Supplementary Online Content

This supplementary material has been provided by the authors to give readers additional information about their work.

eMethod 1. Difference-in-Differences Model.

Unadjusted:

$$Age\ Adjusted\ Cardiovascular\ Mortality\ Rate_{ijk}$$
$$= \beta_0 + \beta_1 Expansion\ status_{ijk} + \beta_2 Pre\ vs.\ Post\ Expansion\ period_{ijk}$$
$$+ \beta_3 Expansion\ status \times period\ (DID)_{ijk} + Y_j + u_{0k} + e_{ijk}$$

Adjusted:

$Age\ Adjusted\ Cardiovascular\ Mortality\ Rate_{ijk}$

$= \beta_0 + \beta_1 Expansion\ status_{ijk} + \beta_2 Pre\ vs.\ Post\ Expansion\ period_{ijk}$

$+ \beta_3 Expansion\ status \times period\ (DID)_{ijk}$

$+ \beta_4 Percentage\ of\ county\ residents\ living\ in\ poverty_{ijk}$

$+ \beta_5 Inflation\ adjusted\ Median\ Household\ Income_{ijk}$

$+ \beta_6 Percentage\ of\ county\ residents\ who\ are\ unemployed_{ijk}$

$+ \beta_7 Percentage\ of\ county\ residents\ age\ 45\ to\ 64\ years\ who\ are\ female_{ijk}$

$+ \beta_8 Precentage\ of\ county\ residents\ age\ 45\ to\ 64\ years\ who\ are\ Black_{ijk}$

$+ \beta_9 Precentage\ of\ county\ residents\ age\ 45\ to\ 64\ years\ who\ are\ Hispanic\ _{ijk}$

$+ \beta_{10} Number\ of\ Primary\ Care\ Providers\ per\ 100,000\ residents_{ijk}$

$+ \beta_{11} Number\ of\ Cardiologists\ per\ 100,000\ residents_{ijk}$

$+ \beta_{12} Percentage\ of\ adult\ county\ residents\ with\ diabetes\ in\ 2010_{ik}$

$+ \beta_{13} Percentage\ of\ adult\ county\ residents\ with\ obesity\ in\ 2010_{ik}$

$+ \beta_{14} Percentage\ of\ adult\ county\ residents\ who\ smoke\ in\ 2010_{ik}$

$+ \beta_{15} Precentage\ of\ county\ residents\ age\ 40\ to\ 64\ with\ health\ insurance\ in\ 2010_{ik}$

$+ \beta_{13} County\ Metropolitan\ status_{ik} + Y_j + u_{0k} + e_{ijk}$

For county i in year j in state k. Y denotes the indicator variables for year. u_{0k} denotes the variation of each state intercept from the overall intercept.

An unstructured covariance structure was used when modeling autocorrelation due to longitudinal design as well as state random intercepts.

eMethod 2. Interaction Between Expansion Status and Year

We examined the interaction between expansion status and year for each year separately. The regression coefficients, which are reported in eTable 3, denote the additional change in annual cardiovascular mortality in expansion counties in a given year compared to non-expansion counties in 2010.

eMethod 3. Sensitivity Analyses.

To test the assumption that mortality trends were similar between the two groups prior to expansion, we created regression models for the years 2010-2013 with expansion status, time as a continuous variable, and an interaction term between time trend and expansion status. The regression coefficient for the interaction term indicates whether there is a difference in the slope of the mortality rates, between expansion and non-expansion states in the pre-expansion period. A regression coefficient that is not significantly different than zero suggests that the slope between the two groups of state do not differ over time. We created unadjusted and adjusted (with the covariates mentioned previously) versions of the model. We tested time as both a linear and a quadratic continuous variable. As in the main model, state random intercepts were included and robust standard errors that accounted for clustering at the state level and autocorrelation were used. Results of coefficients from the regression models are shown in eTable 4. The unadjusted model with time as a continuous linear variable is as follows (notation is the same as described in eMethod1):

$$Age\ Adjusted\ Cardiovascular\ Mortality\ Rate_{ijk}$$
$$= \beta_0 + \beta_1 Expansion\ status_{ijk} + \beta_2 time_{ijk}$$
$$+ \beta_3 Expansion\ status \times time_{ijk} + u_{0k} + e_{ijk}$$

We conducted several sensitivity analyses as follows:

1. Using cardiovascular mortality rates for 65-74 year old residents from 2010-2016 as the outcome measure, as this group was not primarily targeted by Medicaid expansion. Adjusted model does not include percentage of residents with health insurance or adult unemployment rate, as individuals 65 years of age and older are assumed to all have health insurance coverage and also represent a smaller share of the overall employed adult population.

2. Using age-adjusted mortality rates for 25-64 year old residents as the outcome measure.

3. Excluding all states that expanded Medicaid before or after January 2014: Alaska, California, Connecticut, District of Columbia, Indiana, Michigan, Minnesota, Montana, New Hampshire, New Jersey, Pennsylvania, and Washington as well as Massachusetts and Wisconsin from the main analysis. Indicator for year was excluded from this model as all expansion states included, expanded in the same year.

4. All 50 states and the District of Columbia were included in the analysis.

5. Excluding 2014 from the analysis as this was the year that a majority of states expanded Medicaid and there could be a possible lag effect as the policy was being implemented.

6. As the primary outcome in the main model – diseases of the circulatory system – is broad, we examined a subset of largely more acute diseases that are more traditionally considered cardiovascular diseases: I20-I25 (Ischemic heart diseases), I26 (Pulmonary embolism), I42 (Cardiomyopathy), I44 (Atrioventricular and left bundle-branch block), I45 (Other conduction disorders), I46 (Cardiac arrest), I47 (Paroxysmal tachycardia), I48 (Atrial fibrillation and flutter), I49 (Other cardiac arrhythmias), I50 (Heart failure), I51.0 (Cardiac septal defect, acquired), I51.1 (Rupture of chordae tendineae, not elsewhere classified), I51.2 (Rupture of papillary muscle, not elsewhere classified), I51.3 (Intracardiac thrombosis, not elsewhere classified), I60-I69 (Cerebrovascular diseases), I71 (Aortic aneurysm and dissection)

7. Outcomes and covariates aggregated at the state rather than county level. This analysis includes individuals who died in counties with fewer than 10 deaths per year and were censored from the county level analysis.

Results of the sensitivity analysis are included in eTable 5.

eTable 1. Percentage of 40-64 Year Old Residents without Health Insurance Coverage

Year	All Income Groups		Income less than 138% of the Federal Poverty Limit	
	Medicaid Expansion States	Medicaid Non-Expansion States	Medicaid Expansion States	Medicaid Non-Expansion States
2010	14.6 (SD = 5.1)	19.5 (SD = 6.0)	35.6 (SD = 8.0)	44.9 (SD = 7.9)
2011	15.0 (SD = 5.0)	20.0 (SD = 6.0)	35.5 (SD = 7.8)	45.3 (SD = 7.7)
2012	15.0 (SD = 5.2)	20.0 (SD = 5.9)	35.2 (SD = 7.8)	44.4 (SD = 7.6)
2013	14.9 (SD = 5.1)	19.9 (SD = 6.0)	34.1 (SD = 7.6)	43.3 (SD = 7.5)
2014	11.1 (SD = 3.9)	16.8 (SD = 5.0)	24.7 (SD = 6.1)	37.1 (SD = 6.5)
2015	8.2 (SD = 2.9)	14.3 (SD = 4.5)	18.1 (SD = 5.2)	32.8 (SD = 6.7)
2016	7.4 (SD = 2.7)	13.9 (SD = 4.5)	16.0 (SD = 4.7)	31.7 (SD = 6.9)

SD = Standard Deviation

eTable 2. Mean Age-Adjusted Cardiovascular Mortality Rates for 45-64 Year Old Residents (Deaths per 100,000 Residents per year) by Year

Year	Unadjusted Model		Adjusted Model [a]	
	Medicaid Expansion States	Medicaid Non-Expansion States	Medicaid Expansion States	Medicaid Non-Expansion States
2010	147.9 (95% CI 134.0, 161.9)	177.6 (95% CI 155.3, 199.9)	190.7 (95% CI 181.5, 200.0)	195.3 (95% CI 184.9, 205.8)
2011	146.4 (95% CI 132.4, 160.4)	174.4 (95% CI 153.0, 195.9)	187.8 (95% CI 178.7, 196.9)	190.8 (95% CI 181.0, 200.7)
2012	145.7 (95% CI 131.7, 159.8)	175.0 (95% CI 153.1, 196.9)	187.7 (95% CI 178.4, 197.0)	192.0 (95% CI 181.9, 202.0)
2013	145.6 (95% CI 131.4, 159.8)	177.8 (95% CI 154.7, 200.8)	188.6 (95% CI 179.5, 197.7)	196.0 (95% CI 184.6, 207.3)
2014	145.4 (95% CI 130.6, 160.1)	180.3 (95% CI 157.5, 203.2)	190.1 (95% CI 180.4, 199.8)	199.8 (95% CI 188.4, 211.1)
2015	145.9 (95% CI 131.2, 160.5)	182.1 (95% CI 158.7, 205.4)	193.6 (95% CI 183.8, 203.5)	204.9 (95% CI 192.8, 216.9)
2016	148.9 (95% CI 133.8, 164.0)	180.5 (95% CI 157.5, 203.4)	199.2 (95% CI 188.6, 209.8)	205.1 (95% CI 193.5, 216.7)

[a] Adjusted for 2013 National Center for Health Statistics (NCHS) Urban-Rural Classification designation (metropolitan vs. non-metropolitan county), percentage of residents living in poverty, percentage of adults unemployed, inflation-adjusted median household income, percentage of 45-64 year old residents who were female, percentage of 45-64 year old residents who were Black, percentage of 45-64 year old residents who were Hispanic, number of primary care providers per 100,000 residents, number of cardiologists per 100,000 residents, and percentage of 40-64 year old residents with income less than 138% of the federal poverty limit with health insurance in 2010.

eTable 3. Interaction Between Expansion Status and Year

Year	Unadjusted Model	Adjusted Model [a]
2010	Reference	Reference
2011	1.6 (95% CI -1.5, 4.7); p = 0.32	1.5 (95% CI -2.0, 5.0); p = 0.39
2012	0.4 (95% CI -2.9, 3.7); p = 0.81	0.3 (95% CI -3.4, 4.1); p = 0.86
2013	-2.5 (95% CI -5.4, 0.4); p = 0.09	-2.8 (95% CI -6.2, 0.6); p = 0.11
2014	-5.3 (95% CI -9.4, -1.2); p = 0.01	-5.1 (95% CI -9.3, -0.8); p = 0.02
2015	-6.5 (95% CI -10.9, -2.2); p = 0.003	-6.6 (95% CI -11.2, -2.1); p = 0.005
2016	-1.9 (95% CI -6.1, 2.2); p = 0.35	-1.3 (95% CI -5.6, 2.9); p = 0.54

[a] Adjusted for 2013 National Center for Health Statistics (NCHS) Urban-Rural Classification designation (metropolitan vs. non-metropolitan county), percentage of residents living in poverty, percentage of adults unemployed, inflation-adjusted median household income, percentage of 45-64 year old residents who were female, percentage of 45-64 year old residents who were Black, percentage of 45-64 year old residents who were Hispanic, percentage of adult residents with diabetes in 2010, percentage of adult residents with obesity in 2010, percentage of adult residents who smoke in 2010, number of primary care providers per 100,000 residents, number of cardiologists per 100,000 residents, and percentage of 40-64 year old residents with income less than 138% of the federal poverty limit with health insurance in 2010.

eTable 4. Pre-Medicaid Expansion Parallel Trends Assumption (2010-2013)

Term	Unadjusted Model	Adjusted Model [a]
Time as linear continuous variable		
Expansion status x Time	-0.9 (95% CI -1.8, 0.1); p = 0.08	-1.0 (95% CI -2.1, 0.1); p = 0.08
Time as quadratic continuous variable		
Expansion status x Time	2.5 (95% CI -1.2, 6.3); p=0.19	2.5 (95% CI -1.7, 6.7); p=0.24
Expansion status x Time^2	-1.1 (95% CI -2.4, 0.1); p=0.07	-1.2 (95% CI -2.5, 0.1); p=0.07

[a] Adjusted for 2013 National Center for Health Statistics (NCHS) Urban-Rural Classification designation (metropolitan vs. non-metropolitan county), percentage of residents living in poverty, percentage of adults unemployed, inflation-adjusted median household income, percentage of 45-64 year old residents who were female, percentage of 45-64 year old residents who were Black, percentage of 45-64 year old residents who were Hispanic, percentage of adult residents with diabetes in 2010, percentage of adult residents with obesity in 2010, percentage of adult residents who smoke in 2010, number of primary care providers per 100,000 residents, number of cardiologists per 100,000 residents, and percentage of 40-64 year old residents with income less than 138% of the federal poverty limit with health insurance in 2010.

eTable 5. Difference-in-Differences Sensitivity Analyses

	Cardiovascular Mortality Rate (deaths per 100,000 residents per year) in pre-Medicaid expansion period (Unadjusted)	Cardiovascular Mortality Rate (deaths per 100,000 residents per year) in post-Medicaid expansion period (Unadjusted)	Difference-in-Differences Estimate (Unadjusted)	Difference-in-Differences Estimate (Adjusted) [a]
Age-adjusted cardiovascular mortality for 65-74 year old residents as outcome [b]				
Medicaid Expansion States - Mean (95% CI)	498.5 (462.3, 534.6)	497.2 (459.7, 534.7)	-8.6 (-18.3, 1.0); p=0.08	-6.6 (-16.2, 3.1); p=0.18
Medicaid Non-Expansion States - Mean (95% CI)	566.3 (515.2, 617.4)	573.7 (522.6, 624.7)		
Age-adjusted cardiovascular mortality for 25-64 year old residents as outcome [c]				
Medicaid Expansion States - Mean (95% CI)	75.5 (68.2, 82.8)	75.2 (67.8, 82.6)	-2.5 (-4.0, -1.0); p = 0.001	-2.3 (-3.7, -0.9); p = 0.001
Medicaid Non-Expansion States - Mean (95% CI)	90.8 (79.0, 102.6)	93.0 (80.7, 105.3)		
Excluding all early and late adopter states [d]				
Medicaid Expansion States - Mean (95% CI)	152.1 (134.2, 170.2)	153.8 (134.9, 172.6)	-3.2 (-6.4, -0.1); p=0.04	-3.6 (-6.8, -0.4); p = 0.03
Medicaid Non-Expansion States - Mean (95% CI)	176.1 (154.0, 198.2)	180.9 (158.0, 203.8)		
All states included [e]				
Medicaid Expansion States - Mean (95% CI)	145.0 (131.0, 159.0)	144.8 (130.4, 159.3)	-4.4 (-7.2, -1.7); p = 0.002	-4.1 (-6.6, -1.6); p = 0.001
Medicaid Non-Expansion States - Mean (95% CI)	173.8 (152.3, 195.4)	178.1 (155.7, 200.5)		
Excluding 2014 data				
Medicaid Expansion States - Mean (95% CI)	148.9 (134.9, 163.0)	141.1 (126.2, 155.9)	-4.2 (-7.2, -1.3); p = 0.005	-4.0 (-6.8, -1.2); p = 0.005

Medicaid Non-Expansion States - Mean (95% CI)	178.7 (156.5, 200.9)	175.1 (151.8, 198.3)		
Subset of cardiovascular causes of death as outcome [f]				
Medicaid Expansion States - Mean (95% CI)	118.7 (107.0, 130.4)	118.8 (106.8, 130.9)	-3.0 (-5.7, -0.4); p=0.03	-2.9 (-5.4, -0.4); p = 0.02
Medicaid Non-Expansion States - Mean (95% CI)	144.0 (125.6, 162.5)	147.2 (128.4, 166.0)		
Variables aggregated at state level (includes deaths censored in county level analysis) [g]				
Medicaid Expansion States - Mean (95% CI)	1392 (125.7, 152.8)	139.3 (125.5, 153.0)	-4.7 (-7.9, -1.4); p = 0.01	-2.8 (-5.1, -0.5); p = 0.02
Medicaid Non-Expansion States - Mean (95% CI)	168.6 (151.4, 185.8)	173.3 (155.4, 191.1)		

[a] Adjusted for 2013 National Center for Health Statistics (NCHS) Urban-Rural Classification designation (metropolitan vs. non-metropolitan county), percentage of residents living in poverty, percentage of adults unemployed, inflation-adjusted median household income, percentage of 45-64 year old residents who were female, percentage of 45-64 year old residents who were Black, percentage of 45-64 year old residents who were Hispanic, percentage of adult residents with diabetes in 2010, percentage of adult residents with obesity in 2010, percentage of adult residents who smoke in 2010, number of primary care providers per 100,000 residents, number of cardiologists per 100,000 residents, and percentage of 40-64 year old residents with income less than 138% of the federal poverty limit with health insurance in 2010.

[b] Adjusted for percentage of 65-74 year old residents who were Black, Hispanic, and female instead of 45-64 year old residents. Percentage of adults who are unemployed and residents with health insurance coverage in 2010 not included in this model. Other covariates same as above model.

[c] Adjusted for percentage of 25-64 year old residents who were Black, Hispanic, and female instead of 45-64 year old residents and percentage of 18-64 year old residents with health insurance coverage in 2010. Other covariates same as above model.

[d] Excluding the following states, in addition to Massachusetts and Wisconsin: Alaska, California, Connecticut, District of Columbia, Indiana, Michigan, Minnesota, Montana, New Hampshire, New Jersey, Pennsylvania, and Washington

[e] All states, including Massachusetts and Wisconsin, included

^f Age-adjusted mortality from following as outcome (per 100,000 residents) ICD-10 codes: I20-I25 (Ischemic heart diseases), I26 (Pulmonary embolism), I42 (Cardiomyopathy), I44 (Atrioventricular and left bundle-branch block), I45 (Other conduction disorders), I46 (Cardiac arrest), I47 (Paroxysmal tachycardia), I48 (Atrial fibrillation and flutter), I49 (Other cardiac arrhythmias), I50 (Heart failure), I51.0 (Cardiac septal defect, acquired), I51.1 (Rupture of chordae tendineae, not elsewhere classified), I51.2 (Rupture of papillary muscle, not elsewhere classified), I51.3 (Intracardiac thrombosis, not elsewhere classified), I60-I69 (Cerebrovascular diseases), I71 (Aortic aneurysm and dissection)

^g State level model adjusted for state level covariates. Percentage of state residents living in rural areas included in the model.