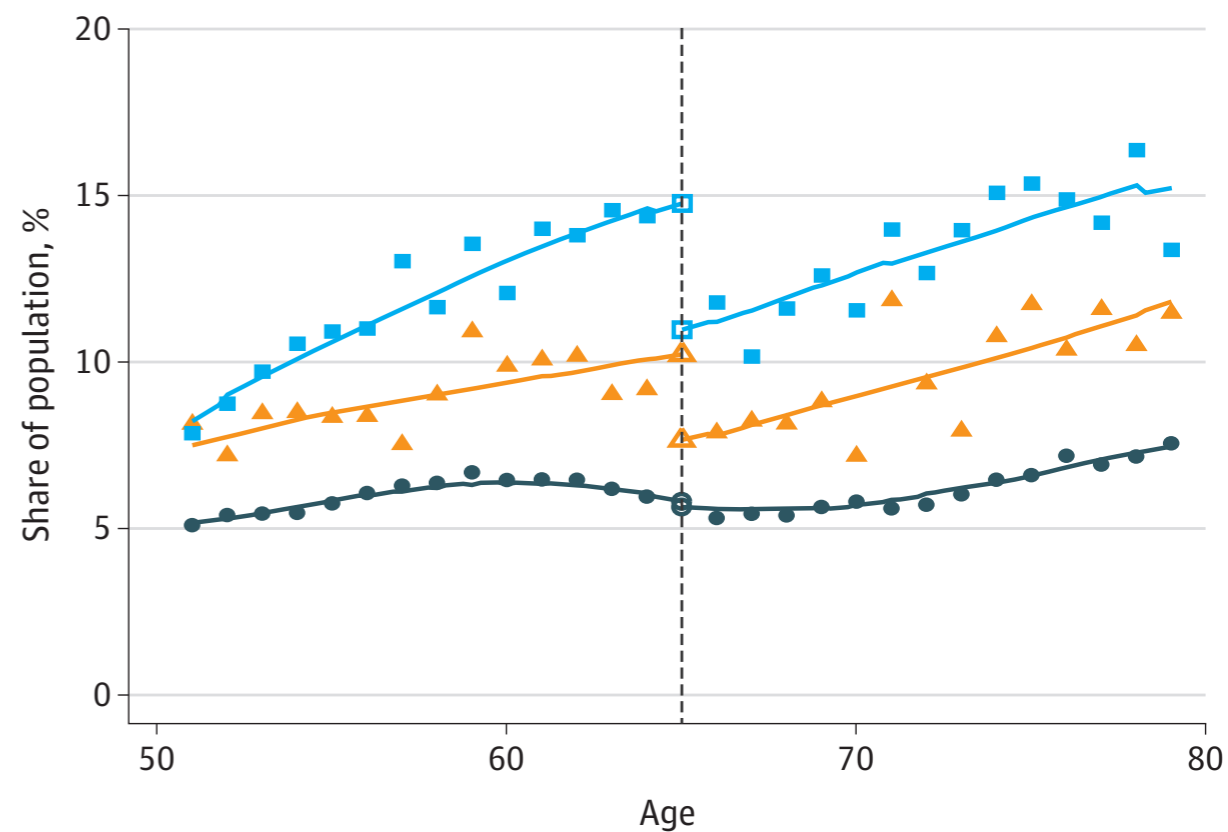


Table 2. Medicare Eligibility Age-Related Discontinuities in Racial and Ethnic Disparities in Coverage, Access, and Health

Characteristic	White individuals		Black individuals		Hispanic individuals		Disparity					
							White and Black individuals			White and Hispanic individuals		
	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	Expected disparity ^c	Adjusted discontinuity in disparity (95% CI) ^b	P value ^d	Expected disparity ^c	Adjusted discontinuity in disparity (95% CI) ^b	P value ^d
Insurance coverage, %	92.0	6.5 (6.1 to 7.0)	86.3	9.5 (7.6 to 11.4)	77.4	13.9 (12.0 to 15.8)	5.7	−3.0 (−5.1 to −0.9)	.003 (.01)	14.6	−7.4 (−9.5 to −5.3)	<.001 (<.001)
Health care access, %												
Have a usual source of care	92.2	1.3 (0.8 to 1.8)	91.0	2.5 (0.8 to 4.3)	81.7	4.4 (1.5 to 7.2)	1.2	−1.2 (−3.2 to 0.7)	.24 (.38)	10.5	−3.0 (−6.1 to 0.0)	.05 (.09)
Unable to see physician in past year because of cost	8.1	−3.0 (−3.5 to −2.5)	13.9	−4.5 (−6.6 to −2.4)	19.5	−7.5 (−9.4 to −5.6)	−5.8	1.5 (−0.8 to 3.8)	.22 (.38)	−11.4	4.5 (2.4 to 6.7)	<.001 (<.001)
Received an influenza vaccination in past year	53.5	2.2 (1.3 to 3.0)	42.5	2.8 (0.8 to 4.9)	45.4	7.0 (3.7 to 10.3)	11.0	−0.7 (−3.1 to 1.7)	.60 (.78)	8.1	−4.8 (−8.4 to −1.3)	.007 (.01)
Health												
Self-reported health, %												
Poor	5.8	−0.2 (−0.7 to 0.3)	10.3	−2.6 (−4.0 to −1.2)	14.8	−3.8 (−6.1 to −1.4)	−4.4	2.4 (0.8 to 4.0)	.002 (.01)	−8.9	3.6 (1.1 to 6.1)	.004 (.01)
Fair	13.6	−0.8 (−1.3 to −0.3)	25.0	−0.3 (−2.3 to 1.6)	31.1	0.2 (−2.8 to 3.2)	−11.3	−0.5 (−2.6 to 1.7)	.69 (.78)	−17.5	−1.0 (−4.1 to 2.2)	.57 (.65)
Good or better	80.7	0.9 (0.2 to 1.7)	64.7	2.8 (0.3 to 5.2)	53.9	3.1 (−0.6 to 6.8)	15.9	−1.8 (−4.5 to 0.9)	.20 (.38)	26.8	−2.1 (−6.1 to 1.8)	.30 (.40)
Mortality rate, per 100 000 ^e	1261.1	−11.3 (−43.7 to 21.1)	1902.6	−7.0 (−61.8 to 47.9)	1032.4	−9.3 (−61.9 to 43.4)	−641.5	−4.3 (−77.2 to 68.5)	.95 (.95)	228.7	−2.0 (−72.6 to 68.5)	.97 (.97)

^a Columns present the expected mean at age 65 years, the age eligibility threshold for Medicare, which is based on the local linear association between age and the outcome. The expected means contain the counterfactual outcome at age 65 years in the absence of the treatment (ie, the expected outcome at age 65 years without Medicare).

^b Adjusted discontinuity estimates are in percentage points.

^c Column presents the expected disparity at age 65 years, the age eligibility threshold for Medicare, which is based on the local linear association between age and the outcomes for non-White and White populations. The

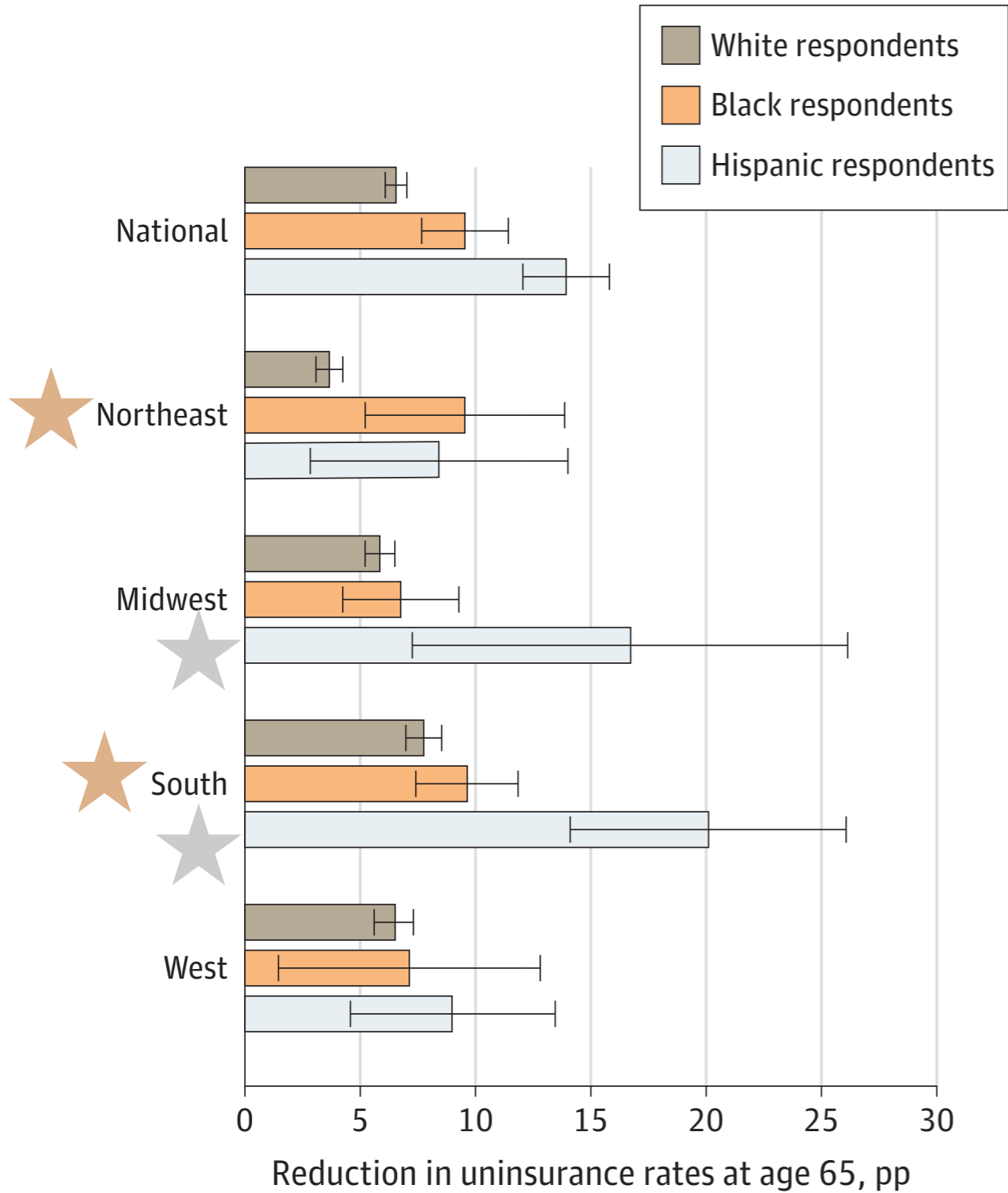
expected disparity subtracts the expected mean for non-White populations from the expected mean for White populations at age 65 years.

^d Benjamini-Hochberg-corrected *P* values are presented in parentheses.

^e Mortality data are from the US Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiologic Research system. All other data are from the Behavioral Risk Factor Surveillance System. Because these data are deidentified, they could not be linked.

Characteristic	White individuals		Black individuals		Hispanic individuals		Disparity					
	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	White and Black individuals			White and Hispanic individuals		
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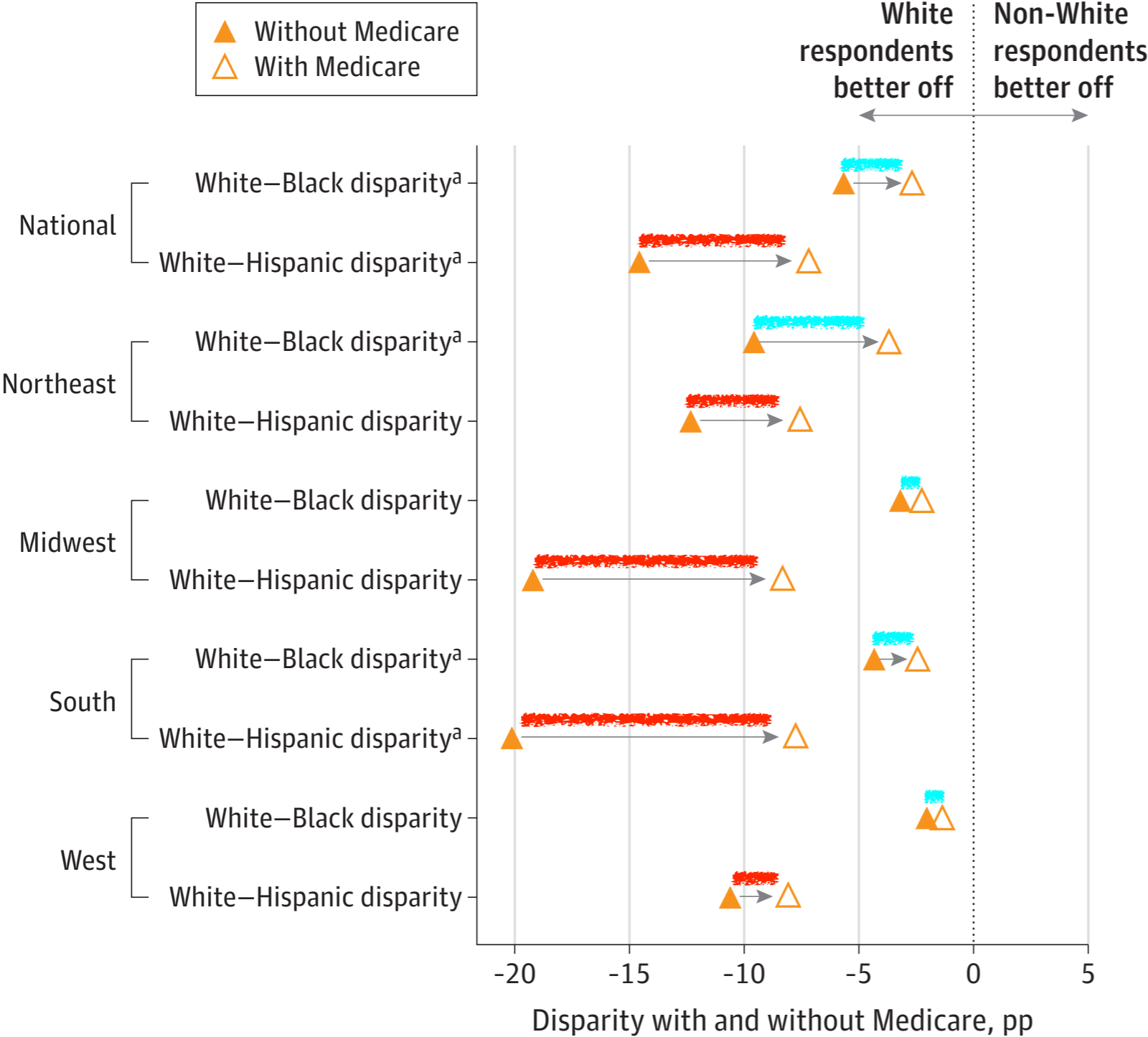
A Reduction in uninsurance rates at age 65



Sensitivity analysis
 Reduction in uninsurance rates by region

Characteristic	White individuals		Black individuals		Hispanic individuals		Disparity					
	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	Expected mean ^a	Adjusted discontinuity (95% CI) ^b	White and Black individuals			White and Hispanic individuals		
							Expected disparity ^c	Adjusted discontinuity in disparity (95% CI) ^b	P value ^d	Expected disparity ^c	Adjusted discontinuity in disparity (95% CI) ^b	P value ^d
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B Disparity with and without Medicare



Sensitivity analysis
 Disparity with and without Medicare by regions

Conclusion

- Eligibility for Medicare at age 65 yrs was associated with
 - Reductions in racial and ethnic disparities in coverage, access, and health, but not mortality
 - Reduction in racial and ethnic disparities in economically, politically, and geographically diverse states

Regression discontinuity designs in healthcare research

Atheendar S Venkataramani,¹ Jacob Bor,² Anupam B Jena³

Future opportunities

- Clinical area that are active controversies around a specific clinical guideline or little evidence of the real world effects of a particular treatment
 - Blood pressure targets for some specific populations
 - Cardiac resynchronization treatment

Table 2 Potential clinical questions that can be addressed by regression discontinuity designs and proposed approach		
Clinical questions	Threshold rules	Outcomes
What are optimal blood pressure goals for specific subpopulations, such as adults with diabetes?	Compare outcomes for people above and below systolic and diastolic blood pressure for different guideline based thresholds (which have changed over time)	Cardiovascular events, mortality
What is the optimal fluid resuscitation strategy in patients with sepsis?	Compare outcomes across different central venous pressure thresholds (which may vary across time, institutions)	Length of stay on intensive care unit stay, mortality
Are steroids appropriate in patients with alcoholic hepatitis and infections?	Compare outcomes for patients with both alcoholic hepatitis and infections just above and just below the Maddrey discriminant cut-off of 32 (above which steroids are indicated)	Mortality
Is liberal or conservative transfusion more appropriate in acute coronary syndromes?	Compare outcomes across different transfusion thresholds (such as hemoglobin <8 mg/L), which may vary across institutions and over time	Length of stay, mortality
What are the real world effects of cardiac resynchronization therapy?	Compare outcomes just above and just below a QRS complex duration of 120 ms (indication for cardiac resynchronization therapy placement)	Hospital admissions for heart failure, quality of life

Conclusion

- **RDD**
 - Applied where clinical trials are not feasible
 - Allows for assessment of real world impact
 - Requires large sample sizes

Q & A

Thank you :)