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Citation	Sommers, Benjamin D., Sharon K. Long, and Katherine Baicker. 2014. "Changes in Mortality After Massachusetts Health Care Reform." Ann Intern Med 160 (9) (May 6): 585. doi:10.7326/m13-2275.
Published Version	doi:10.7326/M13-2275
Citable link	http://nrs.harvard.edu/urn-3:HUL.InstRepos:14085946
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Changes in Mortality after Massachusetts' Health Care Reform

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Word Count: 3210
Abstract: 280
Version Date: 1/23/14

ABSTRACT

Background: Massachusetts' 2006 health reform has been called a model for the Affordable Care Act. The law attained near-universal insurance coverage and increased access to care. Its impact on population health is less clear.

Objective: To determine whether Massachusetts' reform was associated with changes in all-cause mortality and mortality from causes amenable to health care.

Design: Comparison of mortality rates before and after reform in Massachusetts versus a control group with similar population demographics and economic conditions.

Setting: Massachusetts' reform created a natural experiment on health insurance expansion. We compared changes in mortality rates for adults in Massachusetts counties from 2001-2005 (pre-reform) to 2007-2010 (post-reform), versus changes in a propensity-score defined control group of counties in other states.

Participants: Adults ages 20-64 in Massachusetts and control counties.

Outcome Measures: Annual county-level all-cause mortality in sex-age-race specific cells (cells: n=146,825) from the CDC's Compressed Mortality File. Secondary outcomes were deaths from causes amenable to health care; insurance coverage; access to care; and self-reported health.

Results: Massachusetts' reform was associated with a significant decline in all-cause mortality compared to the control group (-2.9 percent, p=0.003, or an absolute decline of 8.2 deaths per 100,000). Deaths from causes amenable to health care also significantly declined (-4.5 percent, p<0.001). Changes were larger in counties with lower household incomes and higher pre-reform uninsured rates. Secondary analyses showed significant gains in coverage, access to care, and self-reported health. The number-needed-to-treat was approximately 830 people gaining health insurance to prevent one death per year.

Limitations: Non-randomized design subject to unmeasured confounders; Massachusetts may not generalize to other states.

Conclusions: Massachusetts' reform was associated with significant declines in all-cause mortality and deaths from causes amenable to health care.

Primary Funding Source: None.

INTRODUCTION

Massachusetts passed comprehensive health reform in 2006 with the goal of near-universal coverage. The law – which expanded Medicaid, offered subsidized private insurance, and created an individual mandate – was a model for the Affordable Care Act (ACA).[1] Thus, understanding the Massachusetts law's impact has important policy implications.

Previous research documents that Massachusetts' reform succeeded in expanding health insurance among adults ages 19 to 64 by 3-8 percentage points.[1-5] Studies also indicate improvements in access to care,[6-8] self-reported physical and mental health,[9] use of preventive services,[2,10] and functional status.[1,11] However, there has been no evidence on the law's effect on mortality. Previous research of health insurance's impact on mortality is mixed. Some observational studies suggest as much as a 40% higher risk of death for uninsured versus insured adults,[12,13] and one analysis of Medicaid expansions to low-income adults detected a 6% decline in statewide mortality.[14] Other studies – including two randomized trials of insurance expansion – found little or no mortality impact.[15-17]

This study's objective was to examine the changes in mortality associated with Massachusetts' reform. We hypothesized that the reform reduced mortality, particularly from causes potentially treatable with timely care (such as cardiovascular disease, infections, and cancer), and that larger changes occurred among groups likely to benefit from the law – previously uninsured adults and those with higher baseline mortality.

METHODS

Study Design

Our study used a quasi-experimental pre-post design with a control group, comparing average mortality in Massachusetts before and after reform to mortality changes over the same period for similar populations in states without reforms (also known as a "differences-in-differences" analysis[18]). Our preferred specification employed propensity-score methods to create a control group of counties in non-reform states that best matched the distribution of pre-reform characteristics in Massachusetts counties.[19,20]

The Massachusetts law had several components: a Medicaid expansion starting in July 2006 for adults; subsidized private plans for adults under 100% of the federal poverty level (FPL) in October 2006; and expanded coverage subsidies for adults up to 300% of FPL in January 2007. It included an individual mandate effective for the 2007 tax year, as well as "minimum creditable coverage" insurance standards.[21] We defined the post-reform period as 2007-2010, with 2006 omitted as a transitional year (though we included 2006 in sensitivity analyses). Our pre-reform period was 2001-2005.

Data

Our data came primarily from the Centers for Disease Control and Prevention (CDC)'s Compressed Mortality File, which provides county-specific annual mortality rates stratified by age, sex, and race.[22] For confidentiality, the publicly-available dataset suppresses death counts for cells with fewer than 10 deaths; we obtained access to the non-suppressed dataset under agreement with the CDC. Our sample contained adults ages 20-64, the group most directly targeted by the reform (with 19 year-olds excluded because 15-19 year-olds are grouped together in the dataset). In addition to age, sex, and race, our estimates adjusted for year-specific county-level poverty rates, median income, unemployment, and Latino percentage of the population, all from the Area Resource File (ARF).[23] Subgroup analyses used pre-reform county-level uninsured rates from the Census Bureau's 2005 Small Area Health Insurance Estimates.[24]

We also analyzed measures of coverage, health care access, and self-reported health status from two nationally-representative household surveys: CDC's Behavioral Risk Factor Surveillance System (BRFSS) and the Census Bureau's Current Population Survey (CPS). These datasets have been used previously to examine the impact of the Massachusetts reform on coverage and access;[2-4,8,9,25] we present independent estimates using methods analogous to our mortality analysis to provide additional context for our results. For these data sources, we were able to include 19 year-olds, so the sample contains all non-elderly adults 19-64.

This project used pre-existing deidentified data and was deemed exempt from review by the Harvard Institutional Review Board. The project received no external funding.

Outcome Measures

Our primary outcome was all-cause mortality. Our secondary outcome was mortality amenable to health care, adapted from previous research, to focus on deaths related to conditions that are more likely to be preventable or treatable with timely care,[26-29] including deaths due to heart disease, stroke, cancer, infections and other conditions.[30] Appendix Table 1 lists the ICD-10 codes in this definition and a more restrictive alternate definition tested in a sensitivity analysis.

Additional outcomes were health insurance from the CPS, and self-reported health (excellent/very good versus good/fair/poor) and access-to-care measures (cost-related delays in care, lacking a usual source of care, and absence of a preventive visit in the past year) from the BRFSS.

Analysis

Annual age-sex-race-specific county-level death counts were the unit of observation for the mortality analysis. Table 1 describes the analytic sample, which contains information on the number of counties, states, age-sex-race-specific county-level cells, and population per year.

Our regression models estimated the average annual pre-post change in mortality for age-sex-race-specific cells in Massachusetts counties relative to comparison counties in non-reform states. Given that our dataset presents deaths as count data within each cell, multivariate regression analyses fitted a generalized linear model (GLM), using a negative binomial distribution and log-link, with cell population as the exposure variable. Analyses adjusted for race, sex, age, state, year, and county-year-specific economic factors listed above (see Appendix for details).

Our study contained five years of pre-reform data (2001-2005) and four years of post-reform data (2007-2010), and our model estimated the change in level of mortality pre- versus post-reform.[31] Robust standard errors were clustered at the state level to account for serial autocorrelation and for the state-level nature of the policy intervention,[18] as is standard in population-based policy analyses.[14,32-37] Sensitivity analyses included pooling annual data into pre-reform and post-reform periods to remove potential autocorrelation, an interrupted time-series model, adding 2006 (the implementation year) to our post-reform data, and county-level clustering of standard errors. We also tested a linear model using death rate per 100,000 adults as the outcome, to provide simple estimates of absolute change and results comparable to prior research.[14] Cells were weighted by population size to yield population-representative estimates.

Secondary analyses used individual-level information from the BRFSS and CPS on coverage, access, and health status, and adjusted for age, sex, race/ethnicity, employment, household income, year, and state. For these binary outcomes, we used a generalized linear model with a logit link, with predicted probabilities used to describe the magnitude of absolute changes.[38]

Selection of Control Group

For the mortality analysis, we used propensity scores to define a control group of counties in non-reform states that were most similar to Massachusetts counties prior to reform. We estimated propensity scores with a population-weighted logistic regression model using age distribution, sex, race/ethnicity, poverty rate, median income, unemployment, uninsured rate, and baseline annual mortality as predictors (Appendix Table 2). The quartile of counties with the highest propensity scores – indicating the closest match to the overall population of Massachusetts' 14 counties – were used as the control group in the mortality analysis. This approach yielded excellent balance on key features between Massachusetts and our control group (Table 2) and provided adequate sample sizes for subgroup analyses. We also tested a more traditional propensity score regression adjustment method and a 2:1 nearest-neighbor propensity score matching approach, which yielded similar overall results (see Appendix for details).

Identifying a control group with similar trends in mortality absent Massachusetts' reform is the key to our approach.[20] We tested for differences in the pre-reform mortality trends for 2001-2006 between Massachusetts and the control group, using both linear and quadratic time trends interacted with an indicator variable for Massachusetts. We repeated this test for the full U.S. population.

For the analysis of coverage, access, and self-reported health in the CPS and BRFSS, we compared Massachusetts to other New England states (Maine, Vermont, New Hampshire, Rhode Island, and Connecticut) before and after reform. These datasets do not contain the county-level detail needed for our propensity score method, so we follow previous research in using this control group.[2,3,11]

Subgroup Analyses

We conducted pre-specified subgroup analyses to test for heterogeneous mortality changes and impact on disparities. We examined 20-34 versus 35-64 year-olds; white non-Latinos versus non-whites and Latinos; residents of low- versus high-income counties (based on Massachusetts' median household income); and residents of counties with low versus high adult uninsured rates (based on Massachusetts' pre-reform median county uninsured rates). In each analysis, we specified an interaction term between Massachusetts' reform and the variable in question, to test whether there were significantly different impacts across subgroups.

Finally, we used elderly adults (65 and older) as an additional control group. This approach subtracts out any secular trend for elderly adults in Massachusetts from the estimated mortality change for non-elderly adults (see Appendix for details). Netting out the mortality changes in this group is a conservative approach: while Massachusetts' reform did not directly affect coverage for most elderly adults, it did expand insurance to the few who do not meet lifetime earnings requirement for Medicare.[2,39] It may thus have had some impact on health in this age group, but one would expect such effects to be much weaker than the impact on the targeted population of non-elderly adults.

RESULTS

Sample

Table 2 presents descriptive statistics and baseline mortality for counties in Massachusetts, our control group, and all U.S. counties outside Massachusetts. Massachusetts had significantly fewer minorities, more women, lower poverty and uninsured rates, and lower baseline mortality than the rest of the U.S. However, there were no statistically significant differences for these outcomes between Massachusetts and the control group, indicating excellent balance from the propensity score approach.

Examination of pre-reform mortality trends further supports the use of control group (Appendix Table 3). We found no evidence of divergence between Massachusetts and the control group in either linear or quadratic models ($p>0.10$). In contrast, Massachusetts' mortality trend diverged from the rest of the U.S. before 2006 ($p<0.001$).

Changes in Mortality

Figure 1 shows unadjusted annual mortality for non-elderly adults in Massachusetts and the control group from 2001-2010. All-cause mortality in the two groups followed a similar pattern until the reform law's implementation in 2006-2007, after which mortality in Massachusetts began to decline relative to the control group. Health-care amenable mortality followed a similar pattern, while trends for other causes of death showed minimal changes within Massachusetts and the control group.

Table 3 presents regression estimates for changes in mortality associated with Massachusetts' reform. In our primary specification, adjusted all-cause mortality declined in Massachusetts after reform by 2.9% (p=0.003), compared to the control group. Mortality amenable to health care declined by 4.5% (p<0.001). An alternate definition of health-care amenable mortality[28] produced a slightly larger relative reduction (-5.5%, p=0.002), and deaths from non-amenable causes showed no significant decline (-2.0%, p=0.26) (Appendix Table 1).

Numerous sensitivity analyses – including using propensity-score regression adjustment or 2:1 matching approaches, county-level clustered standard errors, or a linear model with the death rate as the outcome – produced similar results (Appendix Table 4). The relative decline of 2.9% in all-cause mortality, paired with baseline mortality in Massachusetts of 283 per 100,000, implies an absolute mortality reduction of -8.2 per 100,000, similar to the linear model estimate of -9.3 per 100,000 (p=0.014) reported in the Appendix.

Mortality Changes Among Subgroups

Table 4 presents subgroup analyses. Relative mortality reductions in Massachusetts compared to the control group were significant for whites and non-whites, 20-34 and 35-64 year-olds, and residents of counties with lower incomes and higher baseline uninsured rates. While relative mortality changes were larger for Latinos and non-whites (-4.6%, p<0.001) than for whites (-2.4%, p=0.001), the between-group difference in these estimates was not significant (p=0.062).

Appendix Figure 1 shows unadjusted mortality trends for elderly adults, with no apparent divergence between Massachusetts and the control group before or after reform. A model using elderly adults as an additional within-state control group (Appendix Table 5) showed a -3.3%

change in all-cause mortality (p=0.066) for non-elderly adults and +0.1% for elderly adults (p=0.93) in Massachusetts after reform, and a -4.9% change in health-care amenable mortality (p<0.001) for non-elderly adults and a +0.2% change for elderly adults (p=0.90).

Coverage, Access to Care, and Health

Table 5 shows changes in coverage, access to care, and self-reported health. Compared to other New England states, Massachusetts' reform was associated with significant reductions in the uninsured rate (-6.8 percentage-point change in predicted probability, a 57% relative decline from baseline), cost-related delays in care (-2.0 percentage points, 22% relative decline), lacking a usual source of care (-1.9 percentage points, 13% relative decline), having no preventive visit in the last year (-4.0 percentage points, 13% relative decline), and reporting good, fair or poor health (-1.8 percentage points, 5% relative decline), all changes p<0.01. Results were nearly identical with linear probability models or without state-clustering of standard errors (Appendix Table 6).

Estimated Mortality Effect

To assess the plausibility of our estimated mortality decline, we compared it with the coverage gains we detected (Appendix Table 7). In absolute terms, we found a 0.082 percentage-point decline in mortality (8.2 per 100,000) in the setting of a 6.8 percentage-point coverage gain, which implies that for approximately every 830 individuals who gained insurance, there was one fewer death per year.

DISCUSSION

Massachusetts' 2006 health reform was associated with significant declines in all-cause mortality over 4 years of follow-up, relative to a control group of similar counties in states without reform. Declines were concentrated in causes of death more likely amenable to health care and in populations most likely to benefit from expanded access, particularly residents of counties with lower incomes and higher pre-reform uninsured rates.

Compared to the control group, overall mortality in Massachusetts declined by 2.9%. This relative decline in mortality is smaller than the 6.1% mortality decline associated with several states' Medicaid expansions,[14] consistent with the fact that Massachusetts began its expansion from a much higher baseline rate of insurance coverage. However, two recent experimental studies of insurance have not shown a mortality benefit of insurance,[16,17] nor statistically significant changes in blood pressure or glycated hemoglobin,[40] though both found major gains in self-reported health and access to recommended care. The latter studies have the advantages of a randomized design and individual-level data, but involve much smaller sample sizes (e.g. 916 gaining coverage in one study,[17] roughly 10,000 newly-insured in another,[40] versus approximately 270,000 adults gaining coverage in our study) and shorter follow-up[16,40] than is possible using state-wide population data, giving our study far greater statistical power for small absolute changes such as those detected here.

How does insurance expansion reduce population mortality? Our secondary outcomes trace out a plausible causal pathway: eligibility leads to increased coverage, coverage leads to better access and more utilization of clinical services including office visits, with resulting gains in self-reported health status (a strong predictor of mortality[41,42]). This potential pathway of coverage leading to health gains via access to clinicians and high-quality care is consistent with

Eisenberg and Power's seminal 2000 paper, which outlines a framework for understanding challenges to improving care for patients within the U.S. health care system.[43]

Our results are consistent with the bulk of previous research on Massachusetts' reform, demonstrating gains in coverage, access to care, and self-reported health among Massachusetts residents post-reform.[1,2,8,10,11] Mortality reductions were concentrated in those conditions most likely amenable to health care, such as cancer (which can sometimes be prevented with earlier screening and/or treated more successfully with early detection), infections (treatable with early detection, and preventable or less likely to be fatal with better chronic disease management), and cardiovascular disease (treatable acutely with early detection, and partially preventable with risk factor modification). This is consistent with research demonstrating a decline in potentially avoidable hospitalizations after Massachusetts' reform[2] and other insurance expansions.[44] While research on breast cancer did not find a significant effect of Massachusetts' reform,[25] our use of a more comprehensive health outcome may have given us greater power to detect changes than analysis of a single diagnosis.

Our "number needed to treat" was 830 adults gaining insurance to prevent one death per year. This estimated coverage-to-mortality effect would be consistent with a 30% relative reduction in individual-level mortality for those gaining insurance (compared to an estimated 25% relative reduction in mortality from insurance cited by the Institute of Medicine,[13] and the 40% relative reduction found by Wilper et al.[12]), if overall baseline mortality for these uninsured individuals were 400 per 100,000 (Appendix Table 7). This baseline mortality rate would be roughly 1.5 times that of our overall sample, consistent with prior research on elevated mortality risks for the uninsured.[12,15] In addition, research suggests that insurance expansions disproportionately enroll individuals in worse health,[14,45] and components of the Massachusetts expansion preferentially targeted adults with disabilities or HIV/AIDS.[21] These illustrative calculations assume that mortality reductions occurred only for those obtaining insurance under reform, which may be conservative, since the law also expanded benefits (including preventive care and prescription drugs) for many who already had insurance.

Reductions in mortality were largest in Massachusetts counties with lower incomes and lower pre-reform insurance coverage – areas likely to have experienced the greatest increase in access to care under reform. Mortality reductions were nearly twice as large for minorities as for whites, though this between-group difference was not statistically significant. These results provide useful additional information compared to previous research suggesting that racial/ethnic disparities in coverage and access may not have narrowed after Massachusetts' reform.[3,4]

Our analysis has several limitations. First, we do not have individual-level insurance information and thus cannot directly link mortality changes to those gaining insurance coverage. Second, defining mortality from causes "amenable to health care" is somewhat subjective. We built on methods used in prior research[27-29] and tested two definitions that provided similar results. Future research distinguishing between treatable and curable conditions would also be worthwhile.

Most importantly, our quasi-experimental approach cannot definitively demonstrate a causal relationship underlying the association between Massachusetts' reform and the state's declining mortality relative to other states. It is possible that the post-reform reduction in mortality in Massachusetts was due to other factors that differentially affected Massachusetts, such as the recession. However, our analysis controlled for several distinct time- and county-specific economic measures. We also found no evidence of a similar decline in mortality among elderly adults in Massachusetts that would suggest a secular trend. While we cannot rule out unmeasured confounders, it is challenging to identify factors other than health reform that might have produced this pattern of results: a declining mortality rate in Massachusetts since 2007 not present in similar counties elsewhere in the country, primarily for health-care amenable causes in adults ages 20-64 (but not elderly adults), concentrated among poor and uninsured areas, and not explained by changes in poverty or unemployment rates.

In conclusion, we find a significant reduction in mortality among non-elderly adults in Massachusetts since its 2006 reform, relative to a control group of similar counties in states without such reforms. Though this analysis is unable to demonstrate causality, the results offer suggestive evidence that the ACA – modeled after the Massachusetts law – may impact not only coverage and access, but also mortality. However, it is critical to note the many dimensions along which Massachusetts differs from the rest of the nation, with lower mortality, higher income and baseline insurance coverage rates, fewer minorities, and the most physicians per capita in the country.[46] The extent to which our results generalize to the U.S. as a whole is therefore unclear, underscoring the need to monitor closely across all states the ACA's impact on coverage, access, and population health.

Reprint Requests

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Acknowledgments

We are grateful to James Ware at the Harvard School of Public Health for thoughtful advice on our statistical analysis. We would also like to thank Jacob Robbins and Sarah Gordon, Research Assistants at the Harvard School of Public Health, for their work on this project, and Katherine Hempstead at the Robert Wood Johnson Foundation for helpful suggestions related to health-care amenable mortality. Drs. Sommers and Long reported no financial conflicts of interest. Dr. Baicker reported a relationship with Eli Lilly. Dr. Sommers is currently serving as an advisor in the Office of the Assistant Secretary for Planning and Evaluation, at the U.S. Department of Health and Human Services (HHS). However, this paper was written in Dr. Sommers' capacity as a Harvard employee, and this paper does not represent the views of HHS. Previous versions of this study were presented at the national conferences of the Society of General Internal Medicine and AcademyHealth in 2013.

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Table 1: Analytic Sample

Variable	**Value**
Counties	
Massachusetts Counties	14
Control Group Counties	513
United States (non-Massachusetts)	3127
States (including District of Columbia)	
Massachusetts	1
Control Group States	46
United States (non-Massachusetts)	50
County-Specific Age-Sex-Race Cells	
Massachusetts Cells	3,985
Control Group Cells	142,840
United States (non-Massachusetts)	836,413
Population Per Year, Ages 20-64	
Massachusetts	3,900,000
Control Group	44,300,000
United States (non-Massachusetts)	173,400,000

Table 2: Summary Statistics for Study Sample, Pre-Reform Period

County-Level Characteristic	Massachusetts	Control Group	P value, Massachusetts vs. Control Group	Rest of United States	P value, Massachusetts vs. Rest of United States
Covariates					
Age 20-34	33.2%	33.1%	0.95	34.5%	0.46
Age 35-44	26.3%	25.9%	0.51	25.3%	0.090
Age 45-54	24.0%	24.3%	0.69	23.7%	0.68
Age 55-64	16.5%	16.7%	0.79	16.4%	0.95
Male	48.9%	49.1%	0.13	49.6%	<0.001
White	87.4%	85.0%	0.28	81.0%	0.003
Black	7.0%	9.0%	0.26	12.8%	<0.001
Other Race	5.6%	6.0%	0.62	6.2%	0.46
Latino Ethnicity	7.6%	7.9%	0.86	14.0%	<0.001
Poverty Rate	9.6%	10.2%	0.55	12.7%	0.002
Median Household Income†	$62,271	$59,124	0.30	$52,481	0.001
Unemployment Rate	5.0%	5.1%	0.62	5.4%	0.058
Uninsured Rate	13.6%	14.5%	0.18	19.8%	<0.001
Outcomes					
All-Cause Mortality (deaths per 100,000)	283	297	0.26	341	<0.001
Mortality Amenable to Health Care (deaths per 100,000)	185	197	0.11	221	<0.001

Notes:
† Median income was inflation-adjusted to 2010 dollars.

Table 3: Mortality Before and After Massachusetts' Health Reform Among Adults 20-64 (2001-2010)

OUTCOME	Unadjusted Mortality, per 100,000		Unadjusted Relative Change (percent)			Adjusted Relative Change (percent)		
	Pre-Reform	Post-Reform	Difference in Change, Massachusetts vs. Control Group	95% CI	P value	Difference in Change, Massachusetts vs. Control Group	95% CI	P value
All-Cause Mortality								
Massachusetts	283	274	-4.2	-8.0, -0.4	0.032	-2.9	-4.8, -1.0	0.003
Control Group	297	299						
Health Care Amenable Mortality								
Massachusetts	185	175	-4.3	-7.2, -1.5	0.003	-4.5	-6.2, -2.7	<0.001
Control Group	197	195						

Notes: Relative changes estimated using negative binomial generalized linear models with log-link. Adjusted model controlled for population age, sex, race, and ethnicity distribution, poverty rate, median income, unemployment rate, and state of residence.

Table 4: Subgroup Analyses of All-Cause Mortality Changes After Massachusetts' Health Reform Among Adults 20-64 (2001-2010)

SUBGROUP	Unadjusted Mortality in Massachusetts Prior to Reform, per 100,000	Adjusted Relative Change, Massachusetts vs. Control Group (percent)	95% CI	P value for subgroup	P value for between-group difference	Absolute Change in Predicted Mortality, per 100,000
Full Sample	283	-2.9	-4.8, -1.0	0.003	--	-8.2
White Non-Latino§	295	-2.4	-3.8, -1.0	0.001	0.062	-7.1
Latino or Non-White§	231	-4.6	-6.3, -2.8	<0.001		-10.6
Ages 20-34	77	-3.6	-6.9, -0.4	0.030	0.38	-2.8
Ages 35-64	386	-2.2	-3.8, -0.6	0.008		-8.5
Low-Income County	312	-3.0	-4.6, -1.3	<0.001	0.33	-9.4
High-Income County	257	-1.8	-4.0, 0.5	0.120		-4.6
Low-Uninsured County	295	-1.7	-3.8, 0.4	0.118	0.41	-5.0
High-Uninsured County	273	-3.3	-6.0, -0.6	0.015		-9.0

Notes: Relative changes estimated using negative binomial generalized linear models with log-link. Adjusted model controlled for population age, sex, race, and ethnicity distribution, poverty rate, median income, unemployment rate, and state of residence. Absolute change calculated using estimated relative change multiplied by baseline subgroup-specific mortality for Massachusetts.

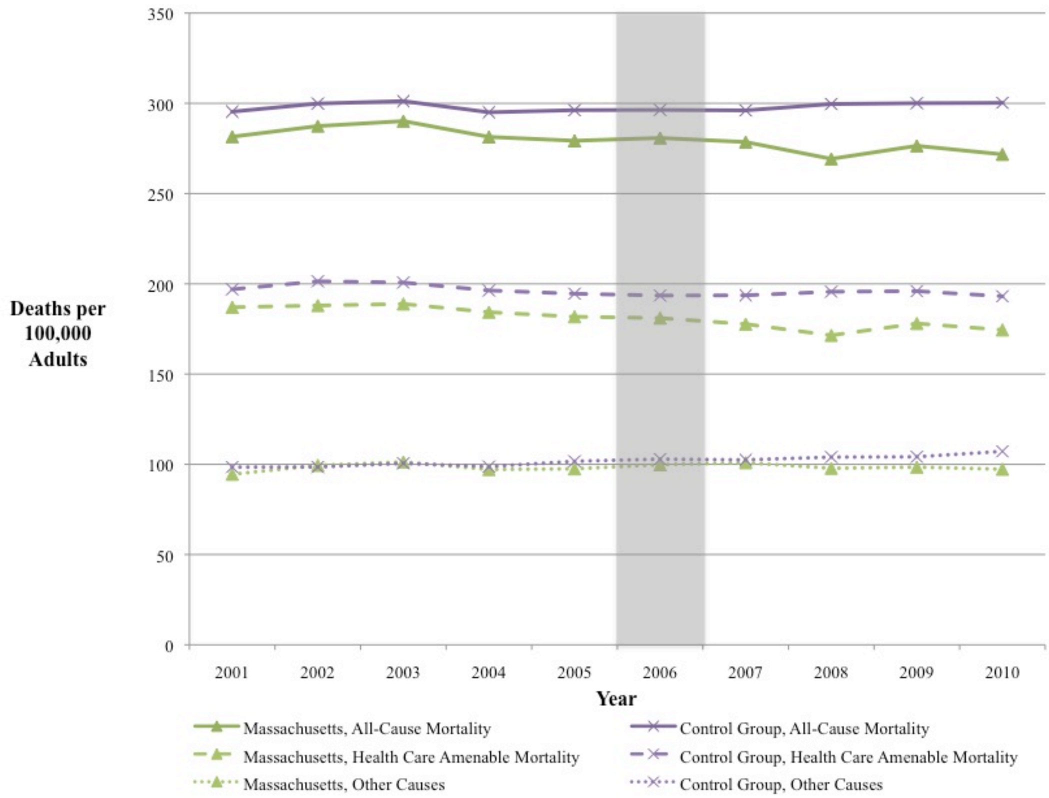
§ While unadjusted mortality is higher for White Non-Latinos than for Latinos or Non-Whites, this is primarily due to the different age distributions of the groups. After adjustment for age by standardizing to the white age distribution, baseline mortality for Latinos or Non-Whites is significantly higher (312/100,000) than mortality for White Non-Latinos (295/100,000). This model omits from the sample any deaths with "unknown" ethnicity, since the dataset has no corresponding population denominator for that group necessary to calculate a death rate.

Table 5: Changes in Coverage, Access to Care, and Self-Reported Health After Massachusetts' Health Reform Among Adults 19-64 (2001-2010)

OUTCOME	Unadjusted Population Mean in Massachusetts Pre-Reform (percent)	Adjusted Odds Ratio, Post-Massachusetts Health Reform	95% CI	P value	Absolute Change in Predicted Probability (percentage points)	N
Uninsured	11.9	0.43	0.41, 0.45	<0.001	-6.8	99,661
Delayed Care Due to Cost in Past Year	9.0	0.78	0.70, 0.86	<0.001	-2.0	215,365
No Usual Source of Care	14.7	0.84	0.78, 0.89	<0.001	-1.9	262,761
No Preventive Doctor's Visit in Past Year	30.5	0.82	0.79, 0.85	<0.001	-4.0	166,642
Good/Fair/Poor Self-Reported Health (versus Excellent/Very Good)	34.7	0.92	0.88, 0.95	<0.001	-1.8	214,510

Notes: All analyses compare pre-post changes in the outcomes for Massachusetts versus other New England states, for the years 2001-2005 versus 2007-2010. Data are from the Current Population Survey (CPS) for uninsured, and from the Behavioral Risk Factor and Surveillance System (BRFSS) for the remaining measures. Sample sizes for BRFSS items differ primarily due to changes in which years of the survey each item was asked and small differences in item non-response. Adjusted model controls for age, sex, race, ethnicity/household income (as percentage of the federal poverty level), employment status, year, and state of residence. Absolute change calculated using change in predicted probabilities.

Figure 1: Unadjusted Mortality Rates for Adults (20-64) from 2001-2010, in Massachusetts versus Control Group



Notes:
Gray band designates the beginning of the Massachusetts state health reform, implemented starting in July 2006. "Healthcare Amenable Mortality" is as defined in Appendix Table 1, with "other causes" containing all other causes of death not included in that definition.

Supplemental Appendix to
"Changes in Mortality After Massachusetts Health Care Reform"
Sommers, Long, and Baicker, *Annals of Internal Medicine*

Details of the Mortality Data Source and Sample Size

The Compressed Mortality File is a county-level database containing information on all U.S. deaths in the prior year, and information on the county-specific population by various demographic features. The database is collected and made publicly available by the National Center for Health Statistics at the Centers for Disease Control and Prevention (CDC), at the following website: http://wonder.cdc.gov/mortSQL.html.[1] However, the publicly-available version suppresses death counts less than 10, so we obtained access under a data-use agreement with the CDC to the full non-suppressed dataset, which we used for our mortality analyses.[2]

Mortality information was obtained directly from death certificates. Population information came from the U.S. Census Bureau, providing information on each county's population by sex, age, ethnicity, and race. Year-specific county-level poverty rates, median income, unemployment, and Latino percentage of the population all came from the Area Resource File (ARF).[3] Data from 2010 economic measures were not available in the most recent ARF release at the time of this analysis, so we carried forward 2009 values; our results were essentially unchanged when we excluded 2010 data.

In our baseline analysis, our sample size was defined by the following equation:

N = # counties * 9 years * 2 sexes * 4 age groups * 4 races

For Massachusetts, this yielded a possible 4032 county-level observations (for 14 counties); however, 47 of these combinations had 0 population members, meaning there was no one of that age-race-sex combination in a county in a particular year. The overall sample for Massachusetts in our analysis was therefore N=3,985 observations.

We did not include Latino ethnicity as a stratification variable in our primary analysis, since ethnicity data are unknown for a portion of deaths in the mortality dataset and lack a corresponding population estimate needed to calculate a death rate. Instead, we adjusted for Latino ethnicity at the county level, as in a previous similar analysis of CDC data.[4] In a sensitivity analysis, we included Latino ethnicity as a stratification variable and excluded those deaths for whom ethnicity was unknown, and the results were quite similar. Our preferred model used county-level data because it allowed us to use the richest set of economic indicators (county and year specific unemployment, median income, and poverty rate), and we felt that these potential confounders represented the greatest threat to the study's internal validity. County-level analyses also allowed us to examine subgroups to assess the plausibility of the causal mechanism implied by our findings – we were able to look differentially at mortality declines by county household income and baseline rates of health insurance coverage.

Definitions and Analyses of Deaths Amenable to Health Care

We adapted previous work by Nolte & McKee (2003, 2008, 2011)[12-14] defining mortality amenable to medical care (Appendix Table 1). Our definition was more inclusive, and included all infectious and malignant causes of death (rather than a subset), congestive heart failure, and certain treatable arrhythmias. We also removed several diagnoses less relevant to our study population (e.g., congenital cardiac malformations). Our overall results were similar using both definitions: the post-reform relative mortality decline using the Nolte & McKee measure was -5.5% (95% CI -8.9, -2.1, p=0.002), from a baseline of 99 per 100,000; the estimate using our revised criteria was -4.5% (95% CI -6.2, -2.7, p<0.001). Non-amenable deaths using our definition did not significantly decline, with an estimate of -2.0% (95% CI -5.5, 1.5, p=0.26).

Details of the Propensity Score Approach

The propensity score (PS) method used here is an adapted version of the approach used in non-randomized clinical trials of interventions such as a medical treatment, and is also analogous to the notion of a synthetic control group as outlined by Abadie and colleagues.[5] We used a logistic regression model with multiple predictor variables to predict the outcome, which is the "treatment condition" – in this case, being a county in Massachusetts. Massachusetts counties have an outcome = 1, and all other U.S. counties = 0. The following variables were used to calculate the propensity scores: county-level information on race, ethnicity, age, sex, poverty rate, median household income, unemployment rate, uninsured rate prior in 2005, and annual baseline mortality rate from 2001-2006. The analysis was conducted at the county level, weighted for the size of each county's non-elderly adult population. Fitted values were then obtained for each non-Massachusetts county, indicating a "propensity" (or more precisely, a similarity index) to Massachusetts. There was significant overlap: the PS range for Massachusetts counties was from 0.00001 to 0.72, and for non-Massachusetts control counties from essentially 0 ($1.21x\ 10^{-27}$) to 0.99. Then, using the propensity score, we identified the quartile of national counties that most closely resembled the overall population of Massachusetts' 14 counties. Table 2 shows that this approach achieved excellent balance, with no statistically significant differences in population characteristics between counties in the control group and those in Massachusetts.

Our approach differed somewhat from more traditional PS approaches. Unlike a typical PS analysis of a patient-level clinical intervention (where each observation is equal sized), our unit of analysis for the mortality data is the county, where population size varies dramatically across each unit, and where our treatment condition (Massachusetts) has just 14 counties. For these reasons, when we use a traditional PS method such as 2:1 nearest-neighbor matching,[6] we end up with an underpowered sample (42 counties total), which is particularly limiting for potential subgroup analyses. We also considered a traditional PS regression adjustment strategy, using the full overlapping U.S. sample of counties, with direct adjustment for propensity scores in 10 deciles.[7] This resulted in similar overall estimates as our preferred baseline model, though the differences in baseline trends in mortality for the U.S. as a whole versus Massachusetts (Appendix Table 3) [even after PS decile adjustment] suggest that this is a less convincing control group for a quasi-experimental approach than our primary specification. However, it is reassuring that our main findings of relative mortality reductions in Massachusetts compared the control group were consistent across all three approaches (Appendix Table 4).

Regression Models and Sensitivity Analyses

<u>Baseline GLM Model</u>

The baseline analysis used a generalized linear model (GLM) with negative binomial family and a log link, with population size as the exposure variable, and the following equation:

$$Deaths_{ijklt} = \beta_0 + \beta_M\, MassReform_{lt} + \beta_1 X_{ijk} + \beta_2\, County\text{-}Level\ Factors_{lt} + \mu\, Year_t + \Omega\, State_l + \varepsilon_{ijklt} \qquad \text{Equation (1)}$$

where i indexed age, j race, k sex, l county, and t year. X_{ijk} was a vector of demographics (age group, race, and sex). *County-Level Factors* included county-year-specific poverty rate, median income (in 2010 inflation-adjusted dollars), unemployment rate, and percentage of the population that is Latino. μ was a vector of year fixed effects, and Ω is a vector of state fixed effects. The coefficient of interest was β_M, which captures the effect of living in Massachusetts after the year 2006. The regression used Huber-White robust standard errors clustered at the state level and was weighted for population size.

<u>Pre-Reform Trend Analyses (Sample limited to 2001-2006):</u>
To test for divergence in mortality trends prior to Massachusetts' health reform, we used a generalized linear model (GLM) with negative binomial family and a log link, with population size as the exposure variable, and the following equation:

$$Deaths_{ijklt} = \beta_0 + \beta_1 X_{ijk} + \beta_2 \textit{County-Level Factors}_{lt} + \mu \textit{ Time Trend}_t + \Phi \textit{ Massachusetts}_s * \textit{Time Trend}_t + \Omega \textit{ State}_l + \varepsilon_{ijklst} \quad \text{Equation (2)}$$

where μ was a linear time trend, and Φ was a Massachusetts-specific time trend, created by the interaction between the *Time Trend* and *Massachusetts*. The quadratic time trend analyses simply replaced the linear time trend with time-trend squared, for both μ and Φ. The other terms were defined as in Equation (1). The results are presented in Appendix Table 3.

<u>Linear Model</u>
For comparability to prior similar analyses of insurance expansions and ease of interpretation of absolute changes,[4] we also tested the following linear model using the mortality rate per 100,000 as the outcome variable:

$$\textit{Mortality Rate}_{ijklt} = \beta_0 + \beta_M \textit{ MassReform}_{lt} + \beta_1 X_{ijk} + \beta_2 \textit{ County-Level Factors}_{lt} + \mu \textit{ Year}_t + \Omega \textit{ County}_l + \varepsilon_{ijklt} \quad \text{Equation (3)}$$

where Ω was a vector of county fixed effects (GLM models with county fixed effects did not converge due to the high number of counties, requiring the use of state fixed effects in Equation 1; the linear model enabled us to adjust for time-invariant features at the county level). The other terms were defined as in Equation (1). The results are presented in Appendix Table 4.

<u>Elderly Adults as an Additional Control Group for Non-Elderly Adults in Massachusetts</u>
To test for changes in Massachusetts' health reform for non-elderly (20-64) versus elderly adults (65 and over), we used a generalized linear model (GLM) with negative binomial family and a log link, with population size as the exposure variable, and the following equation:

$$\begin{aligned} Deaths_{ijklt} = \beta_0 + \beta X_{ijk} &+ \beta_1 \textit{ Post-Reform}_t * \textit{Non-Elderly}_i \\ &+ \beta_2 \textit{ Non-Elderly}_i * \textit{Massachusetts}_l \\ &+ \beta_3 \textit{ Post-Reform}_t * \textit{Massachusetts}_l \\ &+ \beta_4 \textit{ Post-Reform}_t * \textit{Massachusetts}_l * \textit{Non-Elderly}_i \\ &+ \beta_5 \textit{ County-Level Factors}_{lt} + \mu \textit{ Year}_t + \Omega \textit{ State}_l + \varepsilon_{ijklst} \quad \text{Equation (4)} \end{aligned}$$

where direct effects for *Massachusetts* and *Post-Reform* were captured by the state fixed effects and year fixed effects, respectively. The direct effect of *Non-Elderly* was captured by the age dummy variables, which include a cut-point at 65 years. β_3 measures the relative change in mortality after reform among elderly adults in Massachusetts compared to elderly adults in the control states. The coefficient of interest was β_4, which measured the relative change in mortality after health reform among non-elderly adults (20-64) in Massachusetts versus non-elderly adults in the control states, net of the relative change in mortality among elderly adults (65+). The other terms were defined as in Equation (1). This is also known as a "differences-in-differences-in-differences" analysis. The results are presented in Appendix Table 5.

Subgroup Analysis

To test for changes in Massachusetts' health reform among subgroups of adults ages 20-64, we used a generalized linear model (GLM) with negative binomial family and a log link, with population size as the exposure variable, and the following equation:

$$\begin{aligned} Deaths_{ijklt} = \beta_0 + \beta X_{ijk} &+ \beta_1 \, Post\text{-}Reform_t * Subgroup_A \\ &+ \beta_2 \, Subgroup_A * Massachusetts_l \\ &+ \beta_3 \, Post\text{-}Reform_t * Massachusetts_l * Subgroup_B \\ &+ \beta_4 \, Post\text{-}Reform_t * Massachusetts_l * Subgroup_A \\ &+ \beta_5 \, County\text{-}Level\ Factors_{lt} + \mu \, Year_t + \Omega \, State_l + \varepsilon_{ijklst} \end{aligned} \qquad \text{Equation (5)}$$

where direct effects for *Massachusetts* and *Post-Reform* were captured by the state fixed effects and year fixed effects, respectively. The direct effect of $Subgroup_A$ versus $Subgroup_B$ was included in the vector of covariates X_{ijk}. β_3 measured the relative change in mortality after reform among $Subgroup_A$ in Massachusetts, compared to $Subgroup_A$ in control states. β_4, measured the relative change in mortality after health reform among $Subgroup_B$ in Massachusetts versus $Subgroup_B$ in control states. The other terms were defined as in Equation (1). This approach allowed for direct post-estimation testing for between-group differences comparing β_3 and β_4. The results are presented in Appendix Table 5.

Secondary Outcomes – Coverage, Access to Care, and Health Status:

To test for changes in secondary outcomes using the CPS and BRFSS, we used a generalized linear model (GLM) with logit link, and Huber-White robust standard errors clustered at the state level, with the following equation:

$$Pr(Outcome_{ist}) = \beta_0 + \beta_M \, MassReform_{st} + \beta_1 X_{it} + \mu \, Year_t + \Omega \, State_s + \pi \, Year_t + \varepsilon_{ist} \qquad \text{Equation (6)}$$

where i indexed individuals, s states, and t year. X_i was a vector of demographics (age, race/ethnicity, gender, family income as percentage of the federal poverty level, and employment status). μ was a vector of year fixed effects, and Ω was a vector of state fixed effects. The coefficient of interest was β_M, which captured the effect of living in Massachusetts after the year 2006. Analyses of secondary outcomes (uninsured, cost-related barriers to care, usual source of care, checkup within the past year, and good/fair/poor self-reported health) all used Equation 6, with the only difference being the dependent variable.

Estimating the Magnitude of Mortality Changes Related to Coverage Expansion

Appendix Table 7 presents calculations illustrating the implications of our results for individual-level changes in mortality due to the coverage expansion in Massachusetts. This calculation used statistics from various sources: the total non-elderly adult population of Massachusetts (4.0 million) comes from the Kaiser Commission,[8] and the baseline mortality rate in this population (283/100,000 = 0.283%) comes from Table 3. We used the total of 6.8% new insurance enrollees estimated in Table 5. Next we assumed a 30% individual mortality reduction of acquiring insurance, based on prior research.[9,10] Then, we calculated what baseline mortality rate was necessary among new insurance enrollees to have all of the above parameters yield a population-wide mortality reduction due to health reform equal to the result in Table 3 (2.9%). The overall conclusion is that the baseline mortality for new insurance enrollees must be 0.400% (400/100,000) to produce a population-wide mortality reduction from the state's health reform that is consistent with our findings in Table 3.

Sensitivity of Results to Omitted Confounders

To assess the sensitivity of our mortality results to the possibility of an omitted confounder, we followed the approach in Vanderweele et al. (2011).[11] We posited the existence of an unmeasured confounder variable U with a prevalence 10% higher in the Massachusetts population after its health reform than before health reform, with no comparable change in U in the control group during this period. For this confounder to explain the full absolute decline in estimated population mortality (-8.2 deaths per 100,000), the baseline mortality reduction for those with U = 1 compared to the general population (U=0) would need to be X, where 0.10 * -X = -8.2/100,000.

Solving this equation, X = 82 / 100,000. This would amount to a 29% lower mortality rate for those with trait U than for the general Massachusetts population (82 / 283 = 29%).

Overall, we would need to posit a fairly high-prevalence of an unmeasured confounder that increased substantially after reform *only* in Massachusetts (+10 percent of the population) and that has a sizable impact on mortality, cutting it by nearly 30% compared to baseline. Other than the major change in health insurance coverage during this period, it is difficult to identify what such a factor might have been that was not already included in our regression covariates and that did not also affect the elderly population.

Appendix Table 1: Definitions of Deaths Amenable to Health Care

Condition(s)	**ICD-10 Codes**	**Nolte & McKee Definition**	**Authors' Revised Definition**
Infectious & Parasitic Diseases (*ALL*)	A00-B99		X
-Tuberculosis	A16-19, B90	X	X
-Other specific infections (diphtheria, tetanus, septicemia, poliomyelitis, whooping cough, measles)	A35-A37, A40-41, A80, B05	X	X
Neoplasms (*ALL*)	C00-D48		X
-Malignant neoplasm of colon and rectum	C18-C21	X	X
-Malignant neoplasm of skin	C44	X	X
-Malignant neoplasm of breast	C50	X	X
-Malignant neoplasm of cervix or uterus	C53-C55	X	X
-Malignant neoplasm of testis	C62	X	X
-Hodgkin's disease	C81	X	X
-Leukemia	C91-C95	X	X
Disorders of thyroid gland	E00-E07	X	X
Diabetes Mellitus	E10-E14	X	X
Epilepsy	G40-G41	X	X
Chronic rheumatic heart diseases	I05-I09	X	X
Hypertensive diseases	I10-I13, I15	X	X
Ischemic heart diseases	I20-I25	X	X
Cardiomyopathy	I42		X
Atrial fibrillation and flutter	I48		X
Other cardiac arrhythmias	I49		X
Heart failure	I50		X
Cerebrovascular diseases	I60-I69	X	X
All respiratory diseases	J00-J98	X	X
Gastric and duodenal ulcers	K25-K27	X	X
Gastrojejunal ulcers	K28		X
Diseases of appendix	K35-K38	X	X
Hernia	K40-K46	X	X
Diseases of gallbladder and biliary tract	K80-K83	X	X
Acute pancreatitis	K85		X
Infections of the skin and subcutaneous tissue	L00-L08		X
Infectious arthropathies	M00-M02		X
Glomerular diseases	N00-N07	X	X
Renal tubulo-interstitial diseases	N10-N15		X
Renal failure	N17-N19	X	X
Unspecified contracted kidney, small kidney unknown cause	N26-N27	X	
Hyperplasia of prostate	N40	X	
Pregnancy, childbirth and the puerperium	O00-O99	X	X
Congenital malformations originating in the perinatal period	P00-P96	X	
Misadventures to patients during surgical and medical care	Y60-Y69, Y83-Y84	X	X

Appendix Table 2: Variables Used to Calculate Propensity Score

Variable	Odds Ratio	95% Confidence Interval		P Value
Ages 20-34	0.7959	0.5674	1.1163	0.186
Ages 35-44	0.7819	0.4211	1.4519	0.44
Ages 45-54	0.4389	0.1509	1.2769	0.131
Ages 55-64	1.0000	--	--	reference
Male	0.1595	0.0564	0.4507	0.001
White	0.9879	0.9421	1.0360	0.62
Black	0.8450	0.6931	1.0302	0.096
Other Race	1.0000	--	--	reference
Latino	0.9868	0.8929	1.0907	0.80
Poverty Rate	0.9846	0.7848	1.2352	0.89
Median Household Income	1.0000	0.9999	1.0001	0.65
Unemployment Rate	1.4645	1.0873	1.9726	0.012
Percent Uninsured	0.6345	0.5311	0.7580	<0.001
Mortality Rate 2001	0.9934	0.9762	1.0108	0.45
Mortality Rate 2002	1.0134	0.9999	1.0271	0.052
Mortality Rate 2003	1.0100	0.9982	1.0220	0.097
Mortality Rate 2004	1.0027	0.9930	1.0126	0.58
Mortality Rate 2005	0.9841	0.9723	0.9960	0.009
Mortality Rate 2006	0.9870	0.9670	1.0074	0.21
Constant Term	2.23E+56	6.83E+38	7.31E+73	<0.001

Notes: Based on population-weighted county-level logistic regression model using 2000-2006 data for adults ages 20-64. Mortality rates were expressed as deaths per 100,000 adults, and median household income in 2010 inflation-adjusted dollars. All other variables are expressed in percentage points (0-100).

Appendix Table 3: Tests of Pre-Reform Mortality Trends (per 100,000 Adults) in Massachusetts versus Control Group and Overall United States

Comparison Group Relative to Massachusetts	Differential Trend for Massachusetts vs. Control Group	95% CI	P value	Differential Trend for Massachusetts vs. Other U.S. States	95% CI	P value
Linear Time Trend, 2001-2006	-1.1	-2.4, 0.3	0.120	-1.9	-2.9, -0.8	<0.001
Quadratic Time Trend, 2001-2006	-0.15	-0.34, 0.04	0.116	-0.27	-0.42, -0.12	<0.001

Appendix Table 4:
Sensitivity Analyses of Estimates of Mortality Changes After Massachusetts' Health Reform Among Adults 20-64 (2001-2010)

MODEL	Difference in Change, Massachusetts vs. Control Group	95% CI	P value
Alternative Propensity Score (PS) Methods and Control Groups, All-Cause Mortality			
PS Regression Adjustment, in deciles, for all U.S. counties in areas of PS overlap with Massachusetts counties	-2.5%	-4.0, -1.0	0.001
PS Matching (2:1 control:treatment)*	-8.2%	-12.6, -3.7	<0.001
Baseline Model, excluding states with major Medicaid expansions†	-3.3%	-5.9, -0.7	0.012
Baseline Model, with Alternative Standard Errors			
Unadjusted all-cause mortality, county-level clustering	-4.2%	-7.2, -1.2	0.006
Adjusted all-cause mortality, county-level clustering	-2.9%	-5.5, -0.2	0.033
Unadjusted health-care amenable mortality, county-level clustering	-4.3%	-7.8, -0.8	0.015
Adjusted health-care amenable mortality, county-level clustering	-4.5%	-8.4, -0.5	0.028
Linear Model, with Death Rate (per 100,000) as Outcome			
Unadjusted all-cause mortality	-11.4	-22.3, -0.5	0.040
Adjusted all-cause mortality	-6.4	-10.8, -2.0	0.006
Adjusted all-cause mortality, with county fixed effects*	-9.3	-16.7, -1.9	0.014
Unadjusted health-care amenable mortality	-7.2	-12.3, -2.0	0.007
Adjusted health-care amenable mortality	-4.5	-8.3, -0.6	0.024
Adjusted health-care amenable mortality, with county fixed effects*	-7.5	-10.2, -4.7	<0.001
State-Level Analyses§			
Unadjusted state-level mortality	-4.1%	-7.7, -0.5	0.025
Adjusted state-level mortality	-2.3%	-5.1, 0.5	0.103
Unadjusted state-level health-care amenable mortality	-4.2%	-6.8, -1.6	0.002
Adjusted state-level health-care amenable mortality	-4.5%	-6.5, -2.6	<0.001
Alternative Time Frame or Analytic Frame, All-Cause Mortality			
Include 2006 as the first post-reform year	-3.5%	-5.3, -1.8	<0.001
Interrupted times series (pre-reform vs. post-reform trend)#	-1.0% per year	-1.8, -0.3	0.006
Pre-reform versus post-reform pooled data (instead of yearly)	-3.1%	-5.2, -1.1	0.003
Individual-level Latino ethnicity (omitting those with ethnicity unknown)¶	-3.0%	-4.7, -1.4	<0.001

Notes:
* The baseline GLM model uses state level fixed effects; due to the number of counties in the baseline sample, the GLM models do not converge when using county fixed effects. For the PS match model with a much smaller number of counties, and in the linear models, we are able to adjust for time-invariant county-level features using county fixed effects.

† Excluded states were Arizona, Illinois, Maine, and New York, which all implemented large Medicaid expansions to adults between 2001 and 2010.[15]
§ Analysis conducted using the same control group but with mortality data aggregated to the state level (using state-year-age-sex-race cells as the unit of analysis).
# Replaces year fixed effects with a linear time trend, and replaces *Massachusetts Post Reform* binary variable with an interaction term between *Massachusetts* and *Years Since Reform* (i.e., *year* – 2006).
¶ This model adjusts directly for Latino ethnicity, which requires omitting from the sample any deaths with "unknown" ethnicity, since the dataset has no corresponding population denominator for that group necessary to calculate a death rate. This accounts for 0.3% of deaths among 20-64 years old nationally; omitting these deaths results in a reduction in the estimated national mortality rate of -1.2 deaths per 100,000.

Appendix Table 5: Analyses of Mortality Changes After Massachusetts' Health Reform Among Adults 20-64, Using Elderly Adults as an Additional Control Group (2001-2010)

OUTCOME and Variable	Negative Binomial GLM			Linear Regression of Ln(Death Rate), with County Fixed Effects#		
ALL CAUSE MORTALITY	**Coefficient**	**95% CI**	**P value**	**Coefficient**	**95% CI**	**P value**
Post-Reform*Massachusetts*Non-Elderly†	-3.3	-6.6, 0.2	0.066	-3.9	-7.8, -0.1	0.046
Post-Reform*Massachusetts§	0.1	-2.5, 2.7	0.93	-0.3	-1.5, 0.9	0.61
HEALTH-CARE AMENABLE MORTALITY	**Coefficient**	**95% CI**	**P value**	**Coefficient**	**95% CI**	**P value**
Post-Reform*Massachusetts*Non-Elderly†	-4.9	-7.1, -2.7	<0.001	-5.3	-7.9, -2.7	<0.001
Post-Reform*Massachusetts§	0.2	-2.4, 2.7	0.90	-1.1	-2.3, 0.2	0.096

Notes:

† Measures the differential change for non-elderly adults in Massachusetts relative to the control group, subtracting out the analogous changes among elderly adults.

§ Measures the differential change for elderly adults in Massachusetts, relative to elderly adults in the control group.

The baseline GLM model uses state level fixed effects; due to the number of counties in the baseline sample, the GLM models do not converge when using county fixed effects. For the linear model, we are able to adjust for time-invariant county-level features using county fixed effects.

Appendix Table 6: Sensitivity Analyses of Access to Care and Health Status, After Massachusetts' Health Reform

OUTCOME	Logit GLM, Robust Standard Errors, No Clustering				Linear Probability Model, Robust Standard Errors with State Clustering		
	Adjusted Odds Ratio, Post-Massachusetts Health Reform	95% CI	P value	Absolute Change in Predicted Probability (percentage points)	Difference in Change, Massachusetts vs. Control Group (percentage points)	95% CI	P value
Uninsured	0.43	0.37, 0.49	<0.001	-6.8	-6.8	-7.4, -6.3	<0.001
Delayed Care Due to Cost in Past Year	0.78	0.70, 0.87	<0.001	-2.0	-2.0	-3.3, -0.8	0.009
No Usual Source of Care	0.84	0.77, 0.91	<0.001	-1.9	-1.7	-2.6, -0.8	0.006
No Preventive Doctor's Visit in Past Year	0.82	0.74, 0.91	<0.001	-4.0	-3.8	-4.8, -2.8	<0.001
Good/Fair/Poor Self-Reported Health (versus Excellent/Very Good)	0.92	0.86, 0.98	0.008	-1.8	-1.8	-2.9, -0.8	0.007

Notes: Analyses comparing these outcomes in Massachusetts to the propensity-score defined set of comparison counties (as in Tables 1-4) is not possible due to a lack of county-identifying information in these datasets.
GLM = Generalized Linear Model

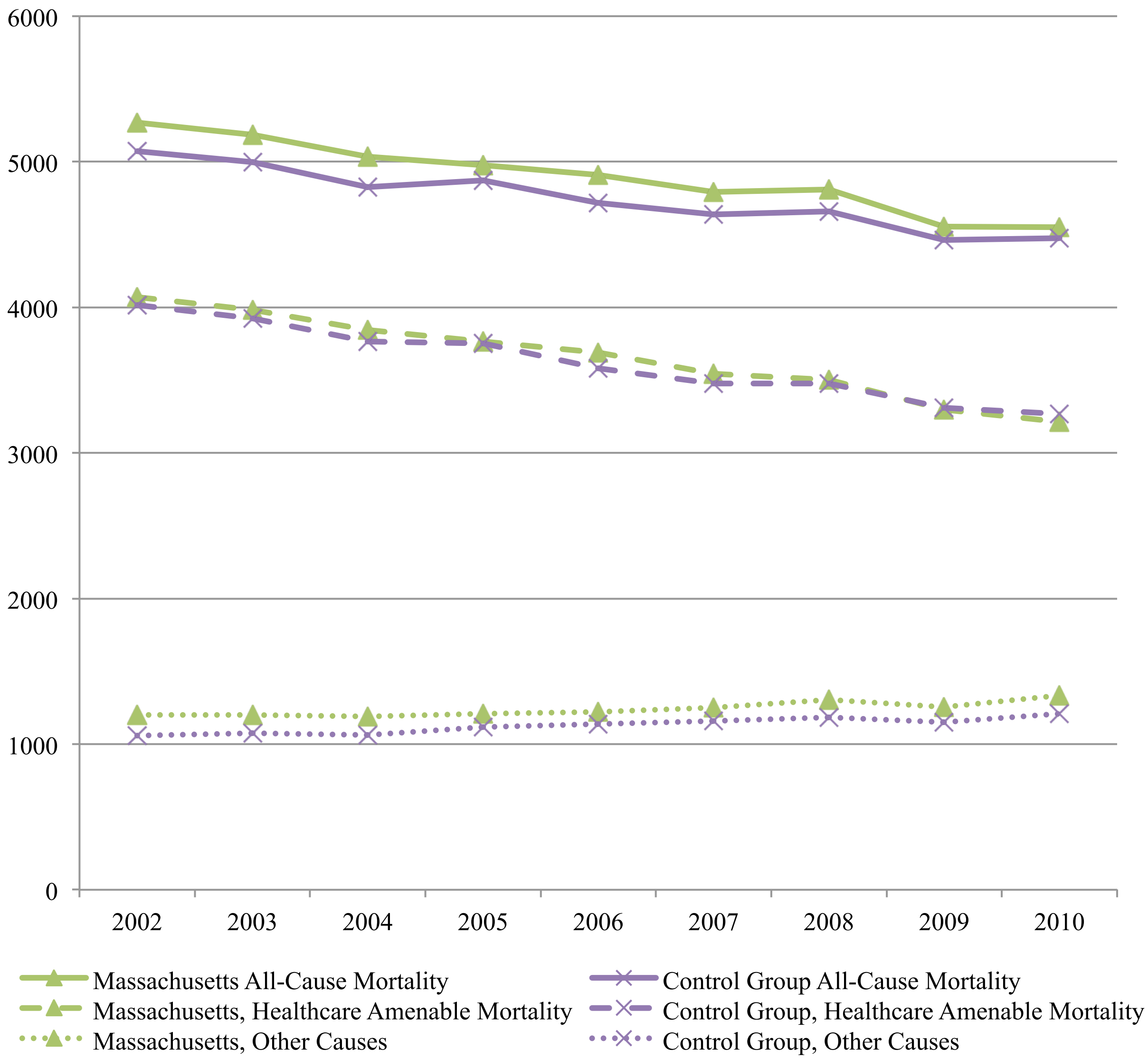
Appendix Table 7: Calculation of Simulated Mortality Benefit from Massachusetts' Health Reform

PRE-REFORM			
Group	**N**	**Mortality Rate**	**Deaths**
New Insurance Enrollees	272,000	0.400%	1,088
All Other Adults	3,728,000	0.274%	10,232
TOTAL	4,000,000	0.283%	11,320
POST-REFORM			
Group	**N**	**Mortality Rate**	**Deaths**
New Insurance Enrollees	272,000	0.280%	762
All Other Adults	3,728,000	0.274%	10,232
TOTAL	4,000,000	0.275%	10,994

Individual Mortality Reduction = (0.400% - 0.280%) / 0.400% = 30%
Population-Wide Mortality Reduction = (11,320 - 10,994) / 11,320 = 2.9%
Number Needed to Treat = 272,000 / (1088-762) = 830

Note:
See description of methods in Appendix.

Appendix Figure 1: Unadjusted Mortality Rates for Elderly Adults (65 and Older) from 2001-2010



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