Did the Great Recession increase suicides in the USA? Evidence from an Interrupted Time Series analysis.

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Abstract

Background Research suggests that the Great Recession of 2007-2009 led to nearly 5000 excess suicides in the United States. However, prior work has not accounted for seasonal patterning and unique suicide trends by age and gender.

Methods We calculated monthly suicide rates from 1999-2013 for men and women aged 15 and over. Suicide rates prior to the Great Recession were used to predict the rate during and after the Great Recession. Death rates for each age-gender group were modeled using Poisson regression with robust variance, accounting for seasonal and non-linear suicide trajectories.

Results There were 56658 suicide deaths during the Great Recession. Age- and gender-specific suicide trends prior to the recession demonstrated clear seasonal and non-linear trajectories. Our models predicted 57140 expected suicide deaths, leading to 482 fewer observed than expected suicides (95% confidence interval -2079, 943).

Conclusions We found little evidence to suggest that the Great Recession interrupted existing trajectories of suicide rates. Suicide rates were already increasing prior to the Great Recession for middle-aged men and women. Future studies estimating the impact of recessions on suicide should account for the diverse and unique suicide trajectories of different social groups.

Background

The worldwide financial crisis of the late 2000s has led to renewed interest in how economic conditions affect population health. In particular, several studies have attempted to quantify the impact of economic recessions on deaths from suicide [1–14]. Recent reviews of the evidence generally suggest that suicide deaths rise during economic recessions, but that the magnitude of the effect varies across social contexts [15–18]. More specifically, studies of the impact of the “Great Recession” of the late-2000s have reported large numbers of excess suicides in North America, particularly in the United States [1, 4, 7, 14].

Despite a number of studies on this topic, several key issues with prior studies remain. First, some studies have either used age-standardized suicide rates or have adjusted for age in regression models. The former can lead to bias if important covariates (e.g., unemployment rates) should also be age-standardized [19], and the latter assumes that secular trends in suicide are similar by age, though there is good evidence to the contrary [20–22]. Age-adjustment masks this heterogeneity, and may have unpredictable impacts on the estimated number of excess suicides [23].

Second, many studies modeled pre-recession trends as linear and used these models to predict “expected” suicide rates in the absence of the Great Recession [1, 4, 7]. However, suicide trends in the USA and elsewhere show evidence of non-linearity and seasonality [21, 24, 25]. Failing to account for these temporal patterns of suicide could produce over- or under-estimates of the impact of the Great Recession.

In this paper we provide an updated and refined estimate of the number of suicides that may have been caused by the Great Recession. First, we use an interrupted time series design that accounts for potential non-linearities in pre-recession trends, relaxing the assumption in prior work that rates were changing linearly prior the Great Recession. Second, we analyze age and gender groups separately to account for the unique trajectories that may arise from factors unrelated to the Great Recession [26]. Third, we control for seasonal patterning in suicide rates. Prior estimates have ignored the fact that suicide is seasonal, with peaks in spring/summer, and valleys in fall/winter. Seasonal patterning is potentially consequential because the Great Recession, which officially began in December 2007 [27], coincided with a traditional seasonal valley in suicide rates. Thus, some component of the “rise” after late 2007 in suicide could reflect pure seasonality rather than a response to the Great Recession. Finally, as a check on whether our modeling strategy is capable of detecting mortality changes consequent to the Great Recession, we also evaluate its impact on another outcome

that has been strongly linked to economic downturns: reduced motor vehicle crash (MVC) deaths [28–30].

Methods

Data and Variables

We abstracted data on monthly deaths by age and gender for 1999-2013 from the Centers for Disease Control (CDC) and Prevention’s Detailed Mortality Files [31]. We obtained monthly population estimates from the US Census Bureau [32–34] for 1999, 2000, and 2010-2013, and estimates for April and July from 2000 to 2010, which we used to linearly interpolate for missing months. We defined suicide and MVC deaths using the International Classification of Diseases, Tenth Revision (ICD-10) coding scheme used by the US National Center for Health Statistics (specific ICD codes are given in Table 1). Given the diversity of trends in suicide rates by gender and age we did analyses separately for men and women and for four broad age groups: 15-24 years, 25-44 years, 45-64 years, and 65 years and above. Prior studies have also used these age categories [4, 35].

We retrieved counts of deaths and population denominators for 180 months spanning January 1999 to December 2013. We chose this time span to permit direct comparisons between our results and prior estimates of excess suicides during the Great Recession. This time span also allows sufficient time for detection of temporal patterns in monthly mortality data that may carry forward into, but not be caused by, the months of the Great Recession. We used the official dates of the beginning and end of the Great Recession as defined by the US National Bureau of Economic Research (NBER) [27]. The NBER marks recession dates based on significant declines in a broad range of economic indicators, including real gross domestic product, employment, industrial production, and wholesale-retail sales. The NBER committee defined the Great Recession as beginning in December 2007, primarily based on declines in domestic production and employment, and ending in June of 2009.

Statistical Analysis

We used an interrupted time-series design to test whether the number of suicides increased above its expected value during the Great Recession. Our tests turn on the notion that the recession “interrupted” the mortality time series, such that the mean monthly rate of mortality rises above or below what we would have expected from prior trends had the Great Recession not occurred. The key assumption for an interrupted time series design is that the pre-intervention trend provides a

suitable estimate for the mortality rates that would have occurred during the intervention period, had the Great Recession not occurred [36, 37].

The time-series literature does not converge on one single method to derive a counterfactual expectation for a post-intervention period. We addressed this issue empirically by using two distinct modeling strategies and comparing their forecast performance of suicides from December 2006 to November 2007—the year before the start of the Great Recession. We compared Box-Jenkins [38] Autoregressive Integrated Moving Average (ARIMA) and restricted cubic spline models, and used method that showed the best forecast performance (pre-Great Recession), as indicated by the smallest symmetric mean absolute percent error. [39] The restricted cubic spline method showed a lower percent error (6.6% vs 7.3% for the ARIMA forecast, results available upon request).

We modeled the pre-intervention monthly mortality trends from January 1999 to November 2007 using Poisson regression with monthly deaths as the outcome, log population size as the offset term, and robust standard errors. In order to capture any non-linearities in the pre-intervention trends we used restricted cubic splines placed at the 25th, 50th, and 75th percentiles of pre-recession time [40], and adjusted for seasonality [25] using indicator variables for each month. To find the most parsimonious model for pre-intervention trends we used an algorithm developed by Royston and Sauerbrei [41] that compares model deviance differences between successive spline models to find the best fit, while preserving the overall type I error rate at $\alpha = 0.05$. The algorithm compares models using a χ^2 test with $m + 1$ degrees of freedom, where m refers to the maximum number of spline knots. If spline terms do not improve model fit then more complex terms are dropped in favor of a linear trend.

We used the parameter estimates from these pre-intervention models to generate the predicted number of suicides in each month during the Great Recession, and compared our predictions in each month to the observed number of deaths. To calculate 95% confidence intervals (CIs) we replicated this procedure 500 times using repeated bootstrap samples (with replacement) of the data. Analyses were conducted using Stata (version 14.1) and R software (<http://r-project.org>). The data and statistical code to replicate our results have been posted to a public repository (<https://dataverse.harvard.edu/dataverse/samharper>). Given the de-identified, aggregate-level nature of the mortality data, our analysis did not warrant human subjects review.

Sensitivity Analysis

To our knowledge, no other studies have attempted to account for seasonality and used an interrupted time series design to estimate excess deaths due to the Great Recession in the USA. We therefore contextualize our approach by using the same model to assess whether we could detect any recessionary impact on MVC deaths, which prior research shows strongly decline during economic downturns [28–30]. Although we take the NBER Business Cycle Dating Committee’s estimates of the beginning and end of the Great Recession as valid, when there is uncertainty in the precise timing of an intervention it is good practice to conduct some robustness checks [42]. We therefore conducted sensitivity analyses using either November 2007 or January 2008 as the starting date for the Great Recession.

Results

Table 1 shows raw counts of suicide and motor vehicle crash deaths and monthly rates per 100,000 population, by gender and age group across the entire period from 1999 to 2013. Rates of both outcomes are higher among men, suicide rates are generally higher among older age groups, and motor vehicle crashes are highest among the youngest and oldest age groups.

Observed and Expected Events

The best-fitting model estimates for each of the age and gender groups are given in Appendix Tables 1 and 2. For a number of the age and gender groups there was evidence of non-linearity in the pre-recession trends (especially for middle-aged men), necessitating the use of splines, and virtually all of the models for suicide demonstrated some persistent seasonal variation, with the highest rates during the spring and summer months. Figures 1 and 2 show the observed and loess-smoothed (bandwidth=0.25) monthly suicide rates and loess-smoothed expected monthly rates (per 100,000) after the Great Recession based on the best fitting pre-recession model. The pattern of results for suicide differed considerably by age. Among both men and women aged 15-24 years and 65 years and over the predicted suicide rates were lower than the observed rates during the Great Recession, but the opposite was true for those aged 25-64. Suicide rates for those aged 25-64 were already rising prior to the onset of the Great Recession and this increase actually leveled off during and after the Great Recession.

Table 2 shows the observed, expected, and observed minus expected suicides during the Great Recession, based on predictions from pre-recession trends. Across all age and gender groups there were 56,658 suicides observed and 57,140 expected during the Great Recession, leading to 482 fewer suicides than expected (95% CI -2079, 943). The only age-gender groups with estimated excess deaths statistically distinguishable from zero were for men aged 65 and over (378 deaths, 95% CI 104, 691) and women aged 15-24 (218 deaths, 95% CI 57, 416).

Table 3 reports the observed and expected estimates for motor vehicle crashes (the best-fitting model coefficients are shown in Appendix Tables 3 and 4 and plots of the observed and expected rates are shown in Appendix Figures 1 and 2). Overall we observed 6610 fewer motor vehicle crash deaths than were expected based on pre-recession trends (95% CI -9299, -5150), and the Great Recession was associated with fewer deaths in all age and gender groups, though not statistically distinguishable from 0 for women aged 45 and over.

Sensitivity Analysis

Appendix Tables 5 and 6 show the results from defining the Great Recession as starting 1 month prior to the official dating by NBER. For suicide this changed the impact to a reduction of 615 deaths (95% CI -2382 to 1014). For motor vehicle crash deaths this increased the magnitude of the impact of the Great Recession from 6610 to 7289 fewer-than-expected deaths (95%CI -9158 to -5210). Allowing the start date to lag by 1 month (Appendix Tables 7 and 8) led to an estimated 443 fewer observed than expected suicide deaths (95%CI -2016 to 989), and 5799 fewer observed than expected MVC deaths (95%CI -8130 to -4231).

Discussion

Our aim in this study was to estimate the number of excess suicides in the USA that may have occurred during the Great Recession. Estimating this effect is complicated by heterogeneity in suicide rates by age and gender, and by strong seasonal and long-term trends in suicide rates. Using an interrupted time series design, we found little evidence that the Great Recession resulted in net excess suicides across all age and gender groups. However, we did find some evidence of excess suicides during the Great Recession among men aged 65 and over and women aged 15-24 years.

Our results contrast rather strikingly with prior estimates of excess deaths during the Great Recession. Whereas we found an imprecisely estimated net reduction of 482 suicides, using national

data Chang et al. [4] reported 1869 more suicides (95% CI 1457, 2280) in 2008 and 2309 more suicides (95% CI 1850, 2767) in 2009 among men relative to expected numbers. The corresponding numbers for women in 2008 and 2009 were 161 (95% CI 36, 286) and 181 among women (95% CI 39, 323), for a total among both genders of 4520 excess suicides. Using data from the 50 states Reeves et al. [1] estimated a similar total of 4750 excess deaths (95% CI 2570, 6920) from 2008 to 2010, and DeFina and Hanson [14] reported 891 additional suicides per year during the Great Recession based on 1970-2010 state-level panel model with linear trends, after allowing the effect of unemployment to vary during the Great Recession. Other studies have estimated the number of excess deaths during the Great Recession by taking an estimate of the effect of unemployment on suicide and scaling it by the magnitude of the increase in unemployment during the Great Recession [1, 14]. This approach has some merit, but hinges on the validity of the causal effect of unemployment on aggregate suicide rates, about which there remains some controversy [12, 28, 35].

Another important divergence between our results and those of prior studies concerns which age and gender groups have been most affected by the Great Recession. Most prior work and syntheses of evidence, including US studies, have argued that working age men have been most adversely affected [15–17]. In contrast, we found that the only age-gender groups that demonstrated excess deaths due to the recession were men aged 65 and over and women aged 15-24 years. Our results suggest that failing to account for non-linear patterns in suicide prior to the Great Recession in earlier studies is likely to explain these divergent results, both in terms of net excess deaths and the social groups most affected by the recession. In particular, for middle-aged men there was strong evidence of both seasonal patterning and non-linear increases in suicide prior to the recession. It is worth noting that when we forced our Poisson model to include only a linear time trend and ignored seasonality, we found evidence more consistent with excess suicide deaths (1117 deaths, 95% CI 91, 2188) during the Great Recession (see Appendix Table 9). This estimate is still considerably smaller than prior estimates and may be due to using age- and gender-specific rates or limiting the calculation of excess deaths to the period of the Great Recession. Nevertheless, our results suggest that estimates of the number of excess deaths are quite sensitive to how the pre-recession trends are modeled.

Prior US studies on the Great Recession and suicide have generally not allowed for non-linearity and seasonality, though interrupted time series analyses in Spain [3], Greece [43] and Ireland [13] have shown detrimental impacts of the Great Recession on suicide. The presence of seasonal and long-term trends complicates interrupted time series designs, but accounting for such factors in the pre-intervention period is the crucial assumption for the validity of any interrupted time series

analysis [36, 37, 44, 45]. We used an algorithm [41] to select the most parsimonious model based on pre-recession trends in each demographic group, and it seems plausible that our results differ from prior studies because the pre-intervention trends differ substantially by demographic group. Moreover, using the same design we found robust, consistent evidence that the Great Recession had a strong and sizable impact on reducing deaths due to motor vehicle crashes, which has been documented in prior studies [29, 30, 46, 47] but has received far less attention than potential excess suicides.

Though we find little evidence for a net discontinuity in suicide trends due to the Great Recession, there remains considerable evidence linking changing economic conditions to suicide [15–17]. One key point of much of this work is that the institutional context in which economic disruptions occur may modify any impact on suicide rates [48]. For example, it has been argued that the impact of recessions is weaker or not evident in places with stronger labor market protections, such as Scandinavia [7, 49]. However, recent cross-national work in Europe [12] found heterogeneity in the effect across countries that is inconsistent with this hypothesis. Other studies have noted that the association between unemployment and suicide was stronger in places with a lower pre-recession unemployment rate [4, 35, 49]. In the USA, DeFina and Hannon found the association between unemployment strengthened during the Great Recession [14], whereas Harper et al. [21] found that the effect of economic conditions in US states varied over time and by demographic group, and noted weak effects during the period of the Great Recession.

Our study has limitations. We used an observational study design based on aggregate data and unmeasured confounding can never be ruled out. We only used information on suicide deaths, which are a severe manifestation of mental distress. The Great Recession is reported to have increased the risk of psychological distress and substance abuse [15, 17], and our results may not generalize to those outcomes. We also used aggregate, nationwide data to conduct our analysis, which may mask important regional heterogeneity in suicide rates, as well as the variation in the economic consequences of the Great Recession [21]. States most adversely affected by the Great Recession included those with both higher than average suicide rates (e.g., Nevada, Arizona), and lower than average rates (e.g., Michigan, Ohio), so state-specific analyses are likely to show heterogeneous effects. Results could also differ by race, but national trends are largely driven by suicide among whites. We also focused specifically on suicides during the Great Recession, a period characterized by multiple measures of economic conditions and not just unemployment, so our results should be put in context with other work on business cycles and suicide.

In sum, we find little evidence of a population-wide shift in suicide rates attributable to the onset of the Great Recession, which implies that other factors likely account for the strong secular trends observed in suicides among age and gender groups in the United States. Our results should not be interpreted to mean that economic conditions are unrelated to suicide. The rise in suicide rates among middle-aged Americans since the early 2000s is consistent with a number of other unfavorable social indicators, including a decade or more of declining economic prospects [50], rising disability due to mental illness [51], and the epidemic of prescription opioid abuse [52]. All of these factors may contribute to the increasing rates of suicide in the US, a problem that lies much deeper than the Great Recession and deserves additional research attention.

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Figure Legend

Figure 1: Observed and predicted monthly suicide rates (per 100,000 population) for men based on best-fitting restricted cubic spline model (Note: shaded area indicates the Great Recession).

Figure 2: Observed and predicted monthly suicide rates (per 100,000) for women based on best-fitting restricted cubic spline model (Note: shaded area indicates the Great Recession).

Table 1: Monthly death rates from suicide and motor vehicle crashes, by age and gender, 1999-2013.

Gender and age	Population ^a	Suicide rates ^b				Motor vehicle crash rates ^b			
		Deaths	Mean	Min	Max	Deaths	Mean	Min	Max
<i>Men</i>									
15-24 yrs	324.4	53781	1.38	1.09	1.66	101842	2.63	1.32	3.85
25-44 yrs	624.6	141918	1.89	1.58	2.35	140453	1.87	1.15	2.45
45-64 yrs	539.8	138821	2.12	1.59	2.81	106482	1.65	1.05	2.09
65+ yrs	242.9	72507	2.49	1.93	3.06	62836	2.18	1.34	3.10
<i>Women</i>									
15-24 yrs	308.4	10781	0.29	0.17	0.48	40223	1.09	0.60	1.68
25-44 yrs	624.0	37983	0.51	0.38	0.68	49563	0.66	0.44	0.89
45-64 yrs	567.7	44288	0.64	0.39	0.86	42858	0.64	0.40	0.87
65+ yrs	329.4	13590	0.34	0.21	0.52	43431	1.11	0.64	1.63
Total	3561.3	513669	1.21	0.17	3.06	587688	1.48	0.40	3.85

^a In millions. ^b Per 100,000 population.

ICD-10 codes: Suicide (*U03,X60-X84,Y87.0) Motor vehicle crashes (V02-V04,V09.0,V09.2,V12-V14,V19.0-V19.2,V19.4-V19.6,V20-V79,V80.3-V80.5,V81.0-V81.1,V82.0-V82.1,V83-V86,V87.0-V87.8,V88.0-V88.8,V89.0,V89.2).

Table 2: Observed and expected suicide deaths during the Great Recession (Dec 2007 to June 2009) based on pre-intervention trends.^a

Gender and age group	Suicide deaths		Observed - expected deaths		
	Observed	Expected	Difference	95%CI LL	95%CI UL
<i>Men</i>					
15-24 yrs	5634	5494	140	-43	364
25-44 yrs	14811	15495	-684	-1635	157
45-64 yrs	16746	17186	-440	-1751	723
65+ yrs	7642	7264	378	104	691
<i>Women</i>					
15-24 yrs	1175	957	218	57	416
25-44 yrs	4047	4053	-6	-182	203
45-64 yrs	5203	5371	-168	-439	23
65+ yrs	1400	1321	79	-14	193
Total	56658	57140	-482	-2079	943

^a Based on separate Poisson regression models with robust standard errors for each gender-age group using population as the offset and adjusted for month of death. See Appendix for model estimates.

Table 3: Observed and expected motor vehicle crash (MVC) deaths during the Great Recession (Dec 2007 to June 2009) based on pre-intervention trends.^a

Gender and age group	MVC deaths		Observed - expected deaths		
	Observed	Expected	Difference	95%CI LL	95%CI UL
<i>Men</i>					
15-24 yrs	9800	11759	-1959	-3353	-1008
25-44 yrs	14094	15601	-1507	-2765	-551
45-64 yrs	11565	12641	-1076	-2140	-523
65+ yrs	6152	6856	-704	-1112	-318
<i>Women</i>					
15-24 yrs	3708	4352	-644	-1154	-270
25-44 yrs	4632	5089	-457	-984	-195
45-64 yrs	4468	4667	-199	-681	68
65+ yrs	3970	4035	-65	-458	85
Total	58389	64999	-6610	-9229	-5150

^a Based on separate Poisson regression models with robust standard errors for each gender-age group using population as the offset and adjusted for month of death. See Appendix for model estimates.

Figure 1: Observed and predicted monthly suicide rates (per 100,000 population) for men based on best-fitting restricted cubic spline model (Note: shaded area indicates the Great Recession).

Figure 2: Observed and predicted monthly suicide rates (per 100,000) for women based on best-fitting restricted cubic spline model (Note: shaded area indicates the Great Recession).

Appendix

Table A.1: Best-fitting pre-recession spline models for men: suicide

	15-24 yrs	25-44 yrs	45-64 yrs	65+ yrs
Month of year vs. Jan				
Feb	-0.140 [-0.207,-0.074]	-0.118 [-0.155,-0.080]	-0.103 [-0.143,-0.063]	-0.108 [-0.160,-0.057]
Mar	-0.016 [-0.066,0.034]	-0.003 [-0.043,0.038]	0.014 [-0.020,0.049]	0.034 [-0.007,0.075]
Apr	-0.039 [-0.086,0.007]	-0.030 [-0.069,0.009]	0.025 [-0.014,0.064]	0.011 [-0.036,0.057]
May	-0.005 [-0.055,0.046]	0.006 [-0.031,0.043]	0.049 [0.012,0.087]	0.097 [0.054,0.140]
Jun	-0.094 [-0.150,-0.038]	-0.003 [-0.044,0.038]	-0.007 [-0.047,0.033]	0.050 [0.012,0.088]
Jul	-0.017 [-0.079,0.044]	0.017 [-0.023,0.056]	0.050 [0.010,0.091]	0.100 [0.060,0.140]
Aug	-0.060 [-0.120,0.000]	0.005 [-0.034,0.043]	0.016 [-0.019,0.051]	0.053 [0.016,0.090]
Sep	-0.063 [-0.113,-0.013]	-0.037 [-0.084,0.010]	-0.047 [-0.092,-0.001]	-0.026 [-0.075,0.022]
Oct	-0.020 [-0.073,0.034]	-0.035 [-0.073,0.002]	-0.028 [-0.064,0.007]	-0.025 [-0.063,0.013]
Nov	-0.046 [-0.092,0.001]	-0.076 [-0.119,-0.034]	-0.071 [-0.107,-0.034]	-0.055 [-0.095,-0.015]
Dec	-0.172 [-0.232,-0.112]	-0.088 [-0.122,-0.053]	-0.083 [-0.123,-0.043]	-0.117 [-0.161,-0.073]
Time as linear term				
Time (linear)	-0.001 [-0.001,-0.000]			-0.001 [-0.002,-0.001]
Time using splines				
Time (base)		0.078 [0.033,0.123]	0.184 [0.132,0.236]	
Spline knot (25th %ile)		0.027 [0.004,0.050]	0.038 [0.012,0.064]	
Spline knot (50th %ile)		0.015 [0.004,0.026]	0.025 [0.013,0.036]	
Spline knot (75th %ile)		-0.014 [-0.025,-0.004]	-0.019 [-0.030,-0.008]	
Constant	-10.788 [-10.979,-10.597]	-10.812 [-10.861,-10.762]	-10.700 [-10.752,-10.648]	-9.873 [-10.015,-9.731]

N=107, 95% CI in brackets. Coefficients from Poisson model with robust variance.

Table A.2: Best-fitting pre-recession spline models for women: suicide

	15-24 yrs	25-44 yrs	45-64 yrs	65+ yrs
Month of year vs. Jan				
Feb	-0.151 [-0.280,-0.022]	-0.074 [-0.136,-0.013]	-0.072 [-0.119,-0.024]	-0.026 [-0.114,0.061]
Mar	-0.007 [-0.156,0.143]	-0.014 [-0.077,0.049]	0.055 [0.003,0.107]	0.097 [0.010,0.185]
Apr	-0.077 [-0.205,0.052]	0.014 [-0.036,0.065]	0.053 [0.009,0.098]	0.123 [0.045,0.201]
May	0.044 [-0.093,0.181]	0.057 [0.001,0.114]	0.098 [0.046,0.151]	0.167 [0.087,0.247]
Jun	-0.126 [-0.253,0.002]	0.060 [-0.000,0.121]	0.030 [-0.023,0.083]	0.107 [0.006,0.208]
Jul	-0.091 [-0.234,0.052]	0.065 [0.005,0.126]	0.056 [0.005,0.107]	0.188 [0.117,0.259]
Aug	-0.151 [-0.274,-0.029]	0.085 [0.039,0.132]	0.016 [-0.045,0.077]	0.224 [0.150,0.297]
Sep	-0.131 [-0.246,-0.017]	-0.025 [-0.074,0.025]	-0.015 [-0.067,0.038]	0.080 [-0.038,0.199]
Oct	-0.000 [-0.130,0.129]	0.036 [-0.024,0.096]	0.032 [-0.012,0.076]	0.179 [0.098,0.260]
Nov	-0.121 [-0.271,0.029]	-0.036 [-0.099,0.026]	-0.056 [-0.120,0.009]	0.015 [-0.070,0.100]
Dec	-0.197 [-0.344,-0.049]	-0.088 [-0.147,-0.030]	-0.089 [-0.139,-0.039]	-0.076 [-0.205,0.054]
Time as linear term				
Time (linear)		0.001 [0.001,0.002]	0.003 [0.003,0.003]	-0.001 [-0.001,-0.000]
Time using splines				
Time (base)	-0.119 [-0.230,-0.009]			
Spline knot (25th %ile)	-0.084 [-0.136,-0.031]			
Spline knot (50th %ile)	0.073 [0.035,0.110]			
Constant	-12.887 [-13.017,-12.756]	-12.898 [-13.113,-12.683]	-13.599 [-13.804,-13.395]	-12.321 [-12.636,-12.006]

N=107, 95% CI in brackets. Coefficients from Poisson model with robust variance.

Table A.3: Best-fitting pre-recession spline models for men: motor vehicle crashes

	15-24 yrs	25-44 yrs	45-64 yrs	65+ yrs
Month of year vs. Jan				
Feb	-0.075 [-0.139,-0.011]	-0.060 [-0.105,-0.015]	-0.087 [-0.135,-0.040]	-0.107 [-0.161,-0.052]
Mar	0.108 [0.040,0.177]	0.048 [-0.002,0.097]	0.035 [-0.016,0.086]	-0.029 [-0.085,0.027]
Apr	0.157 [0.100,0.215]	0.109 [0.058,0.160]	0.040 [-0.007,0.086]	-0.067 [-0.111,-0.024]
May	0.266 [0.221,0.311]	0.201 [0.156,0.246]	0.129 [0.081,0.176]	0.026 [-0.025,0.077]
Jun	0.270 [0.221,0.319]	0.186 [0.139,0.232]	0.152 [0.100,0.204]	-0.041 [-0.084,0.002]
Jul	0.366 [0.319,0.413]	0.245 [0.197,0.292]	0.215 [0.171,0.258]	0.041 [-0.014,0.097]
Aug	0.326 [0.275,0.376]	0.261 [0.218,0.303]	0.218 [0.176,0.261]	0.022 [-0.023,0.067]
Sep	0.221 [0.164,0.278]	0.218 [0.172,0.264]	0.198 [0.156,0.241]	0.023 [-0.033,0.079]
Oct	0.233 [0.185,0.281]	0.202 [0.154,0.249]	0.205 [0.159,0.251]	0.114 [0.063,0.166]
Nov	0.157 [0.085,0.229]	0.086 [0.036,0.135]	0.109 [0.055,0.164]	0.108 [0.048,0.168]
Dec	0.107 [0.055,0.158]	0.094 [0.050,0.137]	0.109 [0.061,0.157]	0.142 [0.084,0.199]
Time as linear term				
Time (linear)				-0.001 [-0.002,-0.001]
Time using splines				
Time (base)	-0.060 [-0.099,-0.020]	-0.007 [-0.053,0.040]	0.016 [-0.012,0.043]	
Spline knot (25th %ile)	-0.025 [-0.045,-0.004]	-0.028 [-0.053,-0.003]	-0.024 [-0.040,-0.009]	
Spline knot (50th %ile)	0.011 [-0.000,0.022]	0.000 [-0.009,0.010]		
Spline knot (75th %ile)		-0.010 [-0.016,-0.003]		
Constant	-10.628 [-10.682,-10.574]	-10.956 [-11.016,-10.896]	-11.078 [-11.127,-11.029]	-9.927 [-10.087,-9.767]

N=107, 95% CI in brackets. Coefficients from Poisson model with robust variance.

Table A.4: Best-fitting pre-recession spline models for women: motor vehicle crashes

	15-24 yrs	25-44 yrs	45-64 yrs	65+ yrs
Month of year vs. Jan				
Feb	-0.107 [-0.180,-0.034]	-0.076 [-0.126,-0.026]	-0.133 [-0.199,-0.067]	-0.153 [-0.222,-0.085]
Mar	0.082 [0.006,0.159]	0.023 [-0.025,0.070]	-0.047 [-0.096,0.002]	-0.029 [-0.102,0.044]
Apr	0.073 [0.016,0.130]	0.071 [0.022,0.120]	-0.051 [-0.113,0.011]	-0.043 [-0.118,0.032]
May	0.131 [0.060,0.203]	0.115 [0.071,0.160]	0.036 [-0.018,0.090]	0.048 [-0.023,0.118]
Jun	0.129 [0.054,0.205]	0.115 [0.062,0.168]	0.086 [0.025,0.147]	0.014 [-0.054,0.081]
Jul	0.163 [0.102,0.225]	0.207 [0.162,0.253]	0.145 [0.089,0.202]	0.085 [0.017,0.154]
Aug	0.170 [0.085,0.256]	0.170 [0.108,0.231]	0.130 [0.073,0.186]	0.084 [0.019,0.149]
Sep	0.071 [0.011,0.131]	0.145 [0.090,0.200]	0.042 [-0.022,0.107]	0.024 [-0.047,0.095]
Oct	0.180 [0.106,0.254]	0.175 [0.132,0.217]	0.105 [0.029,0.180]	0.212 [0.142,0.282]
Nov	0.114 [0.065,0.163]	0.135 [0.092,0.178]	0.126 [0.063,0.190]	0.148 [0.086,0.210]
Dec	0.088 [0.036,0.140]	0.177 [0.122,0.231]	0.161 [0.104,0.218]	0.231 [0.170,0.292]
Time using splines				
Time (base)	-0.128 [-0.178,-0.077]	-0.089 [-0.125,-0.053]	-0.117 [-0.170,-0.065]	-0.215 [-0.260,-0.170]
Spline knot (25th %ile)	-0.038 [-0.062,-0.014]	-0.034 [-0.053,-0.016]	-0.046 [-0.072,-0.020]	-0.058 [-0.084,-0.033]
Constant	-11.464 [-11.525,-11.403]	-12.005 [-12.055,-11.956]	-12.011 [-12.073,-11.948]	-11.519 [-11.589,-11.449]
Time as linear term				
Time (linear)				
Spline knot (50th %ile)				

N=107, 95% CI in brackets. Coefficients from Poisson model with robust variance.

Table A.5: Observed and expected suicide deaths after the Great Recession when dated from November 2007-June 2009.

Gender and age group	Suicide deaths		Observed - expected deaths		
	Observed	Expected	Difference	95%CI LL	95%CI UL
<i>Men</i>					
15-24 yrs	5921	5794	127	-89	351
25-44 yrs	15555	16300	-745	-1737	188
45-64 yrs	17526	18029	-503	-1975	784
65+ yrs	8015	7607	408	129	752
<i>Women</i>					
15-24 yrs	1222	1091	131	21	382
25-44 yrs	4252	4253	-1	-179	220
45-64 yrs	5475	5600	-125	-385	62
65+ yrs	1472	1378	94	-4	215
Total	59438	60053	-615	-2382	1014

Table A.6: Observed and expected motor vehicle crash (MVC) deaths after the Great Recession when dated from November 2007-June 2009.

Gender and age group	Crash deaths		Observed - expected deaths		
	Observed	Expected	Difference	95%CI LL	95%CI UL
<i>Men</i>					
15-24 yrs	10412	12158	-1746	-2715	-722
25-44 yrs	14860	17116	-2256	-3734	-1156
45-64 yrs	12213	13373	-1160	-2109	-444
65+ yrs	6557	7239	-682	-1091	-295
<i>Women</i>					
15-24 yrs	3951	4600	-649	-1161	-176
25-44 yrs	4920	5382	-462	-953	-122
45-64 yrs	4712	5026	-314	-745	58
65+ yrs	4231	4251	-20	-366	265
Total	61856	69145	-7289	-9158	-5210

Table A.7: Observed and expected suicide deaths after the Great Recession when dated from January 2008-June 2009.

Gender and age group	Suicide deaths		Observed - expected deaths		
	Observed	Expected	Difference	95%CI LL	95%CI UL
<i>Men</i>					
15-24 yrs	5350	5251	99	-82	317
25-44 yrs	14058	14777	-719	-1772	134
45-64 yrs	15992	16273	-281	-1353	752
65+ yrs	7290	6938	352	107	622
<i>Women</i>					
15-24 yrs	1127	909	218	80	389
25-44 yrs	3863	3854	9	-161	192
45-64 yrs	4946	5135	-189	-385	5
65+ yrs	1334	1266	68	-21	180
Total	53960	54403	-443	-2016	989

Table A.8: Observed and expected motor vehicle crash (MVC) deaths after the Great Recession when dated from January 2008-June 2009.

Gender and age group	Crash deaths		Observed - expected deaths		
	Observed	Expected	Difference	95%CI LL	95%CI UL
<i>Men</i>					
15-24 yrs	9206	11174	-1968	-3329	-895
25-44 yrs	13345	14536	-1191	-2482	-310
45-64 yrs	10983	11796	-813	-1570	-258
65+ yrs	5788	6420	-632	-1082	-298
<i>Women</i>					
15-24 yrs	3478	4039	-561	-1050	-209
25-44 yrs	4340	4772	-432	-918	-152
45-64 yrs	4182	4385	-203	-612	116
65+ yrs	3726	3725	1	-307	240
Total	55048	60847	-5799	-8130	-4231

Table A.9: Observed and expected suicide deaths after the Great Recession with adjustment only for linear time trend.

Gender and age group	Suicide deaths		Observed - expected deaths		
	Observed	Expected	Difference	95%CI LL	95%CI UL
<i>Men</i>					
15-24 yrs	5634	5521	113	-105	387
25-44 yrs	14811	14802	9	-556	520
45-64 yrs	16746	16008	738	-28	1631
65+ yrs	7642	7284	358	-7	773
<i>Women</i>					
15-24 yrs	1175	1128	47	-42	147
25-44 yrs	4047	4084	-37	-280	216
45-64 yrs	5203	5366	-163	-476	63
65+ yrs	1400	1347	53	-57	176
Total	56658	55541	1117	91	2188

Figure A.1: Observed and predicted motor vehicle crash rates for men based on best-fitting restricted cubic spline model (Note: shaded area indicates the Great Recession).

Figure A.2: Observed and predicted motor vehicle crash rates for women based on best-fitting restricted cubic spline model (Note: shaded area indicates the Great Recession).