Teenage Driving, Mortality, and Risky Behaviors*

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Abstract

We investigate the effect of teenage driving on mortality and risky behaviors in the United States using a regression discontinuity design. We estimate that total mortality rises by 5.84 deaths per 100,000 (15%) at the minimum legal driving age cutoff, driven by an increase in motor vehicle fatalities of 4.92 deaths per 100,000 (44%). We also find that poisoning deaths, which are caused primarily by drug overdoses, rise by 0.31 deaths per 100,000 (29%) at the cutoff and that this effect is concentrated among females. Our findings show that teenage driving contributes to sex differences in risky drug use behaviors.

JEL Codes: I1, H75, R4

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1 Introduction

Suicides and motor vehicle accidents are the two leading causes of death for teenagers in the United States. Both often involve substance abuse, which itself is also a leading cause of teenage death. Over 25% of all teenage hospitalizations are related to mental health or substance abuse disorders (Heslin and Elixhauser, 2016). Yet, the determinants of risky behaviors among youth remain poorly understood, and what little we know about the drivers of risky behaviors among adults may not apply to teenagers. For example, drug overdose deaths among teenagers declined between 2007 and 2014, in stark contrast to the significant nationwide increase in adult "deaths of despair" that has received much attention from researchers (Case and Deaton, 2015, 2017).

We investigate the effects of teenage driving on mortality and risky behaviors. While driving undoubtedly increases motor vehicle mortality risk, the magnitude of this risk is hard to quantify. Moreover, driving enables teenagers to participate in unsupervised risky behaviors away from home, which may in turn lead to changes in mental health or drug use that have additional effects on mortality risk. Investigating these links can shed light on the determinants of risky behaviors among youth. However, identifying the effects of driving on teenage outcomes is challenging. Individual-level data on driving behaviors are scarce, and comparing the behaviors of drivers to non-drivers is unlikely to yield causal estimates because the decision to obtain a license is voluntary. In addition, detecting changes in important but rare outcomes such as drug-related mortality requires large sample sizes.

We overcome these challenges by using a regression discontinuity (RD) approach to identify the causal effect of teenage driving on a number of outcomes.[1] Our research design exploits variation in driving eligibility caused by the minimum legal driving age (henceforth "minimum driving age" or "MDA"), which creates large differences in the teenage driver population on either side of the MDA cutoff. We employ a confidential dataset that includes information about month and year of birth for over 500,000 teenage deaths during 1983–2014, which enables us to compare mortality rates for teenagers just above the MDA to mortality rates for teenagers just below the MDA. We estimate that driving eligibility increases teenage mortality by 5.84 deaths per 100,000 (15%) at the MDA cutoff. This effect is driven primarily by an increase in motor vehicle fatalities of 4.92 per 100,000 (44%).

We also estimate that teenage poisoning deaths rise by 0.314 deaths per 100,000 (29%) at the cutoff. This poisoning effect is driven by a stark rise in female drug overdose deaths of 0.646 per 100,000 (78%) and an accompanying rise in female gas poisoning deaths of 0.127

[1]Our analysis controls for the family-wise error rate in order to address the multiple inference concern that arises when testing many hypotheses. See Section 4 for details.

per 100,000 (82%).[2] These deaths reflect changes in both suicides and accidental deaths, although our analysis suggests that the increase in poisoning suicides reflects substitution away from other methods of suicide. By contrast, we find no effect on male poisoning deaths. This null effect is meaningfully precise: the 95% confidence interval rules out the corresponding female estimate.

The most common MDA during our sample period is 16, which raises the concern that our results might be driven by a "birthday effect" or some other regulation that takes effect at age 16, such as the federal minimum legal working age or a state's minimum school leaving age. However, the discontinuities that we observe are long-lasting, which is inconsistent with a temporary birthday effect, and we do not detect changes in the probability of working or leaving school at the MDA cutoff. Furthermore, our main results are similar when we limit our analysis to the subsample of states with MDAs other than 16. We therefore conclude that the MDA is the causal mechanism underlying our results.

Youth risky behaviors differ significantly by sex. During our sample period, 29% of young female deaths from suicides and accidents were caused by poisonings, compared to just 15% for young males. Prior studies have also noted that poisonings make up a significantly larger share of young female suicides than young male suicides (Ruch et al., 2019). Our results reveal that teenage driving contributes to these behavioral differences among male and female youth.

Much of the research on the causal determinants of drug abuse comes from studies of adults. For example, several studies find that drug overdose deaths increase after the first of the month and following the receipt of money, suggesting a causal relationship between a "full wallet" and substance abuse (Phillips, Christenfeld and Ryan, 1999; Riddell and Riddell, 2006; Dobkin and Puller, 2007; Evans and Moore, 2012). Less is known about the causal determinants of drug abuse among adolescents.[3] Indeed, Gruber (2001) calls for economists to pay more attention to the risk-taking behavior of youth, noting that while economic incentives appear to matter, most of the variation remains unexplained. Anderson (2010), who finds no effect of a Montana anti-drug advertising campaign on methamphetamine use among highschoolers, emphasizes the need for further research on the determinants of illegal

[2]During our sample period, about 80% of teenage poisoning deaths are caused by drug overdoses and about 20% are caused by gas poisonings. Most gas poisoning deaths are caused by carbon monoxide.

[3]Most of the prior literature on youth drug use focuses on tobacco, alcohol, and marijuana (e.g., Glied, 2002; Cawley, Markowitz and Tauras, 2004; Carpenter et al., 2019). Drug overdose deaths among teenagers, however, are mostly caused by opioids (both illegal and prescription) and sedatives. The teenage driving literature has investigated the effects of Graduated Driver Licensing laws on motor vehicle fatalities (Dee, Grabowski and Morrisey, 2005; Morrisey et al., 2006; Karaca-Mandic and Ridgeway, 2010; Gilpin, 2019) and on crime (Deza and Litwok, 2016), and has investigated the effects of the MDA on crash risk (Foss et al., 2011; Chapman, Masten and Browning, 2014; Curry et al., 2015).

drug use among the young. Our study advances this literature by using a novel source of exogenous variation to uncover a strong, causal relationship between driving and drug overdose deaths among teenagers.

The remainder of our paper is organized as follows. Section 2 provides background information. Section 3 describes our data. Section 4 outlines our empirical strategy. Section 5 describes our results, and Section 6 concludes.

2 Background

2.1 Teenage driving

Every US state requires drivers to be licensed. Teenagers begin the licensing process by obtaining a learner's permit, which allows them to drive under adult supervision. Depending on the state, the adult must be at least 18–25 years of age and have up to 5 years of driving experience. The minimum legal age for obtaining a learner's permit ranges from 14 to 16 over our 1983–2014 sample period. With rare exception, teenagers must then complete a driver's education course and behind-the-wheel training to become eligible to take their state's driving test, which typically consists of two components: a written test and a behind-the-wheel test. The teenager receives her driver's license after passing both components.

Beginning in 1996, states began adopting Graduated Driver Licensing (GDL) programs. Teenagers who live in a state with a GDL program earn an "intermediate" driver's license after passing their state's driving test. An intermediate license imposes driving restrictions on newly licensed teenagers in an effort to encourage safer driving. For example, it typically prohibits unsupervised driving during certain nighttime hours and limits the number and age of passengers in the teenage driver's vehicle. These restrictions are lifted after a set period of time that ranges from three months up to two years, at which point the teenager earns a "full" license.

Our study focuses on the MDA, the minimum legal age at which teenagers become eligible to pass their state's driving test. In states with GDL programs in place, this eligibility threshold corresponds to the minimum legal intermediate licensing age. The MDA, which varies by state and over time, ranges from 14 to 18 years of age during our 1983–2014 sample period. On average, about 40% of 16-year-olds have a driver's license during this period, although this declines to less than 30% in more recent years (Appendix B.1). A similar decline occurs for vehicle miles traveled.

2.2 Teenage mortality

Accidents and suicides are the two leading causes of death among teenagers, respectively. Motor vehicle fatalities, which comprise over 60% of all accidental teenage deaths, are nearly as common as teenage suicides (CDC, 2018). About 25% of teenage motor vehicle fatalities are alcohol-related, and over 50% occur during nighttime (Dee and Evans, 2001). Motor vehicle fatality rates have declined significantly in recent decades, falling by over 50% during our 1983–2014 sample period. Prior studies have attributed this decline to a reduction in drunk driving, an increase in seat belt use, and the introduction of GDL programs (Dee and Evans, 2001; Gilpin, 2019). As of 1998, all states have implemented zero-tolerance drunk driving laws that set a limit of 0.02% blood alcohol concentration (∼1 drink) or lower for drivers under age 21 (Carpenter, 2004). Air bags were also introduced during this time period, but Dee and Evans (2001) argue that they played only a small role in reducing teenage motor vehicle fatalities.

Poisonings are the second-leading cause of accidental death among teenagers (CDC, 2018). Two-thirds of drug overdose deaths for youth ages 15–24 are related to heroin and illegal opioids, and one-third are related to sedatives and prescription opioids (National Institute on Drug Abuse, 2019). Prior studies find that young females exceed males in their nonmedical use of sedatives and prescription opioids, and are also more likely to overdose than males (Cotto et al., 2010; Lyons et al., 2019).

Poisonings also make up a significantly larger share of young female suicides than young male suicides (Ruch et al., 2019). Teenage females show higher rates of suicidal thinking and are more likely to attempt suicide than teenage males, but males die by suicide at higher rates (Swahn and Bossarte, 2007). Section 3.2 documents sex disparities in poisoning deaths—both accidental and suicidal—over our sample period.

3 Data

3.1 Minimum driving age laws

We obtained data on MDA laws from the Insurance Institute for Highway Safety for the years 1995–2014. Data for the years 1983–1994 were hand-collected from databases of state session laws. These data are reported in the appendix (Table B.1).

3.2 Mortality

We measure mortality using the National Vital Statistics. This dataset is based on death certificate records and includes information on decedents' month and year of death, cause of death, race, and sex. The medical classification codes used to define the cause of death outcomes employed in our analysis are reported in the appendix (Table B.2). We obtained a restricted-use version of the National Vital Statistics for the years 1983–2014 that includes information on decedents' state of residence and month and year of birth. We use these data to calculate age in months at death for all decedents. We then aggregate to the age-in-months level and calculate age-specific deaths per 100,000 person-years by combining these count data with population estimates provided by the Surveillance, Epidemiology, and End Results (SEER) Program.[4] Our final dataset includes information on 501,193 teenage deaths.

The average death rate for teenagers ages 15–19 is 68.63 deaths per 100,000 during our sample period (Table B.3). The majority of these deaths are attributable to external causes, and the leading external cause of teenage death is motor vehicle accidents.[5] The motor vehicle mortality rate is over five times larger for ages 15–19 than for ages 10–14. This mortality rate increases further for ages 20–24 but then decreases for ages 25–29.

Suicides and accidents comprise 25% of all deaths for ages 15–19. Males in this age group are four times more likely than females to die by suicide or accident. The cause of these deaths varies by sex. For ages 15–19, 38% of male suicides and accidents are caused by firearms, compared to just 22% for females. By contrast, only 15% of male suicides and accidents are caused by poisonings, compared to 29% for females.

Deaths from all causes and deaths from motor vehicle accidents have both declined significantly for males and females during our sample period (Figure B.3). However, although male deaths from suicides and accidents have declined steadily since 1994, female deaths from suicides and accidents increase beginning in 2003.

Male and female poisoning deaths evolved similarly from 1983 until 2000 (Figure B.4). The trends then diverged: the male poisoning death rate climbs and falls significantly over the next 15 years while the female poisoning death rate remains relatively constant after 2003. Neither group experiences sustained increases in poisoning deaths after 2007. By contrast, Case and Deaton (2015) document a steeply increasing trend in poisoning deaths among midlife whites for 2007–2013.

[4]These population data are available for integer ages only. When calculating age-specific death rates, we divide the count of deaths for a specific age in months by one-twelfth of the corresponding integer age population.

[5]Deaths not caused by external factors are attributable to "internal causes." Cancer, circulatory system diseases, and nervous system diseases are the three largest subcategories within internal causes, and they make up more than half of all deaths due to internal causes at these ages.

Our main estimates combine suicides and accidents into one category to minimize measurement error concerns (Cutler, Glaeser and Norberg, 2001; Alexander and Schnell, 2019). When someone dies from a drug overdose, for example, it may not be clear whether the death should be classified as a suicide or an accident. We report estimates separately for suicides and accidents in the appendix.

3.3 Driving behaviors

We measure driving behaviors using the National Longitudinal Study of Adolescent to Adult Health ("Add Health"). This nationally representative study began in 1994 with a classroom survey of about 20,000 students in grades 7–12. The study then followed up with a series of in-home interviews in 1995 and 1996. We obtained a restricted-use version of the in-home survey data that includes month and year of birth. After excluding observations with missing data, our sample includes 32,307 person-year observations (Appendix B.4). This sample includes respondents ranging in age from 11 to 21; 97.9% of respondents are between the ages of 13 and 19. We aggregate these data to the age-in-months level using Add Health's cross-sectional weights.

The in-home survey asks respondents whether they have a driver's license and whether they drive 0, 1–50, 51–100, or "over 100" miles per week, which we use to measure vehicle miles driven. We assign values of 25 and 75 to respondents who selected the ranges 1–50 and 51–100, respectively. For "over 100", our baseline specification assigns a value of 150. By way of comparison, the typical adult driver drove 265 miles per week in 1996 (Federal Highway Administration, 1997, 2003). To account for uncertainty, we also report results from an alternate specification that instead assigns a value of 265 to the "over 100" response.

Add Health also asks questions about drug consumption and mental health. We do not present results for these outcomes because the low prevalence of the most important behaviors (suicide attempts and illegal drug consumption), together with the survey's small sample size, cause the analysis to be underpowered.

4 Empirical strategy

We employ an RD design to identify the effect of driving eligibility on teenage driving behaviors and mortality. Eligibility depends on year, age, and state of residence. For analytical convenience, we recenter the age variable for decedents in our data by measuring it in months from the MDA law in force during the month of death.

Our main identifying assumption is that assignment to either side of the MDA threshold is as good as random. This assumption is very reasonable: age cannot be manipulated, and we do not suffer from sample selection bias because we observe the universe of deaths.

We estimate the following model:

$$Y_a = \alpha AGE_a + \beta POST_a + \gamma(POST_a \times AGE_a) + \delta D_a + \varepsilon_a \tag{1}$$

The dependent variable, Y_a, is an outcome for the one-month age cell a. The running variable, AGE_a, is measured in months from the MDA, and $POST_a$ is an indicator equal to one if $AGE_a \geq 0$. This indicator suffers from measurement error at the age cutoff because we do not know whether a teenager who died in the month she reaches the MDA was over or under the MDA on the day of her death. We remove the bias associated with this measurement error by including the indicator variable D_a, which is equal to one when $AGE_a = 0$ and is zero otherwise (Dong, 2015).

All of our regressions employ a triangular kernel. Our preferred specification employs a mean-squared error (MSE) optimal bandwidth that is constant on each side of the cutoff but allowed to vary across outcomes. We report robust bias-corrected confidence intervals that account for the possibility that our estimating equation is misspecified (Calonico, Cattaneo and Titiunik, 2014).

We address multiple inference concerns by controlling for the family-wise error rate using the Sidak-Holm step-down correction.[6] In our setting, the family includes all 13 mortality outcomes reported in our main table. When estimating models separately for males and females, we include outcomes from both subgroups in the family, i.e., we report p-values that adjust for testing 26 different hypotheses.

5 Results

5.1 Driving

We begin by estimating the effect of driving eligibility on license status and vehicle miles driven. Figure 1a shows that about 25% of teenagers obtain a license within their first two months of eligibility, and that this proportion rises to over 50% after 12 months. The increase at the age cutoff (value 0 on the x-axis) is attenuated because of the measurement error discussed in Section 4. Figure 1b shows a corresponding rise in vehicle miles driven. Miles driven is positive prior to the MDA because teenagers with learner's permits can drive

[6] This correction is conservative because it does not account for the significant collinearity among our outcomes (see Appendix C of Jones, Molitor and Reif (2019)). We are unaware of any resampling-based multiple testing corrections for RD designs with discrete running variables.

under parental supervision.

The first three rows of Panel A in Table 1 report RD estimates of β from equation (1) for our driving outcomes. Column (2) reports that driving eligibility increases a teenager's probability of obtaining a driver's license by 18.6 percentage points. It also increases her annual driving amount by 375 miles using the baseline definition of average vehicle miles driven, or by 575 miles using the alternate definition (Figure A.1). The increase in licensing rates at the cutoff is similar for males and females, but the increase in vehicle miles driven is larger for males.

5.2 Mortality

Figure 1c and Figure 1d show the effect of driving eligibility on total mortality and motor vehicle fatalities. Both of these mortality outcomes increase by about 5 deaths per 100,000 during the first two months of driving eligibility, for both males and females. There is little change in their overall trends: total mortality and motor vehicle fatalities both increase with age at about the same rate in the periods before and after the age cutoff.

Figure 2a illustrates a stark increase in female poisoning deaths in the months immediately following the age cutoff. Figure 2b and Figure 2c show that female deaths from drug overdoses and gas poisonings—which together comprise all poisoning deaths—both rise significantly at the age cutoff. By contrast, Figure 3 shows that trends in male poisoning deaths appear continuous at the age cutoff.

Panel B in Table 1 reports estimates of β from equation (1) for thirteen different causes of death.[7] Column (2) reports that total mortality increases by 5.84 deaths per 100,000 at the age cutoff, an increase of 15% relative to a mean of 38.9 deaths per 100,000. The estimated effect on deaths from internal causes is small and statistically insignificant. By contrast, the estimated effect on deaths from external causes is 5.20 deaths per 100,000 (19%) and remains marginally significant after conservatively accounting for multiple inference (family-wise $p = 0.0523$). Scaling the all-cause mortality estimate by the driver's license estimate reported in Panel A implies that driving increases total mortality at the cutoff by 31.4 deaths per 100,000 (81%) among teenagers who receive a license.

Columns (4) and (6) of Table 1 report RD estimates separately for males and females. Comparing Column (3) to Column (5) shows that—for every cause of death—death rates are higher for males than females in the year prior to reaching the MDA. Thus, while the

[7] Because bandwidths vary by outcome, estimates for specific causes of death do not add up to the estimate for total deaths. Estimates from a specification that uses a constant bandwidth of 24 months are available in the appendix (Table A.12). When using that specification, subcategory estimates do add up to the total estimate.

absolute increase in all-cause mortality at the age cutoff is about the same for both males and females, the relative increase for females (22%) is double the relative increase for males (11%).

Table 1 also decomposes deaths due to external causes into its four main subcategories: motor vehicle accidents, suicides and accidents, homicides, and other. Column (2) reports a significant increase in motor vehicle fatalities of 4.92 deaths per 100,000 (44%) at the age cutoff. Columns (4) and (6) report that this increase is significant for both males and females (family-wise $p < 0.01$) and can explain the majority of the increase in total mortality for both subgroups. As with all-cause mortality, the absolute increase in motor vehicle fatalities at the cutoff is similar for males and females, but the relative increase is larger for females.

Column (2) of Table 1 also reports a significant increase in poisoning deaths of 0.314 per 100,000 (29%). This poisoning effect can be further decomposed into a 0.315 per 100,000 (36%) increase in drug overdose deaths and a 0.103 per 100,000 (48%) increase in gas poisoning deaths.[8] Comparing the estimates in Column (6) to those in Column (4) reveals that this effect is driven by female poisoning deaths, which increase by 0.747 per 100,000 (76%) at the cutoff (family-wise $p < 0.0001$). This increase can be attributed primarily to a 0.646 per 100,000 (78%) increase in drug overdose deaths (family-wise $p < 0.0001$). Gas poisoning deaths rise by 0.127 per 100,000 (82%) at the cutoff, although this effect is not statistically significant after accounting for multiple hypothesis testing (family-wise $p = 0.163$).

Column (4) of Table 1 reports that the estimate for male poisoning deaths is small and statistically insignificant, and that its 95% confidence interval rules out the corresponding female estimate. We do estimate a statistically significant decrease in male drownings of 0.690 per 100,000 (26%) (Figure A.3a). Unlike the change in female poisoning deaths shown in Figure 2a, this change in male drownings is short-lived. Similarly, while Column (6) of Table 1 reports a statistically significant increase in female deaths due to "other external" causes, the RD plot does not provide compelling evidence of an effect (Figure A.4b).

Finally, we assess how our estimates change over time by estimating our model for different four-year bins. Figures 4a and 4c reveal a steady decline in our estimated effects for male and female motor vehicle fatalities beginning in the mid-1990s. Likewise, Figure 4d exhibits a declining trend in the estimates for female poisoning deaths. By contrast, Figure 4b shows that the effects of driving eligibility on male poisoning deaths remain centered around zero for the majority of our sample period.

We cannot directly investigate the cause of the declines shown in Figures 4a, 4c, and 4d because our driving behavior data are available only for 1995 and 1996. That said, these

[8]Nearly 90% of all gas poisoning deaths are caused by carbon monoxide, an odorless gas produced by motor vehicle exhaust. Source: authors' calculations using the 1983–1998 National Vital Statistics.

declines coincide with a decline in teenage driving documented in national statistics. For example, license counts published by the Federal Highway Administration show a steady decline in the proportion of US teenagers with a driver's license over our sample period (Figure B.1), and McGuckin and Fucci (2018) report a decline in average vehicle miles traveled among licensed teenagers beginning in 1990 (Figure B.2). In addition, prior studies of GDL programs—which were introduced beginning in 1996—suggest that these programs successfully reduced teenage motor vehicle fatalities by limiting, rather than improving, teenage driving (Karaca-Mandic and Ridgeway, 2010; Gilpin, 2019).

5.3 Extensions

Our RD estimates account neither for accidents with multiple fatalities nor for people killed by a teenage driver who survives the accident. According to data published by the Fatality Analysis Reporting System (FARS), on average an additional 0.24 people died for every car accident where a newly eligible teenage driver died at the wheel. In addition, among all fatal car accidents involving a newly eligible teenage driver at the wheel, the accidents where that teenage driver died accounted for only 45% of the total fatalities.[9] If we assume these statistics apply proportionally to our RD estimate, then they imply that total motor vehicle fatalities increase by 13.6 ($= 4.92 \times 1.24/0.45$) deaths per 100,000 at the age cutoff.

In the appendix, we decompose the female poisoning death estimates by estimating our model separately for deaths classified as suicides versus accidents (Table A.1). A few results stand out in this exploratory analysis. First, the increase in female drug overdose deaths is caused by both accidents and suicides. Second, although most gas poisoning deaths among female teenagers are accidental in the aggregate, the increase in these deaths at the age cutoff is driven by suicides. Finally, the net effect of driving eligibility on total suicides is small and statistically insignificant because of an offsetting reduction in firearm suicides, suggesting that female teenagers who die by suicide substitute away from using firearms and toward using drugs and gas poisoning upon gaining access to a car.

We caution that the reliability of the suicide/accident classification is unclear. For example, some of the increase in accidental drug overdose deaths may in fact be suicides. We also lack statistical power to discern with confidence whether the increase in poisoning suicides reflects a net increase in suicide or substitution away from other methods of suicide, making it difficult to test different theories of youth suicide (Cutler, Glaeser and Norberg, 2001). Overall, we conclude that the rise in female poisoning deaths represents changes in both accidental deaths and suicides, and that the effects on suicide might reflect a compositional

[9] These statistics are calculated using FARS data published for the years 1983–2014. Those data report integer ages only.

shift in the method of suicide.

5.4 Robustness

The most common MDA in our sample is 16 years, which also happens to be the federal minimum legal working age as well as the minimum legal school leaving age in many states. We do not believe these other laws confound our estimates, however. Analysis of the Add Health data shows small and statistically insignificant changes in working for pay or leaving school at the MDA cutoff (Figure A.5). Moreover, our results are similar when we limit our analysis to states with an MDA that is not 16 years (Tables A.2 and A.3).[10] Because the MDA differs from the minimum legal ages for both working and leaving school in this subsample (Appendix B.5), we conclude that the MDA is the causal mechanism underlying our results.

Our analysis examines a large number of outcomes across two different subgroups. Although we adjust for multiple inference, our outcomes and subgroups were not specified prior to analysis. However, we emphasize that our most surprising result—the increase in female poisoning deaths illustrated in Figure 2—is far too large to be spurious. A multiple testing correction would need to adjust for many thousands of hypotheses to increase the unadjusted p-value ($p < 0.00001$) above the conventional significance level of 0.05.

Our appendix reports our main results separately by race, sex, and their pairwise combinations (Tables A.4–A.7). Whites are more likely than nonwhites to obtain a driver's license upon becoming eligible, consistent with prior studies (Shults and Williams, 2013). This differential driving effect is reflected in the mortality estimates: motor vehicle fatalities increase the most at the cutoff for white males and white females, and poisoning deaths increase the most for white females. We also detect some modest seasonality in our estimate for motor vehicle fatalities, with effect sizes peaking during the summer months in both absolute and relative terms (Figure A.6).

Our estimates are not sensitive to using different bandwidth selection procedures or polynomial approximations, or to imposing a uniform bandwidth of 24 months (Tables A.10–A.12). Estimating our model using placebo cutoffs generates estimates that are centered around 0, and our motor vehicle fatality and female poisoning death estimates lie in the far tails of those placebo distributions (Figure A.8).

[10]For example, female poisoning deaths rise by 0.509 deaths per 100,000 at the cutoff in states where the MDA is not 16. This estimate is statistically significant and its 95% confidence interval includes the full sample estimate of 0.747 deaths per 100,000 (Table 1).

6 Conclusion

Employing a regression discontinuity design, we estimate that driving eligibility increases teenage mortality at the MDA cutoff by 5.84 deaths per 100,000 over the 1983–2014 time period. The relationship between this threshold estimate and changes in the MDA is ambiguous. For example, raising the MDA could reduce the effect of eligibility on mortality if older teenagers are more careful drivers, or increase the effect if older teenagers are more likely to drink and drive. If we assume the effect remains constant, then our estimate implies that a one-year increase in the MDA would have saved 228 teenage lives annually during our sample period.[11] This estimate, which does not account for the additional people killed in motor vehicle accidents involving newly eligible teenage drivers, is similar in magnitude to the estimated benefits of raising the minimum legal drinking age (Carpenter and Dobkin, 2009).

We also estimate that female poisoning deaths increase by 76% following driving eligibility, but we find no effect on male poisoning deaths. These findings reveal that teenage driving is an important causal factor behind sex disparities in teenage poisoning deaths. While the increase in female poisoning deaths reflects changes in both accidents and suicides, the specific behavioral mechanisms underlying our results remain unclear. Driving may enable female teenagers to purchase or consume drugs more easily, and may affect mental health by altering social environments. We encourage future researchers to investigate these different possibilities.

[11] There was an average of 3.9 million 16-year-olds alive in the United States during 1983–2014.

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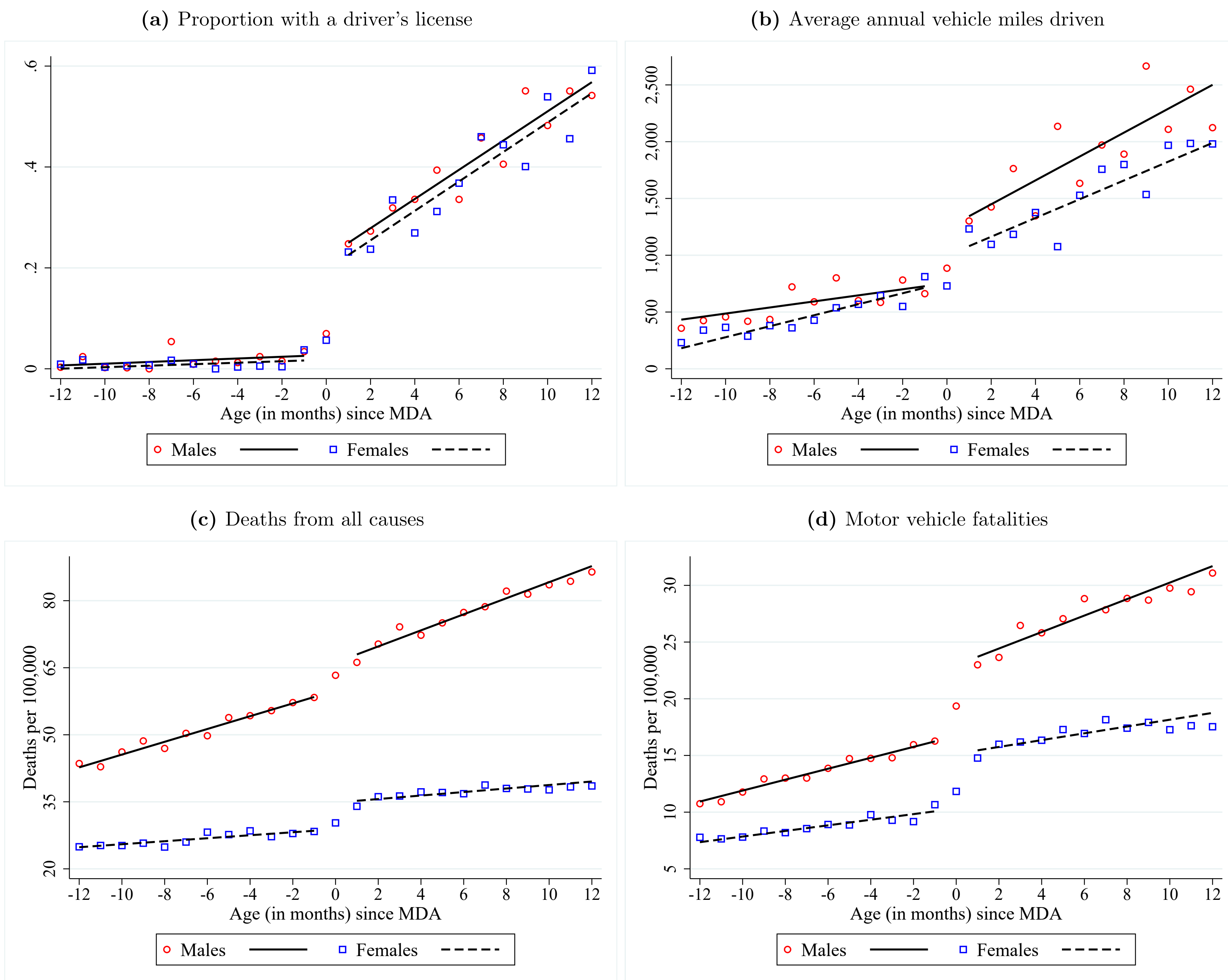
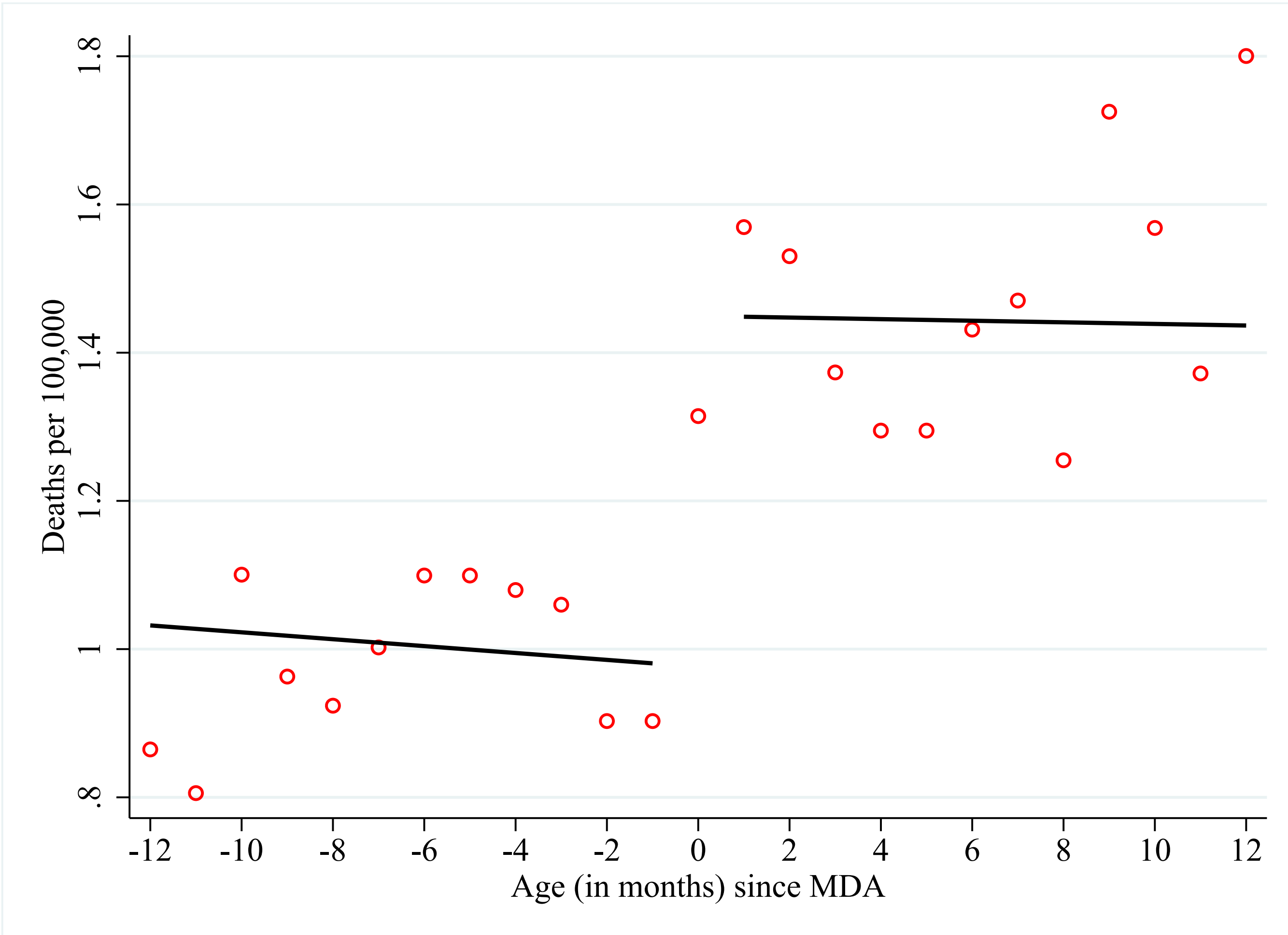
Figure 1: Teenage driving and mortality



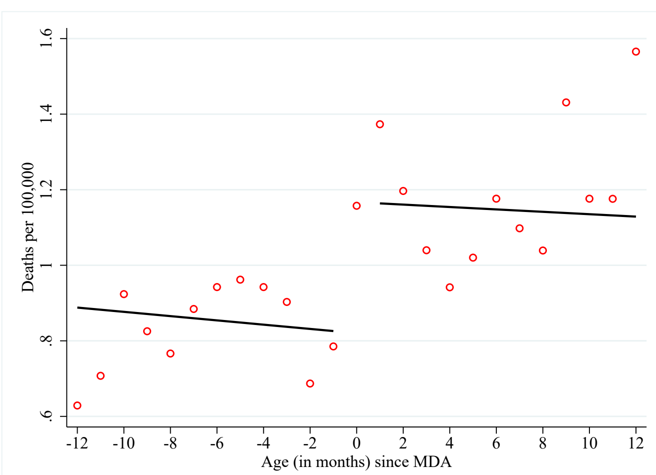
Notes: The figure shows the proportion of teenagers with a driver's license, average annual vehicle miles driven (baseline specification), all-cause death rates, and motor vehicle accident death rates by age, relative to the minimum driving age (MDA). Estimates in Panels (a) and (b) are based on weighted responses to the 1995–1996 Add Health surveys. Estimates in Panels (c) and (d) are based on death counts from the 1983–2014 National Vital Statistics and population data from the 1983–2014 Surveillance, Epidemiology, and End Results (SEER) Program. The fitted lines are estimated using equation (1) with a bandwidth of 24 months. Table 1 provides RD estimates.

Figure 2: Female poisoning deaths, 1983–2014

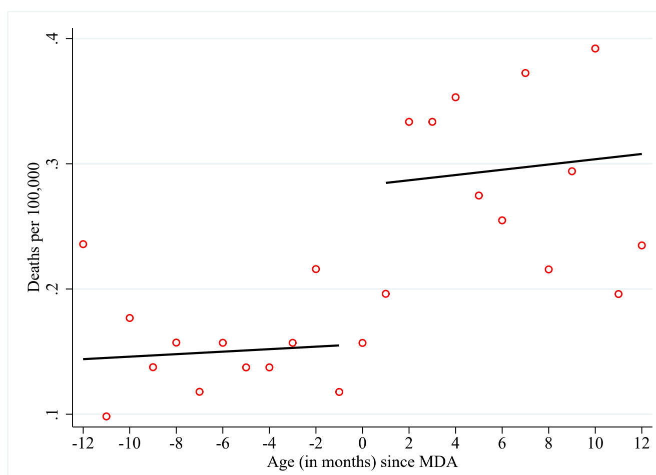
(a) All poisonings



(b) Drug overdoses



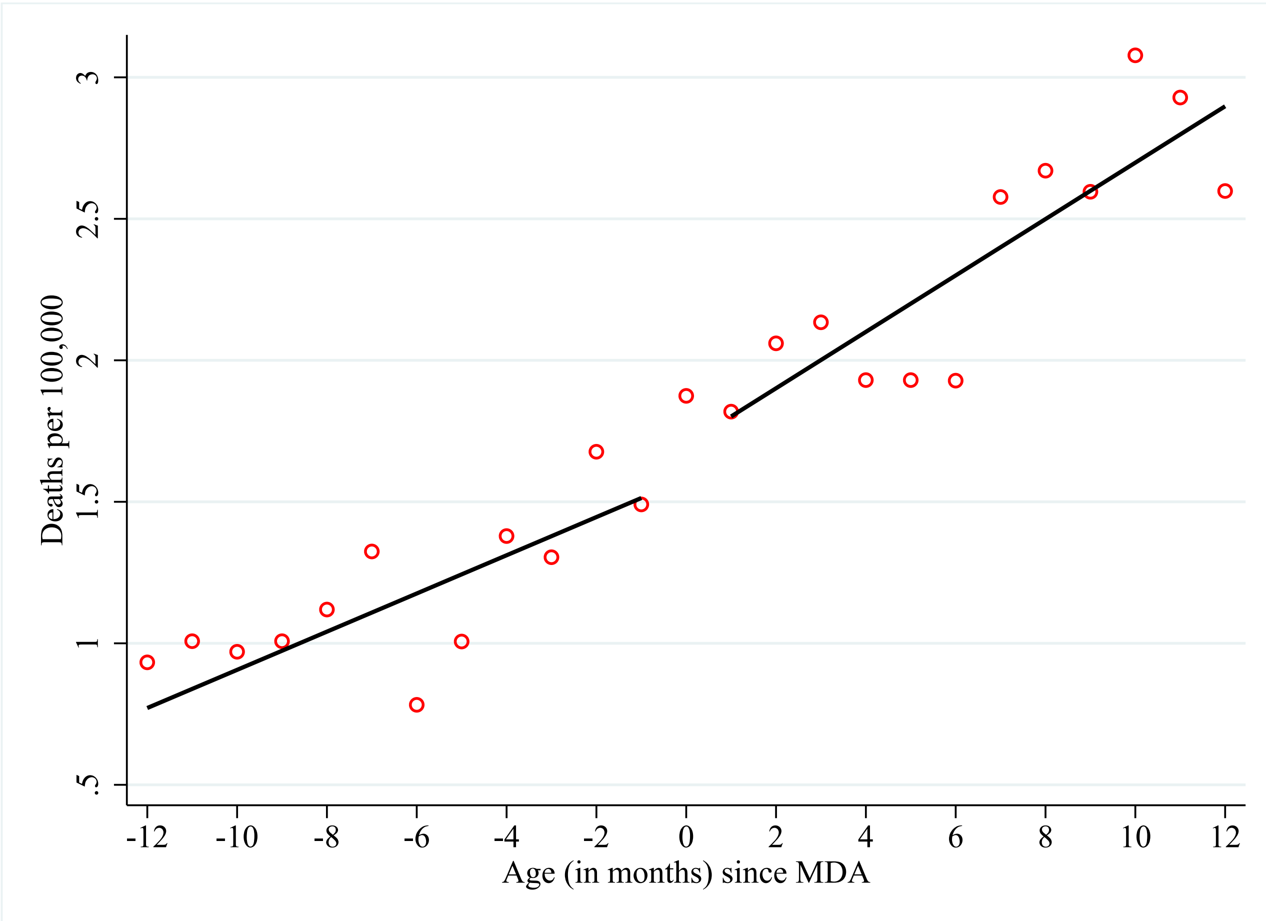
(c) Carbon monoxide and other gas poisonings



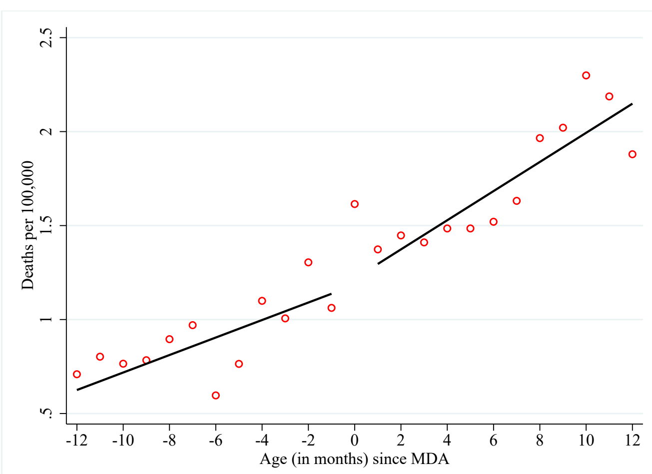
Notes: The figure shows female death rates for different causes of death by age, relative to the minimum driving age (MDA). Deaths from all poisonings, shown in Panel (a), equal the sum of deaths from drug overdoses and from carbon monoxide and other gas poisonings. The fitted lines are estimated using equation (1) with a bandwidth of 24 months. Table 1 provides RD estimates.

Figure 3: Male poisoning deaths, 1983–2014

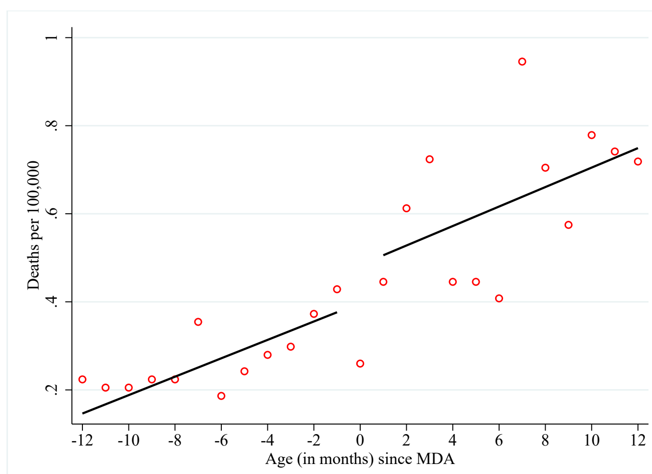
(a) All poisonings



(b) Drug overdoses

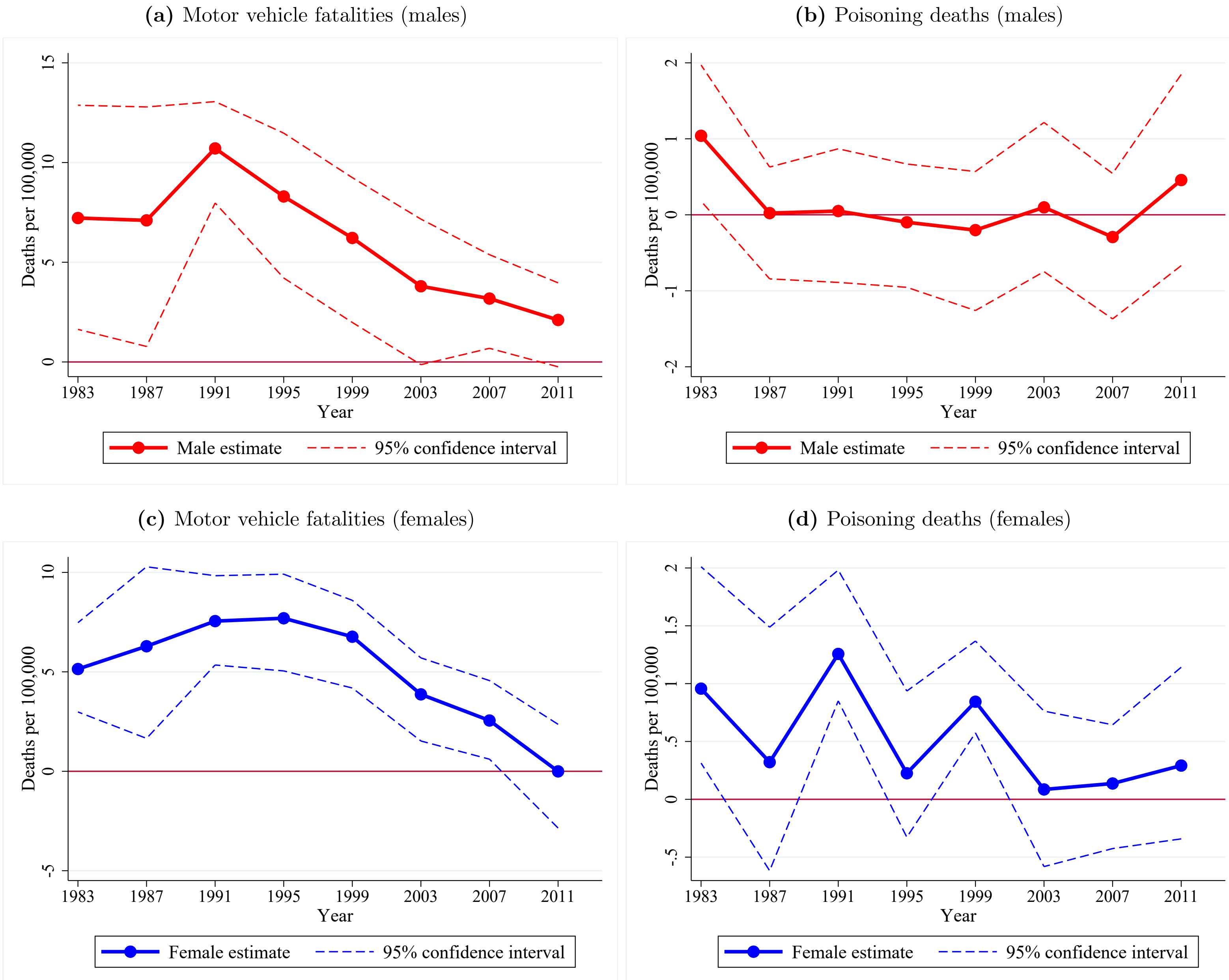


(c) Carbon monoxide and other gas poisonings



Notes: The figure shows male death rates for different causes of death by age, relative to the minimum driving age (MDA). Deaths from all poisonings, shown in Panel (a), equal the sum of deaths from drug overdoses and from carbon monoxide and other gas poisonings. The fitted lines are estimated using equation (1) with a bandwidth of 24 months. Table 1 provides RD estimates.

Figure 4: Trends in the effect of driving eligibility on motor vehicle fatalities and poisoning deaths



Notes: The figure plots MSE-optimal estimates of β from equation (1), separately for 4-year bins. The dependent variable is deaths per 100,000 person-years. The dashed lines report robust bias-corrected 95% confidence intervals. Table 1 provides estimates for outcomes measured over the whole 1983–2014 sample period.

Table 1: Effect of driving eligibility on teenage driving and mortality

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample		Male		Female	
Outcome variable	Mean	RD	Mean	RD	Mean	RD
A. Driving						
Has driver's license	0.0130	0.186** [0.124, 0.231]	0.0163	0.193** [0.139, 0.231]	0.0101	0.179** [0.103, 0.232]
Miles driven (miles/yr) (baseline)	514	375** [159, 530]	569	486** [195, 734]	458	234 [–105, 479]
Miles driven (miles/yr) (alternate)	549	575** [231, 856]	613	753** [328, 1,194]	484	327 [–144, 676]
B. Mortality						
All causes	38.9	5.84** [1.99, 9.36] {0.0252}	50.6	5.72 [–0.809, 11.3] {0.643}	26.7	5.76** [4.35, 7.53] {<0.0001}
Internal causes	12.2	0.406 [–0.120, 1.17] {0.560}	13.8	–0.0589 [–0.979, 1.03] {1.00}	10.5	0.820 [–0.0420, 2.00] {0.554}
External causes	26.7	5.20** [1.42, 8.47] {0.0523}	36.8	5.56* [0.0377, 10.3] {0.524}	16.1	4.82** [2.81, 6.66] {<0.0001}
Motor vehicle accident	11.2	4.92** [2.36, 7.07] {<0.001}	13.6	5.67** [2.76, 8.10] {<0.01}	8.75	4.46** [2.41, 6.14] {<0.001}
Suicide and accident	10.5	0.167 [–0.680, 0.924] {0.998}	15.6	–0.0506 [–1.63, 1.22] {1.00}	5.07	0.337 [–0.0259, 0.849] {0.555}
Firearm	3.64	0.0914 [–0.326, 0.474] {0.998}	5.87	0.529* [0.0108, 1.04] {0.524}	1.29	–0.333* [–0.715, -0.0560] {0.313}
Poisoning	1.08	0.314** [0.183, 0.522] {<0.001}	1.17	0.133 [–0.218, 0.458] {0.998}	0.984	0.747** [0.591, 1.07] {<0.0001}
Drug overdose	0.864	0.315** [0.233, 0.496] {<0.0001}	0.897	0.0447 [–0.242, 0.305] {1.00}	0.830	0.646** [0.476, 0.999] {<0.0001}
Carbon monoxide and other gases	0.214	0.103 [–0.0301, 0.215] {0.593}	0.270	0.0798 [–0.149, 0.258] {0.998}	0.154	0.127** [0.0333, 0.243] {0.163}
Drowning	1.53	–0.294** [–0.576, -0.0967] {0.0523}	2.64	–0.690** [–1.20, -0.352] {<0.01}	0.367	0.126 [–0.00258, 0.270] {0.544}
Other	4.23	0.105 [–0.316, 0.463] {0.998}	5.93	0.0406 [–0.511, 0.512] {1.00}	2.43	0.0749 [–0.519, 0.639] {1.00}
Homicide	4.80	–0.0423 [–0.623, 0.534] {0.998}	7.33	–0.0320 [–1.18, 1.10] {1.00}	2.14	–0.0779 [–0.335, 0.154] {0.998}
Other external	0.243	0.00608 [–0.148, 0.154] {0.998}	0.328	–0.0571 [–0.316, 0.154] {0.998}	0.154	0.143** [0.0872, 0.247] {<0.001}

Notes: The driving estimates in Panel A are based on weighted responses to the 1995–1996 Add Health surveys. The mortality estimates in Panel B, which are measured in deaths per 100,000 person-years, are based on death counts from the 1983–2014 National Vital Statistics and population data from the 1983–2014 Surveillance, Epidemiology, and End Results (SEER) Program. Columns (1), (3), and (5) report means of the dependent variable one year before reaching the minimum driving age (MDA). Columns (2), (4), and (6) report MSE-optimal estimates of β from equation (1). Robust, bias-corrected 95% confidence intervals are reported in brackets. A */** indicates significance at the 5%/1% level using conventional inference. Family-wise p-values, reported in braces, adjust for the number of outcome variables in each family and for the number of subgroups.

Online Appendix

"Teenage Driving, Mortality, and Risky Behaviors"

Jason Huh and Julian Reif

A Supplementary results

Table A.1 decomposes the female poisoning death estimates into those classified as suicides versus accidents. Tables A.2 and A.3 report estimates for motor vehicle fatalities and poisoning deaths, separately for sample observations where the MDA is 16 years and 0 months versus observations where it is not 16 years and 0 months.

Plots of additional outcomes, by age in months:

- Figure A.1: vehicle miles driven (baseline and alternate specifications)
- Figure A.2: deaths from all causes, external causes, and internal causes
- Figure A.3: drowning deaths
- Figure A.4: deaths from other external causes
- Figure A.5: working for pay and school enrollment

Heterogeneity by race and sex:

- Table A.4: driver's licensing rates
- Table A.5: vehicle miles driven
- Table A.6: motor vehicle fatalities
- Table A.7: poisoning deaths

Heterogeneity by month of birth:

- Table A.8: motor vehicle fatalities (see also Figure A.6)
- Table A.9: female poisoning deaths (see also Figure A.7)

Alternative specifications and robustness checks:

- Table A.10: different bandwidth selection procedures
- Table A.11: different polynomial approximations
- Table A.12: constant bandwidth of 24 months (OLS)
- Figure A.8: placebo tests

Figure A.1: Annual vehicle miles driven, 1995–1996

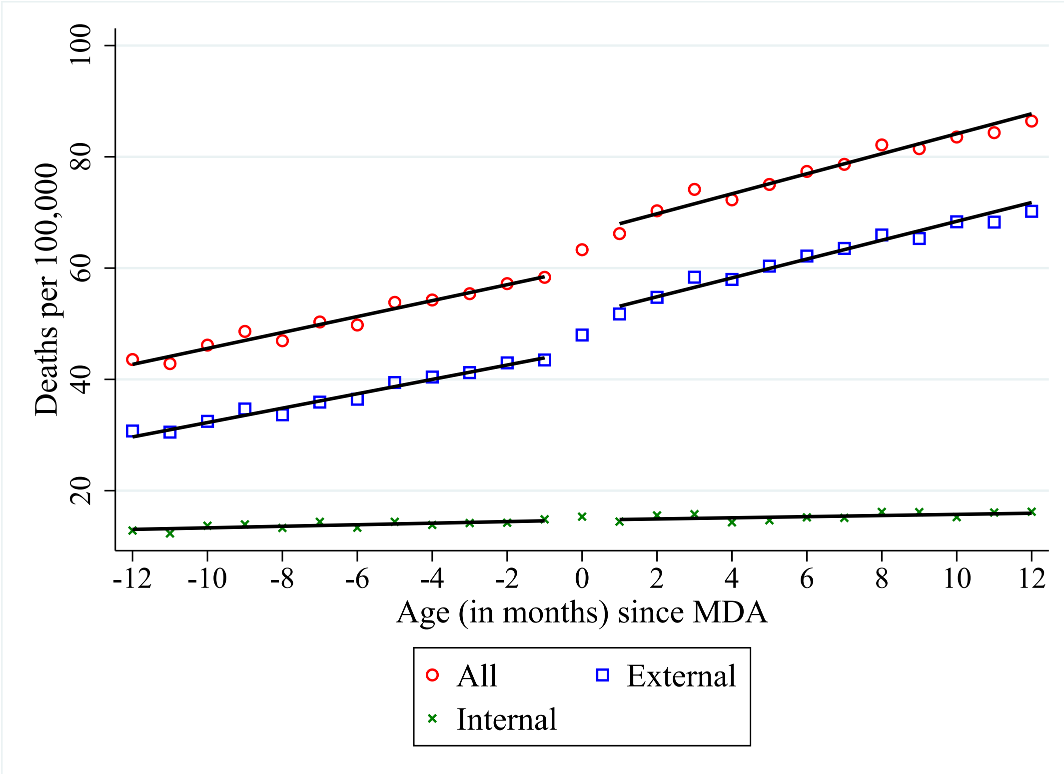
(a) Baseline specification

(b) Alternate specification

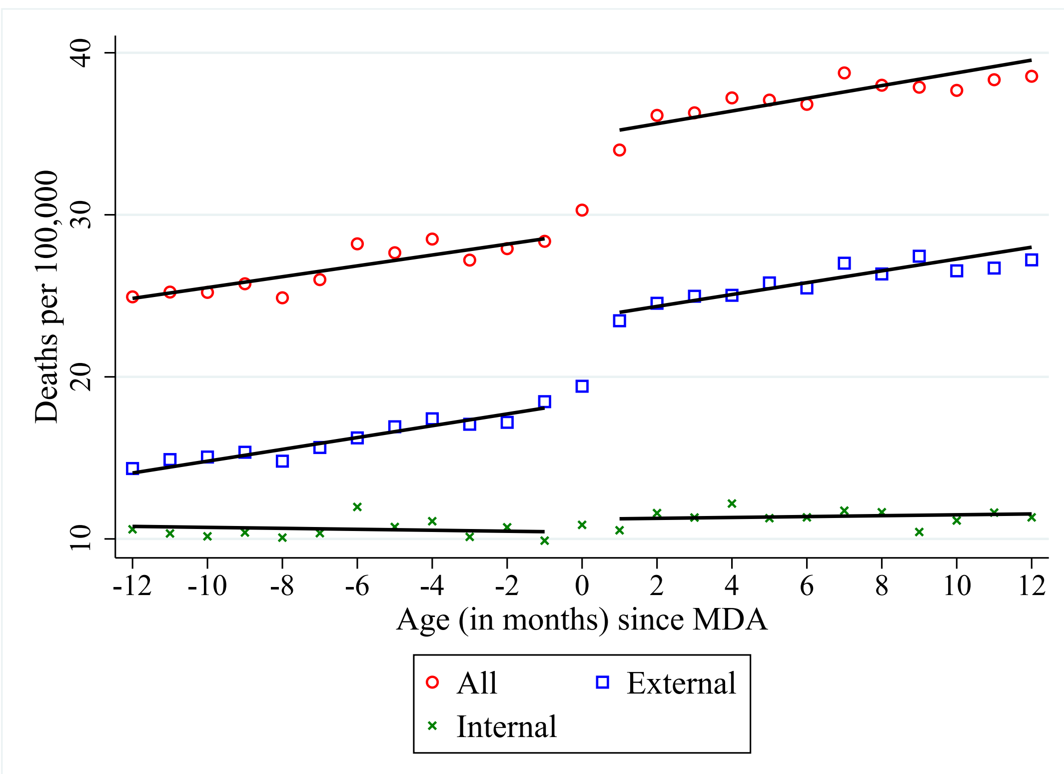
Notes: These figures show average annual vehicle miles driven by age, relative to the minimum driving age (MDA). Estimates are weighted using Add Health's cross-sectional weights. The fitted lines are estimated using equation (1) with a bandwidth of 24 months. The baseline specification assigns a value of 150 to respondents who report driving "over 100" miles per week. The alternate specification assigns a value of 265.

Figure A.2: Teenage deaths from all causes, external causes, and internal causes, 1983–2014

(a) Males



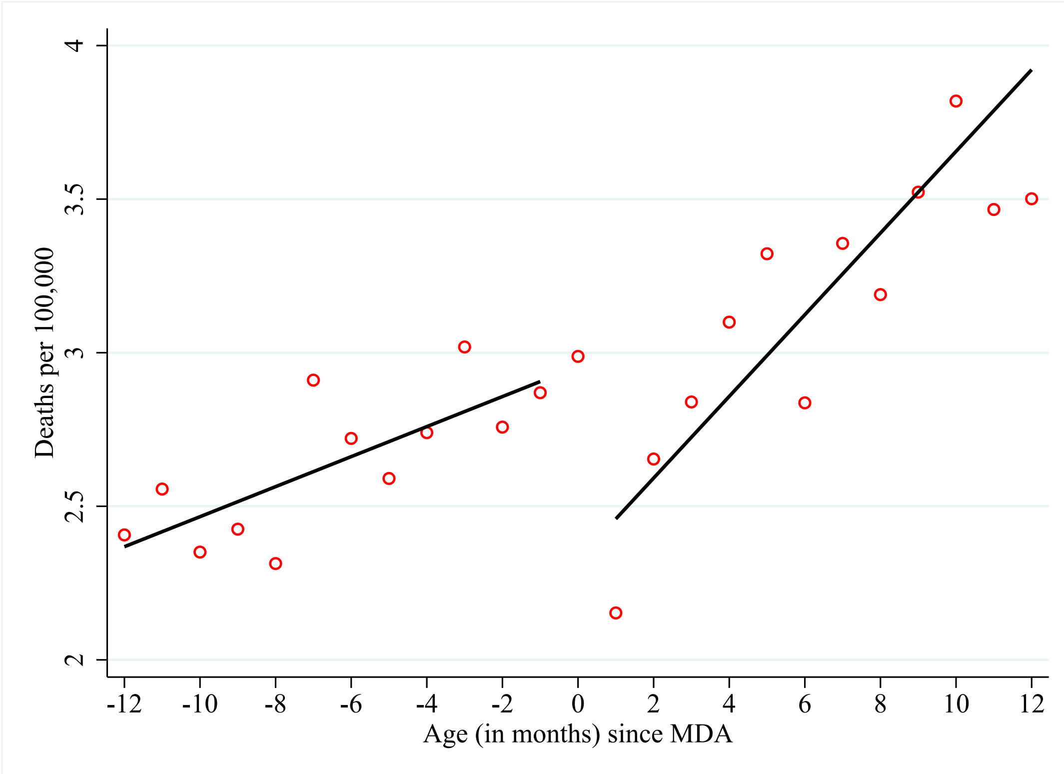
(b) Females



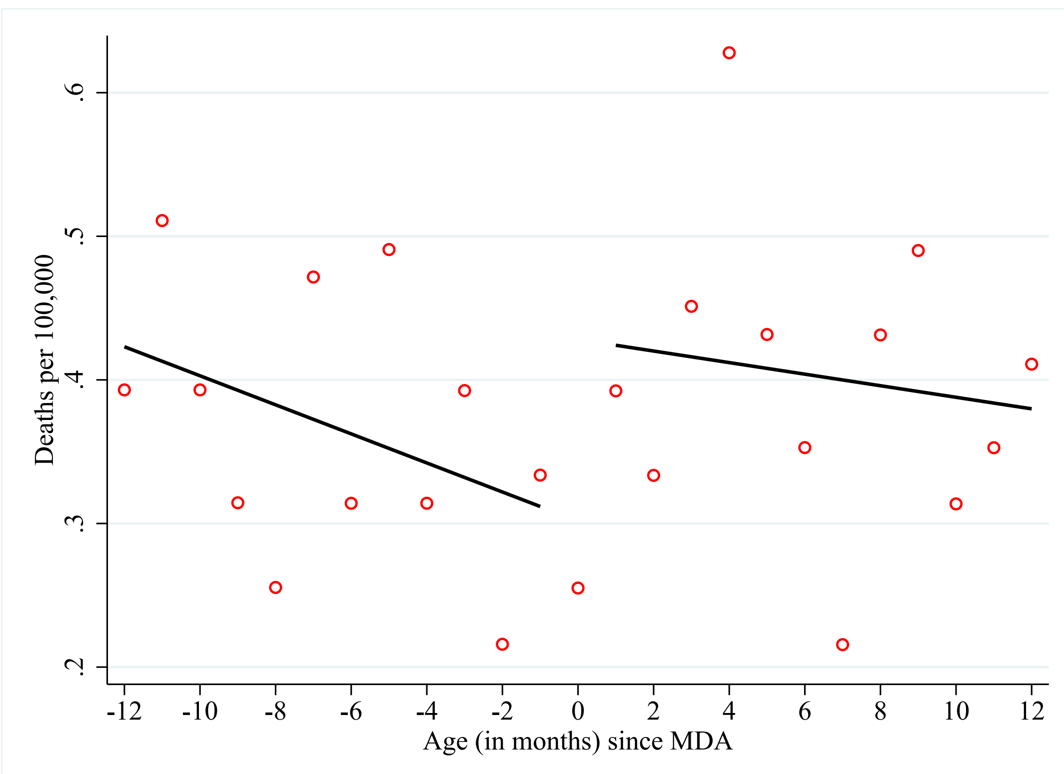
Notes: The figure shows US death rates by age, relative to the minimum driving age (MDA). The fitted lines are estimated using equation (1) with a bandwidth of 24 months.

Figure A.3: Teenage drowning deaths, 1983–2014

(a) Males



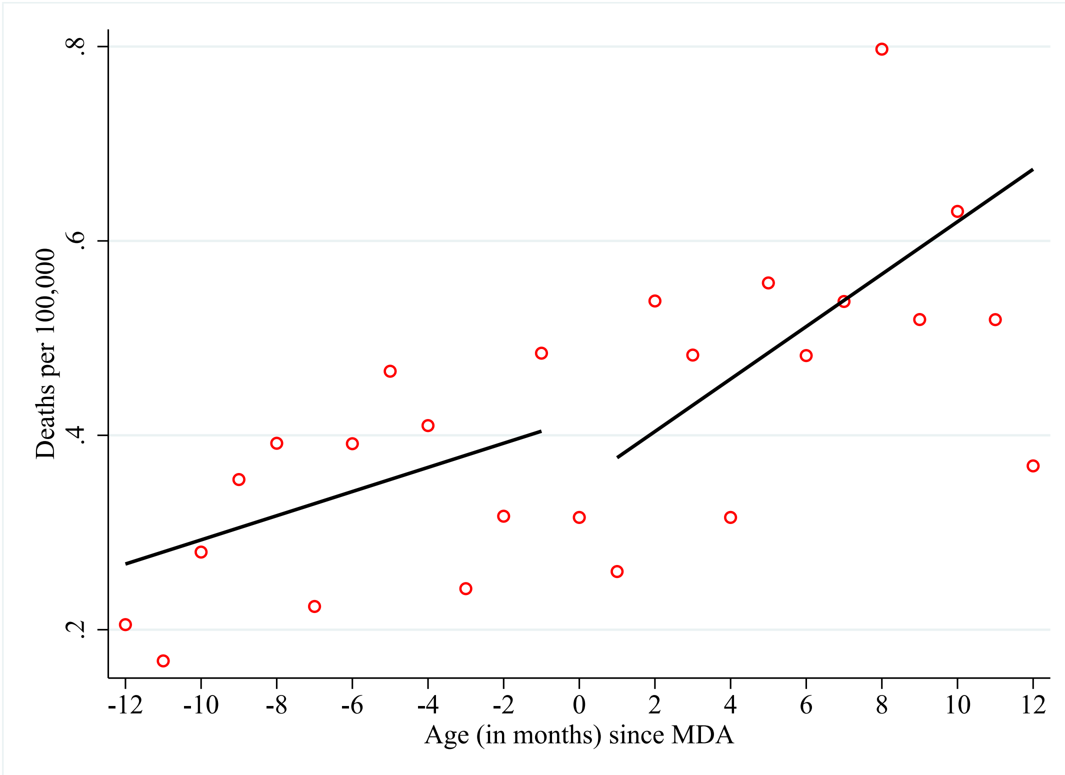
(b) Females



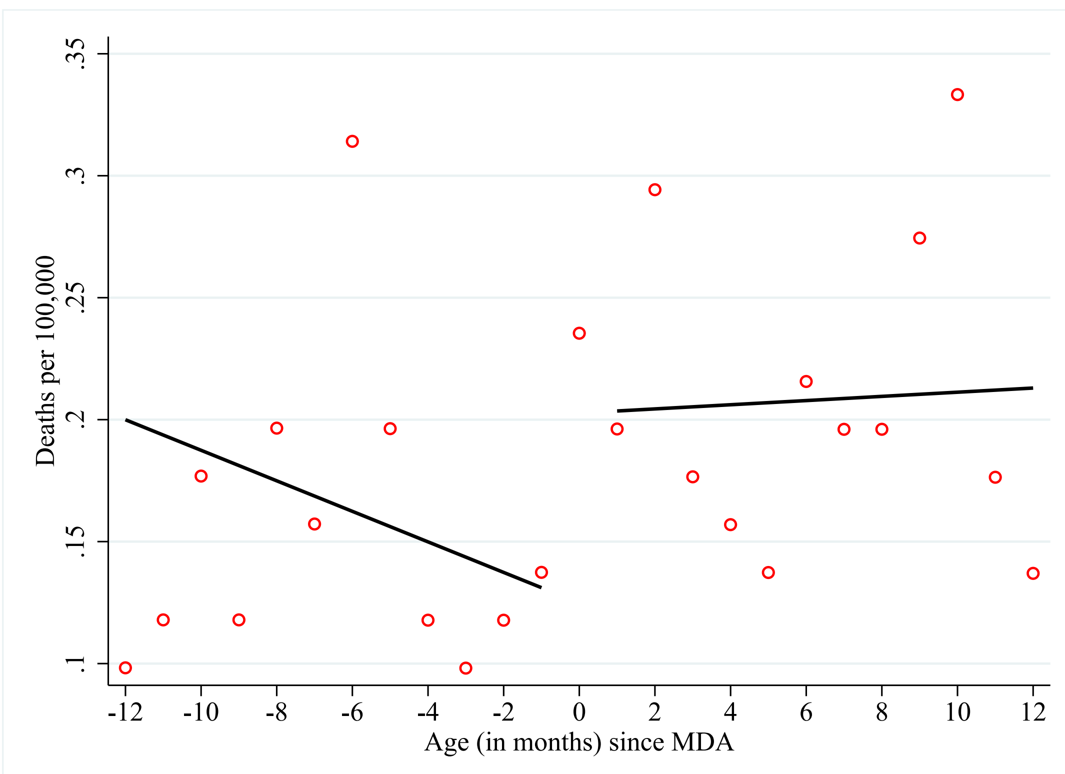
Notes: The figure shows US death rates by age, relative to the minimum driving age (MDA). The fitted lines are estimated using equation (1) with a bandwidth of 24 months.

Figure A.4: Teenage deaths categorized as "other external", 1983–2014

(a) Males



(b) Females

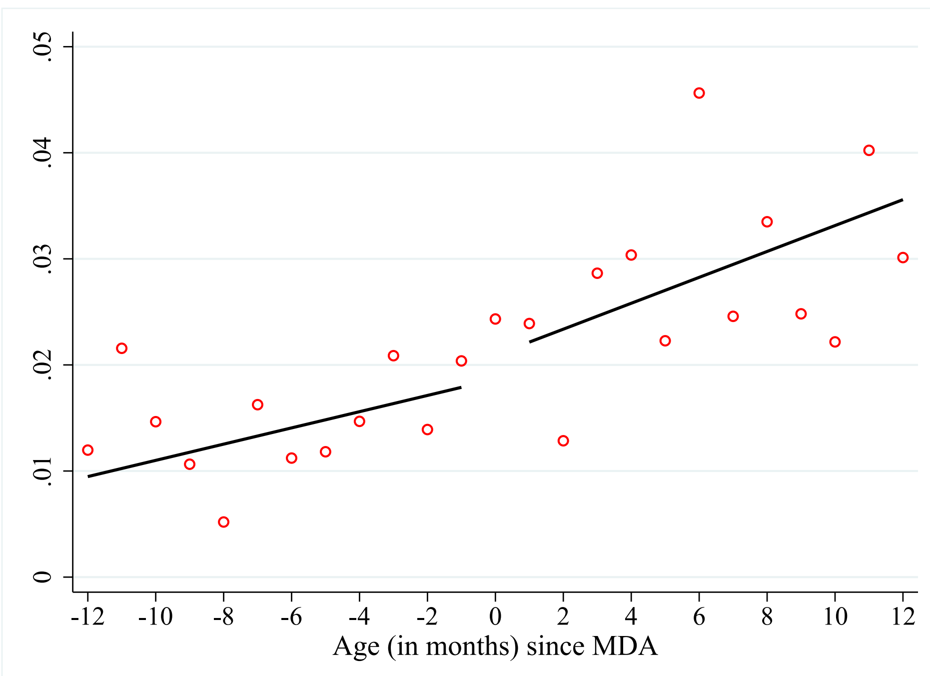


Notes: The figure shows US death rates by age, relative to the minimum driving age (MDA). The fitted lines are estimated using equation (1) with a bandwidth of 24 months.

Figure A.5: Proportion of teenagers working for pay and proportion not enrolled in school, 1995–1996

(a) Working for pay during last four weeks

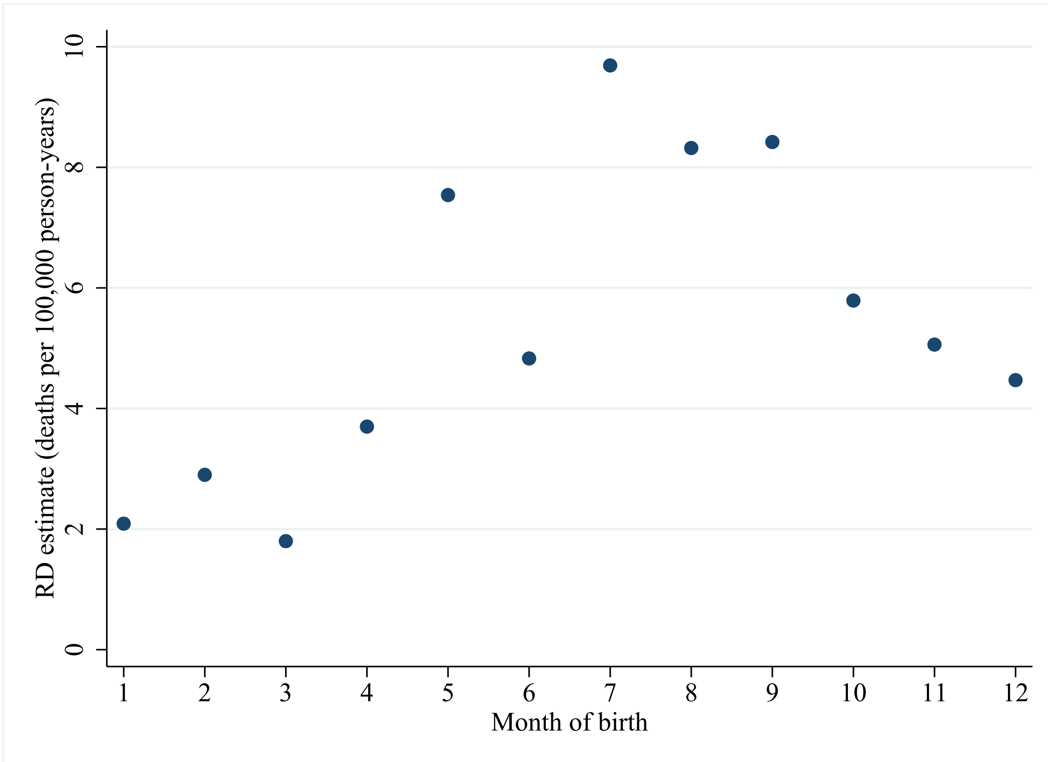
(b) Not enrolled in school



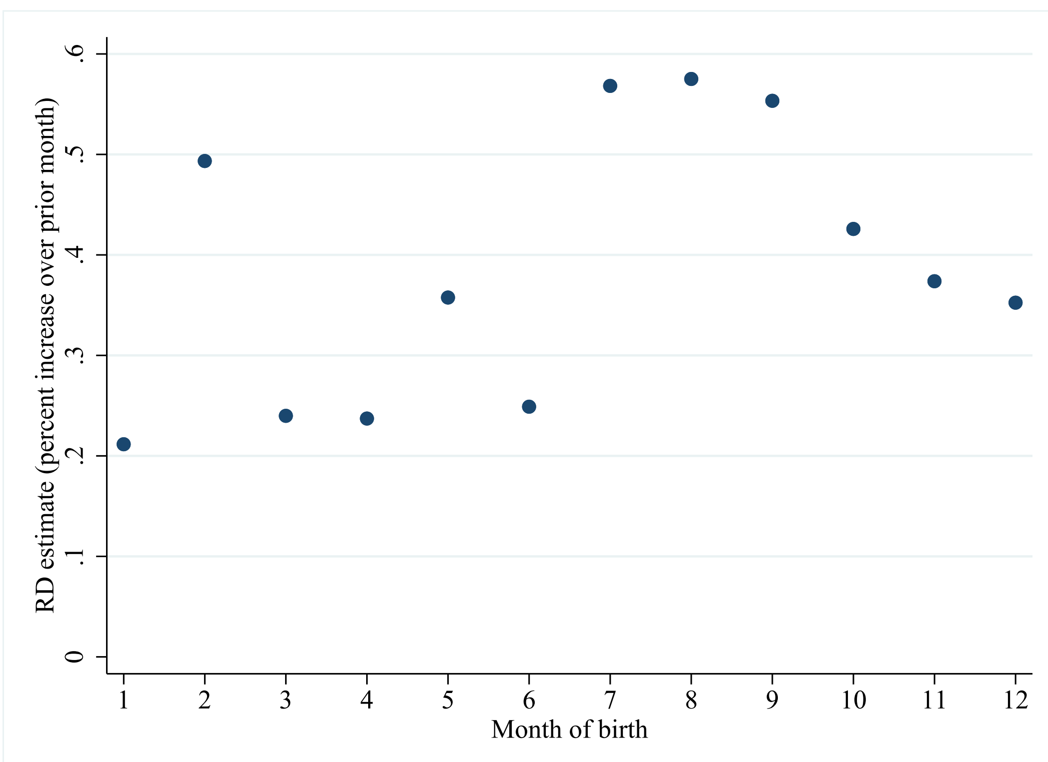
Notes: Panel (a) reports the proportion of teenagers who report ever working for pay during the last four weeks by age, relative to the minimum driving age (MDA). Working includes both formal jobs and informal jobs like babysitting or yard work. Panel (b) reports the proportion who report not being enrolled in school. The MSE-optimal RD estimate from equation (1) is an increase in working for pay of 2.9 percentage points ($p = 0.411$), with a 95% robust bias-corrected confidence interval of [–0.0385, 0.0942]. The MSE-optimal estimate for not enrolled in school is –0.021 percentage points ($p = 0.829$), with a 95% robust bias-corrected confidence interval of [–0.0104, 0.0083]. These estimates are based on weighted responses to the 1995–1996 Add Health surveys.

Figure A.6: Effect of driving eligibility on motor vehicle fatalities, by month of birth

(a) Motor vehicle fatalities



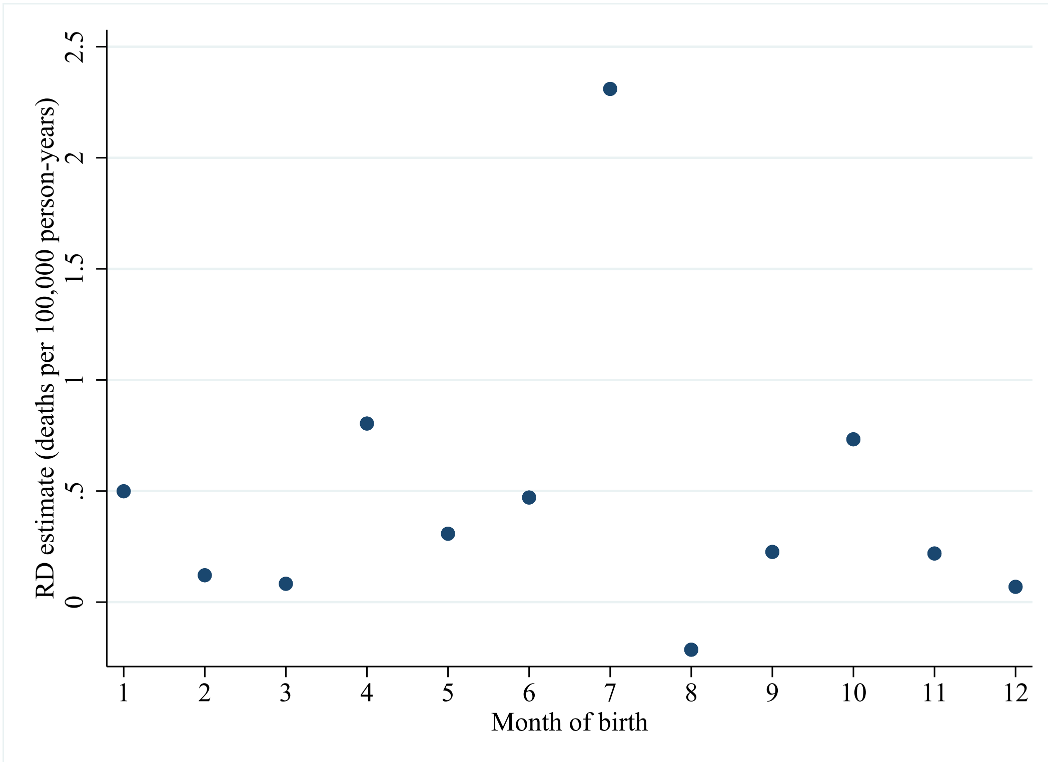
(b) Motor vehicle fatalities (relative to monthly mean)



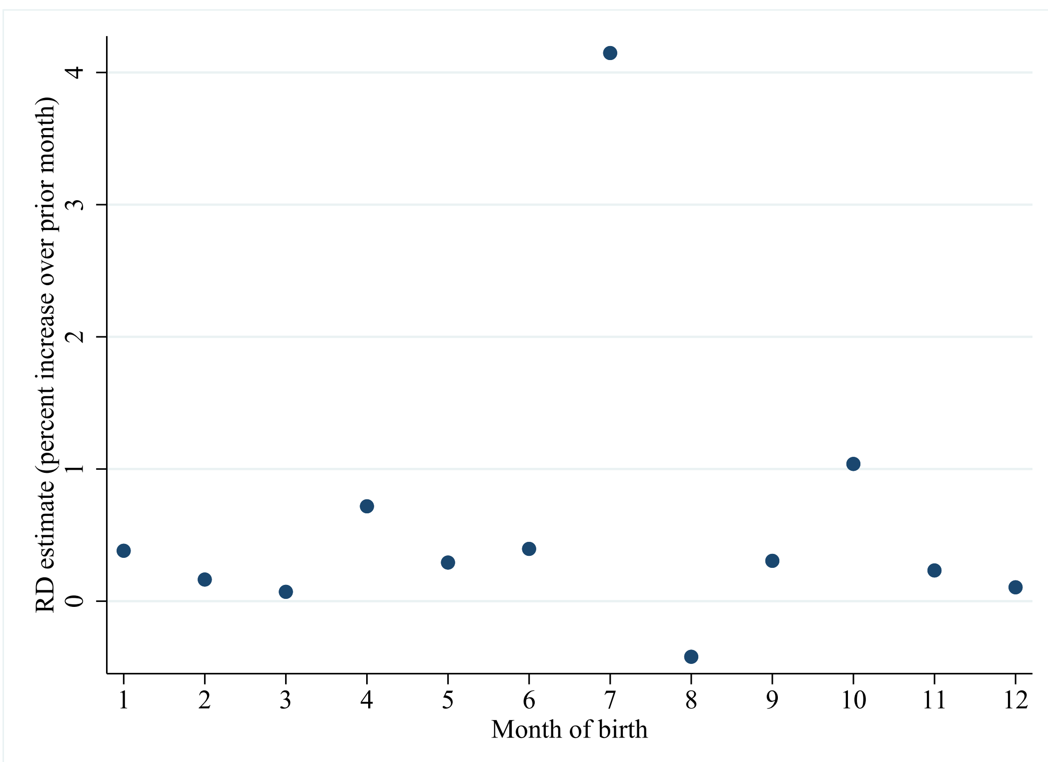
Notes: Panel (a) plots estimates from Table A.8. Panel (b) normalizes the point estimates by the mean reported in Column (1) of those tables. January is denoted as month 1.

Figure A.7: Effect of driving eligibility on female poisoning deaths, by month of birth

(a) Poisoning deaths



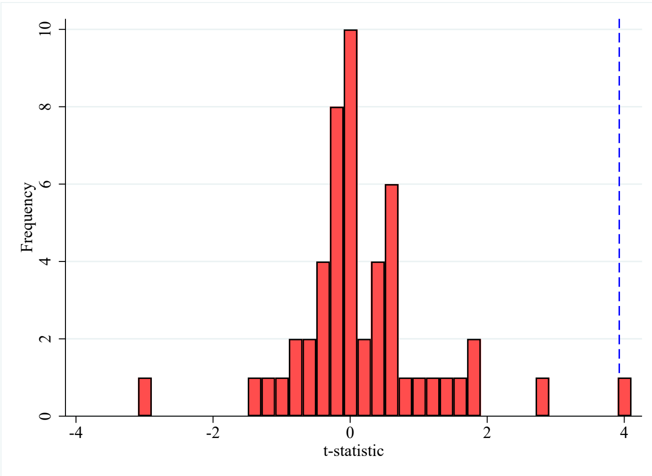
(b) Poisoning deaths (relative to monthly mean)



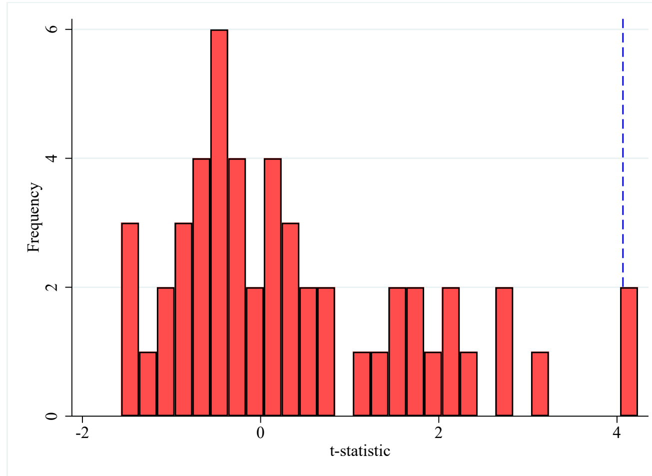
Notes: Panel (a) plots estimates from Table A.9. Panel (b) normalizes the point estimates by the mean reported in Column (1) of that table. January is denoted as month 1.

Figure A.8: Placebo estimates for motor vehicle fatalities and poisoning deaths

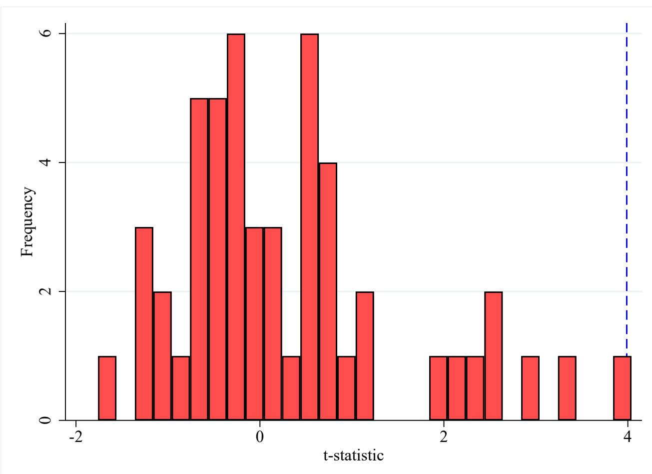
(a) Full sample: Motor vehicle fatalities



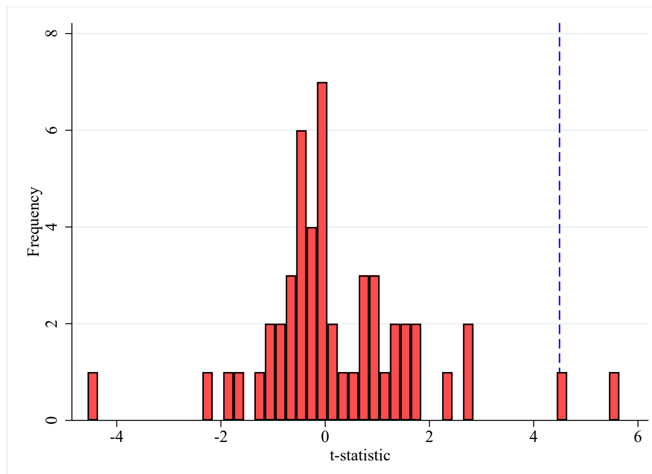
(b) Full sample: Poisoning deaths



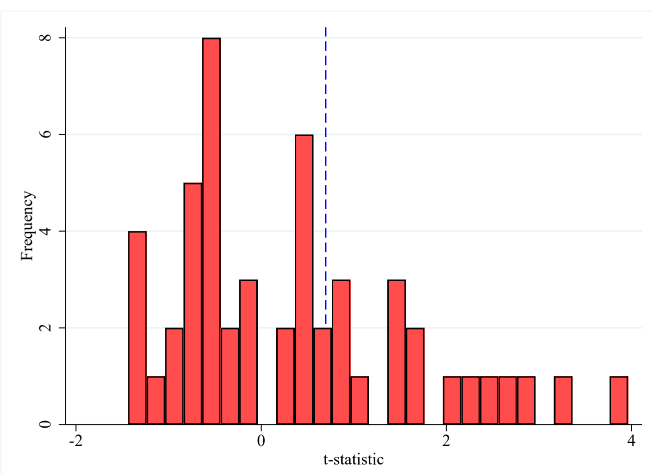
(c) Male: Motor vehicle fatalities



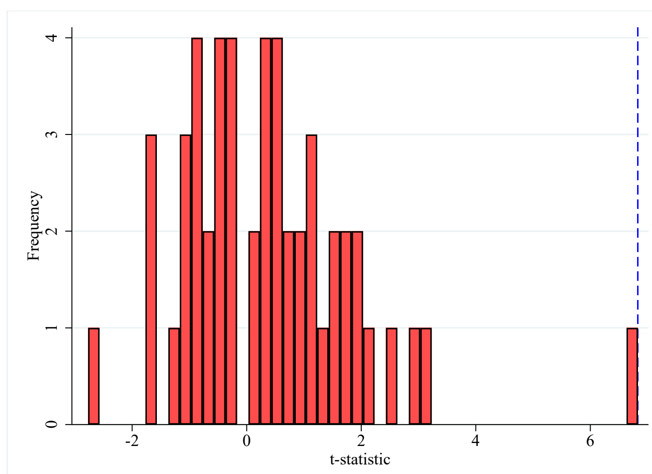
(d) Female: Motor vehicle fatalities



(e) Male: Poisoning deaths



(f) Female: Poisoning deaths



Notes: The figure shows the distribution of t-statistics for estimates of β from equation (1) using 50 placebo cutoffs (25 on each side of the true cutoff). The figure also reports the t-statistic obtained when using the true cutoff and tags that value with a vertical dashed line.

Table A.1: Effect of driving eligibility on female suicides and accidents

	(1)	(2)	(3)	(4)	(5)	(6)
	Female suicides		Female accidents		Female suicides and accidents	
Cause of death	Mean	RD	Mean	RD	Mean	RD
Total suicides/accidents	3.05	0.0449	2.02	0.280*	5.07	0.337
		[–0.341, 0.545]		[0.0421, 0.589]		[–0.0259, 0.849]
Firearm	1.15	–0.322*	0.144	–0.0254	1.29	–0.333*
		[–0.678, -0.0497]		[–0.142, 0.0753]		[–0.715, -0.0560]
Poisoning	0.537	0.233**	0.447	0.339**	0.984	0.747**
		[0.0957, 0.443]		[0.229, 0.547]		[0.591, 1.07]
Drug overdose	0.488	0.180*	0.342	0.341**	0.830	0.646**
		[0.0281, 0.426]		[0.287, 0.503]		[0.476, 0.999]
Carbon monoxide and other gases	0.0491	0.105**	0.105	0.0219	0.154	0.127**
		[0.0371, 0.174]		[–0.0426, 0.107]		[0.0333, 0.243]
Drowning	0.0295	0.00725	0.337	0.117*	0.367	0.126
		[–0.0160, 0.0421]		[0.00739, 0.258]		[–0.00258, 0.270]
Other	1.33	0.0440	1.09	–0.0462	2.43	0.0749
		[–0.361, 0.489]		[–0.373, 0.186]		[–0.519, 0.639]

Notes: This table reports MSE-optimal estimates of β from equation (1). The dependent variable is deaths per 100,000 person-years. Columns (1), (3), and (5) report means of the dependent variable one year before reaching the minimum driving age (MDA). Columns (5)–(6) reproduce the numbers reported in Columns (5)–(6) of Table 1. The estimates in Columns (2) and (4) do not necessarily add up to the estimate in Column (6) because bandwidths are not constant across different regressions. Robust, bias-corrected 95% confidence intervals are reported in brackets. A */** indicates significance at the 5%/1% level using conventional inference. Familywise p-values are not reported in this exploratory analysis.

Table A.2: Effect of driving eligibility on motor vehicle fatalities by state minimum driving age

	(1)	(2)	(3)
		RD estimate	
Subgroup	Mean	OLS	MSE optimal
Male			
Full sample	13.560	6.25**	5.67**
		(0.636)	[2.76, 8.10]
MDA is 16	13.786	6.72**	5.92**
		(0.816)	[2.90, 8.37]
MDA is not 16	12.789	4.67**	4.66**
		(0.974)	[1.58, 6.98]
Female			
Full sample	8.748	4.83**	4.46**
		(0.564)	[2.41, 6.14]
MDA is 16	9.116	5.52**	5.26**
		(0.570)	[3.46, 6.87]
MDA is not 16	7.496	2.49	2.67
		(1.32)	[–0.597, 4.90]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.3: Effect of driving eligibility on poisoning deaths by state minimum driving age

	(1)	(2)	(3)
		RD estimate	
Subgroup	Mean	OLS	MSE optimal
Male			
Full sample	1.167	0.121	0.133
		(0.133)	[–0.218, 0.458]
MDA is 16	1.168	0.172	0.161
		(0.159)	[–0.315, 0.570]
MDA is not 16	1.164	–0.0518	–0.0554
		(0.404)	[–0.943, 0.792]
Female			
Full sample	0.984	0.473**	0.747**
		(0.104)	[0.591, 1.07]
MDA is 16	1.023	0.477**	0.739**
		(0.115)	[0.516, 1.16]
MDA is not 16	0.851	0.462*	0.509**
		(0.220)	[0.200, 0.972]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.4: Effect of driving eligibility on proportion of teenagers with a license for different subgroups

	(1)	(2)	(3)
		RD estimate	
Subgroup	Mean	OLS	MSE optimal
Full sample	0.013	0.186**	0.186**
		(0.0138)	[0.124, 0.231]
Race			
White	0.013	0.230**	0.229**
		(0.0185)	[0.149, 0.286]
Nonwhite	0.013	0.0501	0.0623**
		(0.0263)	[0.0232, 0.101]
Sex			
Male	0.016	0.193**	0.193**
		(0.0103)	[0.139, 0.231]
Female	0.010	0.178**	0.179**
		(0.0229)	[0.103, 0.232]
Race and sex			
White male	0.015	0.246**	0.246**
		(0.0124)	[0.178, 0.293]
White female	0.011	0.215**	0.217**
		(0.0338)	[0.113, 0.289]
Nonwhite male	0.021	0.0390	0.0586
		(0.0345)	[–0.00354, 0.125]
Nonwhite female	0.007	0.0585	0.0561*
		(0.0316)	[0.00752, 0.0987]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is the proportion of teenagers with a driver's license. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.5: Effect of driving eligibility on vehicle miles driven (baseline) for different subgroups

	(1)	(2)	(3)
		RD estimate	
Subgroup	Mean	OLS	MSE optimal
Full sample	514	371**	375**
		(53.3)	[159, 530]
Race			
White	536	499**	497**
		(66.3)	[242, 682]
Nonwhite	450	–5.23	–40.8
		(82.1)	[–340, 179]
Sex			
Male	569	484**	486**
		(116)	[195, 734]
Female	458	235	234
		(116)	[–105, 479]
Race and sex			
White male	575	720**	709**
		(146)	[366, 1,045]
White female	496	272	272
		(165)	[–138, 566]
Nonwhite male	552	–113	–78.7
		(128)	[–435, 216]
Nonwhite female	350	101	94.3
		(72)	[–118, 235]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is average annual vehicle miles driven (baseline specification). Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.6: Effect of driving eligibility on motor vehicle fatalities for different subgroups

	(1)	(2)	(3)
		RD estimate	
Subgroup	Mean	OLS	MSE optimal
Full sample	11.217	5.57**	4.92**
		(0.492)	[2.36, 7.07]
Race			
White	12.204	7.20**	6.39**
		(0.637)	[3.71, 8.57]
Nonwhite	7.634	–0.448	–0.507
		(0.541)	[–2.81, 1.37]
Sex			
Male	13.560	6.25**	5.67**
		(0.636)	[2.76, 8.10]
Female	8.748	4.83**	4.46**
		(0.564)	[2.41, 6.14]
Race and sex			
White male	14.469	7.95**	7.50**
		(0.918)	[4.68, 9.77]
White female	9.807	6.40**	6.04**
		(0.740)	[3.74, 8.02]
Nonwhite male	10.228	–0.0517	–0.107
		(0.936)	[–3.70, 2.91]
Nonwhite female	4.949	–0.872	–0.903
		(0.539)	[–2.41, 0.0198]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.7: Effect of driving eligibility on poisoning deaths for different subgroups

	(1)	(2)	(3)
		RD estimate	
Subgroup	Mean	OLS	MSE optimal
Full sample	1.078	0.293**	0.314**
		(0.0848)	[0.183, 0.522]
Race			
White	1.196	0.268*	0.258*
		(0.121)	[0.0216, 0.558]
Nonwhite	0.649	0.379	0.412**
		(0.185)	[0.157, 0.839]
Sex			
Male	1.167	0.121	0.133
		(0.133)	[–0.218, 0.458]
Female	0.984	0.473**	0.747**
		(0.104)	[0.591, 1.07]
Race and sex			
White male	1.325	0.0788	0.105
		(0.178)	[–0.345, 0.506]
White female	1.059	0.467**	0.653**
		(0.110)	[0.581, 0.898]
Nonwhite male	0.588	0.271	0.280
		(0.159)	[–0.0669, 0.694]
Nonwhite female	0.714	0.492	0.565*
		(0.310)	[0.121, 1.32]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.8: Effect of driving eligibility on motor vehicle fatalities by month of birth

	(1)	(2)	(3)
		RD estimate	
Month of birth	Mean (monthly)	OLS	MSE optimal
January	9.877	2.40*	2.09*
		(1)	[0.0258, 3.58]
February	5.877	3.11**	2.90**
		(0.870)	[1.13, 4.99]
March	7.504	2.07	1.80
		(1.06)	[–1.45, 4.33]
April	15.600	3.65*	3.70
		(1.53)	[–1.14, 7.60]
May	21.084	7.86**	7.54**
		(1.62)	[2.58, 13.5]
June	19.400	6.02**	4.83*
		(1.21)	[0.353, 7.84]
July	17.053	9.81**	9.69**
		(1.40)	[7.12, 12.3]
August	14.467	9.29**	8.32**
		(1.14)	[6.03, 10.1]
September	15.216	8.42**	8.42**
		(0.370)	[7.46, 9.04]
October	13.596	6.12**	5.79**
		(1.04)	[1.83, 8.70]
November	13.535	6.09**	5.06**
		(0.777)	[2.30, 6.82]
December	12.681	4.61**	4.47**
		(1.23)	[1.75, 6.76]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.9: Effect of driving eligibility on female poisoning deaths by month of birth

	(1)	(2)	(3)
		RD estimate	
Month of birth	Mean (monthly)	OLS	MSE optimal
January	1.308	0.394	0.499
		(0.359)	[–0.226, 1.34]
February	0.739	0.347	0.121
		(0.492)	[–0.720, 1.02]
March	1.166	0.0752	0.0826
		(0.378)	[–0.664, 0.833]
April	1.120	0.978	0.804**
		(0.476)	[0.252, 1.65]
May	1.054	0.110	0.308
		(0.503)	[–0.566, 1.51]
June	1.190	0.303	0.471
		(0.506)	[–0.597, 2.05]
July	0.557	2.20**	2.31**
		(0.388)	[1.83, 3.22]
August	0.509	0.0430	–0.214
		(0.249)	[–0.681, 0.369]
September	0.740	0.227	0.226
		(0.543)	[–0.486, 1.10]
October	0.706	0.747**	0.733**
		(0.235)	[0.450, 1.24]
November	0.942	0.243	0.219
		(0.371)	[–0.420, 0.921]
December	0.657	0.154	0.0690
		(0.383)	[–0.671, 0.929]

Notes: This table reports estimates of β from equation (1) for different subgroups. The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Column (2) reports OLS estimates from a model employing a bandwidth of 24 months and reports robust standard errors in parentheses. Column (3) reports MSE-optimal estimates and reports robust, bias-corrected 95% confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.10: Effect of driving eligibility on mortality using different bandwidth selection procedures

	(1)	(2)	(3)	(4)	(5)
		RD estimate			
Subgroup	Mean	MSE optimal (1)	MSE optimal (2)	CER optimal (1)	CER optimal (2)
A. All deaths					
Full sample	38.9	5.84** [1.99, 9.36] ±11	5.81** [1.98, 8.92] –12/+11	5.66** [1.43, 9.67] ±8	5.55** [1.39, 9.22] –10/+8
Male	50.6	5.72 [–0.809, 11.3] ±10	5.93 [–0.0738, 10.6] –13/+11	5.58 [–1.44, 12.0] ±8	5.62 [–0.759, 11.1] –11/+8
Female	26.7	5.76** [4.35, 7.53] ±11	5.99** [4.42, 7.69] –9/+11	5.70** [3.99, 7.63] ±9	5.99** [4.17, 7.89] –7/+8
B. Motor vehicle fatalities					
Full sample	11.2	4.92** [2.36, 7.07] ±9	4.98** [2.70, 6.54] –15/+9	4.66** [1.75, 7.31] ±7	4.74** [2.21, 6.80] –12/+7
Male	13.6	5.67** [2.76, 8.10] ±9	5.55** [2.58, 7.60] –13/+9	5.29** [2.00, 8.28] ±7	5.22** [1.89, 7.96] –10/+7
Female	8.75	4.46** [2.41, 6.14] ±10	4.43** [2.76, 5.68] –17/+10	4.20** [1.93, 6.23] ±8	4.28** [2.48, 5.82] –14/+8
C. Poisoning deaths					
Full sample	1.08	0.314** [0.183, 0.522] ±11	0.294** [0.154, 0.519] –10/+12	0.386** [0.273, 0.553] ±9	0.361** [0.235, 0.546] –8/+10
Male	1.17	0.133 [–0.218, 0.458] ±14	0.130 [–0.220, 0.458] –14/+13	0.111 [–0.242, 0.444] ±11	0.127 [–0.219, 0.457] –11/+11
Female	0.984	0.747** [0.591, 1.07] ±7	0.644** [0.460, 0.978] –6/+12	0.838** [0.589, 1.20] ±6	0.713** [0.496, 1.04] –5/+10

Notes: The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Columns (2)–(5) report estimates of β from equation (1) using different bandwidths. The MSE-optimal method selects a bandwidth that minimizes the mean squared error (MSE) of the point estimator. The coverage error rate (CER) optimal method selects a bandwidth that minimizes the asymptotic CER of the robust bias-corrected confidence interval. Column (2) reports estimates from our preferred specification, MSE optimal (1), which selects one common bandwidth on each side of the cutoff. Columns (3)–(5) report estimates using different bandwidth selection procedures: MSE optimal with different bandwidths on each side of the cutoff, CER optimal with one common bandwidth, and CER optimal with different bandwidths on each side of the cutoff. Robust, bias-corrected 95% confidence intervals are reported in brackets. The selected bandwidths (rounded to the nearest month) are reported below the confidence interval. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.11: Effect of driving eligibility on mortality using different polynomial approximations

	(1)	(2)	(3)	(4)
		RD estimate		
Subgroup	Mean	Linear	Quadratic	Cubic
A. All deaths				
Full sample	38.9	5.84** [1.99, 9.36]	5.58* [1.14, 10.1]	5.23* [0.338, 10.4]
Male	50.6	5.72 [–0.809, 11.3]	5.22 [–1.96, 11.9]	4.66 [–3.80, 13.3]
Female	26.7	5.76** [4.35, 7.53]	5.50** [3.30, 8.06]	5.79** [3.60, 8.33]
B. Motor vehicle fatalities				
Full sample	11.2	4.92** [2.36, 7.07]	4.68** [1.72, 7.37]	4.50** [1.53, 7.37]
Male	13.6	5.67** [2.76, 8.10]	5.31** [1.95, 8.51]	5.02** [1.63, 8.55]
Female	8.75	4.46** [2.41, 6.14]	3.95** [1.11, 6.40]	3.91** [1.03, 6.47]
C. Poisoning deaths				
Full sample	1.08	0.314** [0.183, 0.522]	0.423** [0.282, 0.601]	0.587** [0.319, 0.872]
Male	1.17	0.133 [–0.218, 0.458]	0.115 [–0.335, 0.493]	0.151 [–0.250, 0.554]
Female	0.984	0.747** [0.591, 1.07]	0.881** [0.605, 1.26]	0.970** [0.617, 1.40]

Notes: The dependent variable is deaths per 100,000 person-years. Column (1) reports means of the dependent variable one year before reaching the minimum driving age (MDA). Columns (2)–(4) report estimates of β from equation (1) using different polynomial approximations: linear (our preferred specification), quadratic, and cubic. Robust, bias-corrected 95% confidence intervals are reported in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.12: OLS estimates of effect of driving eligibility on teenage driving and mortality

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample		Male		Female	
Outcome variable	Mean	RD	Mean	RD	Mean	RD
A. Driving						
Has driver's license	0.0130	0.186** (0.0138)	0.0163	0.193** (0.0103)	0.0101	0.178** (0.0229)
Miles driven (miles/yr) (baseline)	514	371** (53.3)	569	484** (116)	458	235 (116)
Miles driven (miles/yr) (alternate)	549	581** (96.4)	613	798** (198)	484	327 (181)
B. Mortality						
All causes	38.9	6.16** (0.934) {<0.0001}	50.6	6.29** (1.23) {<0.01}	26.7	5.98** (0.758) {<0.0001}
Internal causes	12.2	0.390 (0.375) {0.844}	13.8	–0.00387 (0.455) {1.00}	10.5	0.799 (0.545) {0.850}
External causes	26.7	5.77** (0.608) {<0.0001}	36.8	6.29** (0.948) {<0.0001}	16.1	5.18** (0.439) {<0.0001}
Motor vehicle accident	11.2	5.57** (0.492) {<0.0001}	13.6	6.25** (0.636) {<0.0001}	8.75	4.83** (0.564) {<0.0001}
Suicide and accident	10.5	0.221 (0.159) {0.696}	15.6	0.0940 (0.210) {0.999}	5.07	0.334 (0.185) {0.716}
Firearm	3.64	0.102 (0.121) {0.877}	5.87	0.514** (0.136) {0.0217}	1.29	–0.342 (0.183) {0.697}
Poisoning	1.08	0.293** (0.0848) {0.0248}	1.17	0.121 (0.133) {0.985}	0.984	0.473** (0.104) {<0.01}
Drug overdose	0.864	0.187 (0.0944) {0.401}	0.897	0.0345 (0.114) {0.999}	0.830	0.347* (0.142) {0.335}
Carbon monoxide and other gases	0.214	0.106 (0.0598) {0.486}	0.270	0.0865 (0.0785) {0.964}	0.154	0.127 (0.0618) {0.587}
Drowning	1.53	–0.260* (0.118) {0.305}	2.64	–0.629** (0.191) {0.0622}	0.367	0.126 (0.0741) {0.730}
Other	4.23	0.0856 (0.202) {0.966}	5.93	0.0879 (0.202) {0.999}	2.43	0.0764 (0.298) {0.999}
Homicide	4.80	–0.0204 (0.210) {0.994}	7.33	0.0114 (0.411) {1.00}	2.14	–0.0653 (0.132) {0.999}
Other external	0.243	0.00378 (0.0714) {0.994}	0.328	–0.0667 (0.109) {0.998}	0.154	0.0778 (0.0437) {0.716}

Notes: This table replicates Table 1 but uses an OLS estimator with a bandwidth of 24 months instead of an MSE-optimal estimator. Columns (1), (3), and (5) report means of the dependent variable one year before reaching the minimum driving age (MDA). Columns (2), (4), and (6) report OLS estimates of β from equation (1). Robust standard errors are reported in parentheses. A */** indicates significance at the 5%/1% level using conventional inference. Family-wise p-values, reported in braces, adjust for the number of outcome variables in each family and for the number of subgroups.

B Data and additional background

B.1 Background information on teenage driver's licenses

Figure B.1 presents trends in the proportion of teenagers with a restricted or full driver's license during our 1983–2014 sample period.[1] Figure B.2 presents corresponding trends in vehicle miles traveled for licensed teenagers.

States with a Graduated Driver Licensing (GDL) program have three distinct licensing stages: learner's permit, intermediate licensure, and full licensure. States without a GDL program generally have just two stages: learner's permit and full licensure. Below, we provide details about the licensing process for teenage drivers.

B.1.1 Learner's permit

Teenagers begin the licensing process by first obtaining a learner's permit, allowing them to drive under the supervision of an adult. The minimum age for a learner's permit ranges from 14 to 16. Since 1991, 7 states have decreased this minimum age, 3 states have increased it, and 2 states did both. In 38 states, a driver's education program is required either before applying for a learner's permit or a restricted driver's license. There is no driver's education program requirement in the remaining 12 states plus DC. Instead, those states have alternative requirements. For instance, learner's permit holders in Arizona who did not complete driver's education must have a minimum of 30 hours of supervised driving (10 of which must be during nighttime) before they can apply for a restricted license.[2]

In all states, a teenager with a learner's permit must be supervised by a licensed driver when driving a motor vehicle. A majority of the states (36 states plus DC) require the supervisor to be at least 21 years of age. The lowest/highest age requirement for the supervisor is 18/25. In addition, states usually impose driving experience, ranging from 1 to 5 years, on a supervisor.

B.1.2 Intermediate licensure

Beginning in 1996, states began adopting GDL programs. These programs introduced new restrictions that prohibit unsupervised driving by licensed teenagers under the age of 18 during certain nighttime hours and limit the number and age of passengers in their cars. The minimum age for a restricted driver's license (also known as a "probationary," "provisional," "junior," or "intermediate" license) ranges from 14 to 17. Upon reaching the MDA for a restricted license, the teenager becomes eligible to take a driving test and to apply for a restricted driver's license after satisfying the following requirements:

[1] The figure is based on license counts from the Federal Highway Administration (FHWA). Those data are publicly available at: www.fhwa.dot.gov/policyinformation/quickfinddata/qfdrivers.cfm.

[2] See https://www.dmv.org/drivers-ed.php for specific driver's education requirements by state.

1. Learner's permit holding period. This holding period ranges from 10 days to 12 months and was required in all states by the end of our sample period. Some states also require that the teenager has no traffic violations or accidents within a certain number of months, such as 3 or 6 months, before applying for a restricted driver's license.

2. Behind-the-wheel training. This required training was introduced in all but four states during our sample period. The hours required for the training vary between 12 and 70, and some states waive or reduce this requirement with completion of an optional driver's education course.

Two types of driving restrictions were adopted or modified during our sample period: nighttime restrictions (42 states plus DC) and passenger restrictions (44 states plus DC). By the end of our sample period, 42 states plus DC had both nighttime and passenger restrictions. The night driving restrictions prohibit unsupervised driving during certain times, for example, between 8pm and 6am. The passenger driving restrictions limit the number and age of passengers, and sometimes the relationship of passengers to the driver. For instance, restricted driver's licenses typically do not allow more than one to three non-adult passengers in the teenager's vehicle, and under stricter GDL laws, no passengers are allowed other than family members or driving instructors.

B.1.3 Full licensure

After both nighttime and passenger restrictions (if in force) are lifted at ages 16 to 18, restricted driver's license holders become eligible to apply for a full driver's license. Teenagers with traffic violations or accidents within a certain number of months before the application may have their eligibility for a full driver's license delayed in some states.

B.2 Minimum driving age laws

Table B.1 provides the data we collected on MDAs. Indiana, Kansas, and South Dakota have lower MDAs for teenagers who complete a driver's education program.[3] For these three states, we use the MDAs that apply to teenagers who have completed a driver's education program.

The data for the time period 1995–2014 were obtained from the Insurance Institute for Highway Safety and the data for the 1983–1994 period were obtained from HeinOnline.[4] We made two corrections to the Insurance Institute for Highway Safety data. The original data reported that Hawaii increased the MDA from 15 years and 3 months to 16 on 1/9/2006, and Nevada had an MDA of 15 years and 9 months before 1995. However, the corresponding dates indicated in the session laws are 1/1/2001 for Hawaii and 7/1/2001 for Nevada, so we use these corrected dates in our analysis.

[3] In Indiana, starting in July 2010, the MDA is 16 years and 9 months for teenagers who did not complete a driver's education program, but it is 16 years and 6 months for those who did complete the program. In Kansas, the MDA is 16 years without completion and 15 years with completion. In South Dakota, starting in January 1999, the MDA is 14 years and 6 months without completion and 14 years and 3 months with completion.

[4] The HeinOnline database is available at https://home.heinonline.org/content/session-laws-library.

Most states have hardship exemptions that allow teenagers below the MDA to obtain a limited license for certain occupational, medical, and educational purposes.[5] However, hardship exemptions are very rare. For example, less than 1% of teenagers within one year of the MDA obtained a hardship license in Ohio in 2017 (authors' calculations using Ohio administrative licensing data). In addition, some states issue farmer's permits that have a lower MDA than the MDA we employ (e.g., Kansas, Minnesota, and New Jersey), but these permits are uncommon and are intended only for farming purposes.

B.3 Mortality

Table B.2 provides the list of ICD-9 and ICD-10 codes used to classify the cause of death in the Vital Statistics data. (The ICD-9 classification was replaced by ICD-10 in 1999.) We follow Carpenter and Dobkin (2009) and classify alcohol- or drug-related internal causes of death as "other external" (e.g., ICD-9 codes 291 and 292). A small number of deaths are classified as "undetermined intent," i.e., neither accidents nor suicides. These deaths are more likely to be suicides than accidents: prior work has argued that medical examiners and coroners may classify a death as "undetermined" when there is pressure to avoid a classification of suicide (Gray et al., 2014; Stone et al., 2017). We therefore classify deaths of undetermined intent as suicides.

Table B.3 reports annual death rates by sex for different five-year age groups during our sample period. Figure B.3 reports annual teenage death rates for the years 1983–2014, separately for males and females. Figure B.4 shows how trends in suicides and accidents vary across different categories for both males and females.

B.4 Add Health

We obtained a restricted-use version of the 1995 and 1996 Add Health survey data that includes pseudo-state identifiers and age in months. Table B.4 documents the codings for the Add Health variables employed in our analysis. Minimum driving ages for each combination of pseudo-state and survey year (1995 or 1996) were inferred by plotting the proportion of respondents with a license as a function of age in months and visually locating the discontinuity. We validated this procedure by checking that the aggregate number of pseudo-states with a particular MDA was consistent with the data presented in Table B.1.

We dropped person-year observations that were missing values for the pseudo-state identifier, sample weight, birth month, or birth year. We also dropped observations from eight pseudo-states for which we were unable to reliably infer an MDA. In total, we excluded 3,177 observations. Our final sample included 32,307 person-year observations.

We confirmed that respondents' answers to questions about driving behavior are consistent with national data on license counts published by the Federal Highway Administration (FHWA). In 1995, the MDA was 16 in most states (Table B.1). According to Figure B.1, data published by the FHWA

[5] See https://automobiles.uslegal.com/drivers-hardship-license-law for details.

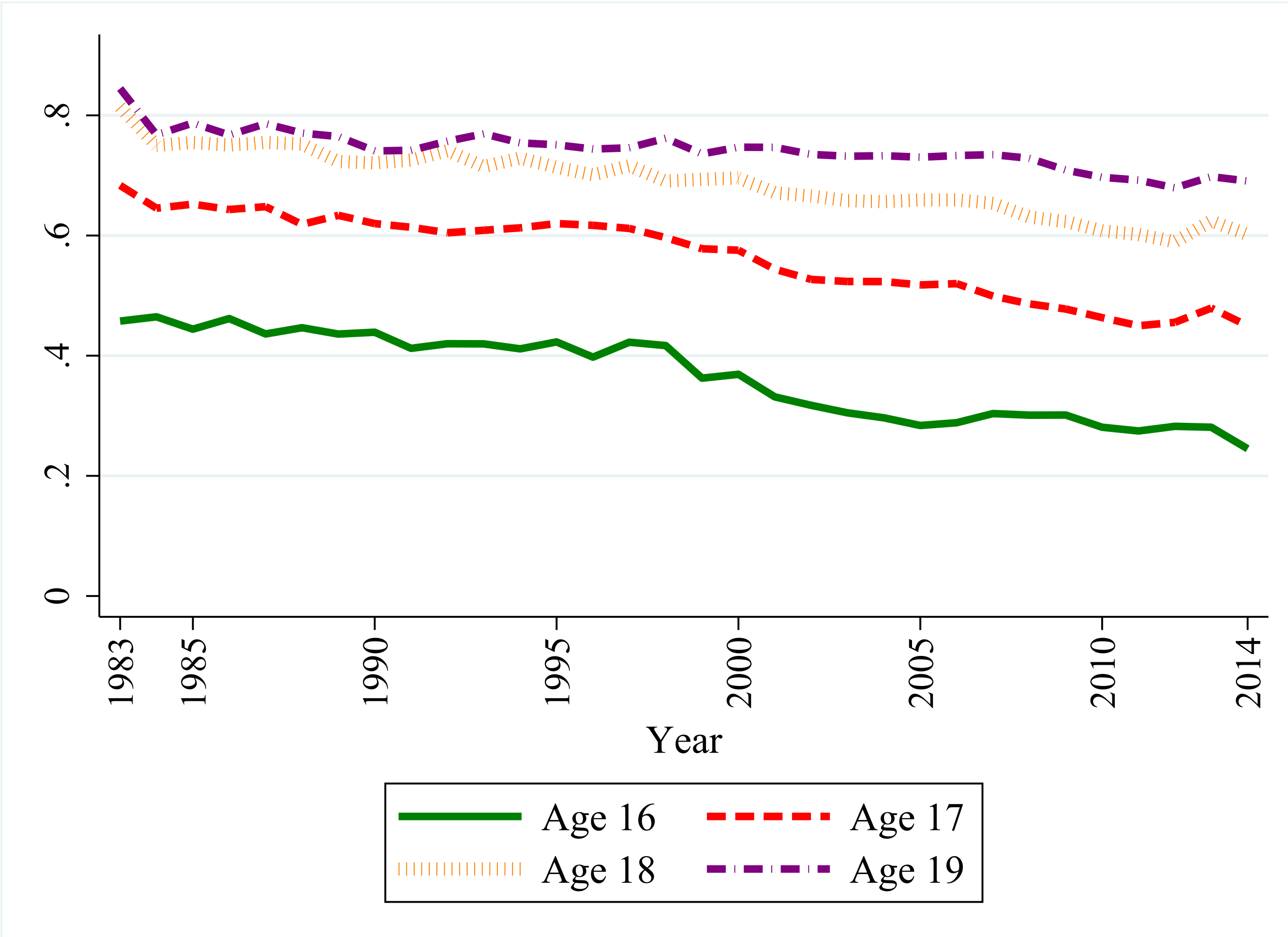
indicate that just over 40% of all 16-year-olds and just over 60% of all 17-year-olds were licensed drivers in 1995. Similarly, Figure 1a shows that our Add Health data estimate that just under 40% of teenagers in Add Health had a driver's license 6 months after eligibility (i.e., at 16y6m for a state where the MDA was 16). Extending the x-axis of Figure 1a further out (not reported) reveals that about 65% of teenagers in Add Health had a driver's license 18 months after eligibility (i.e., at 17y6m for a state where the MDA was 16).

B.5 Minimum legal school leaving age

We collected state-level information on the minimum legal school leaving age from the National Center for Education Statistics (https://nces.ed.gov/programs/digest/). Data are available for the following 13 years: 1994, 1996, 1997, 2000, 2002, 2004, 2006–2010, 2013, and 2014.

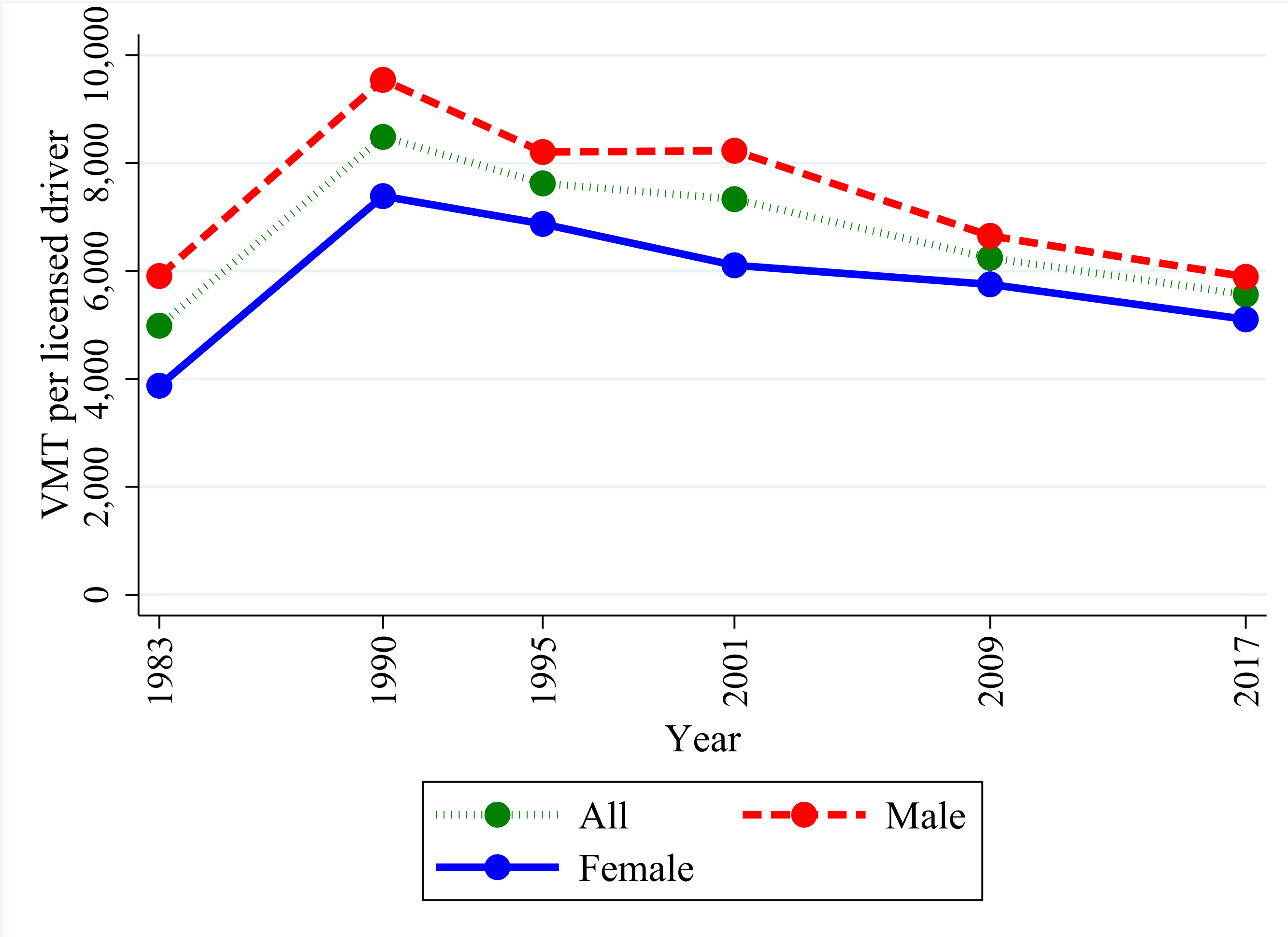
For those 13 years, 52% of our state-year observations have a minimum school leaving age equal to 16 years. The MDA in 31% of states is the same as the minimum school leaving age during those 13 years. However, the minimum school leaving age is not equal to the MDA in any state where the MDA is not 16 years.

Figure B.1: Proportion of US teenagers with a driver's license, by age and year



Notes: The figure reports the proportion of US teenagers with a restricted or full driver's license. Annual counts of licensed drivers are obtained from the Federal Highway Administration (FHWA). Annual population estimates come from the Surveillance, Epidemiology, and End Results (SEER) Program.

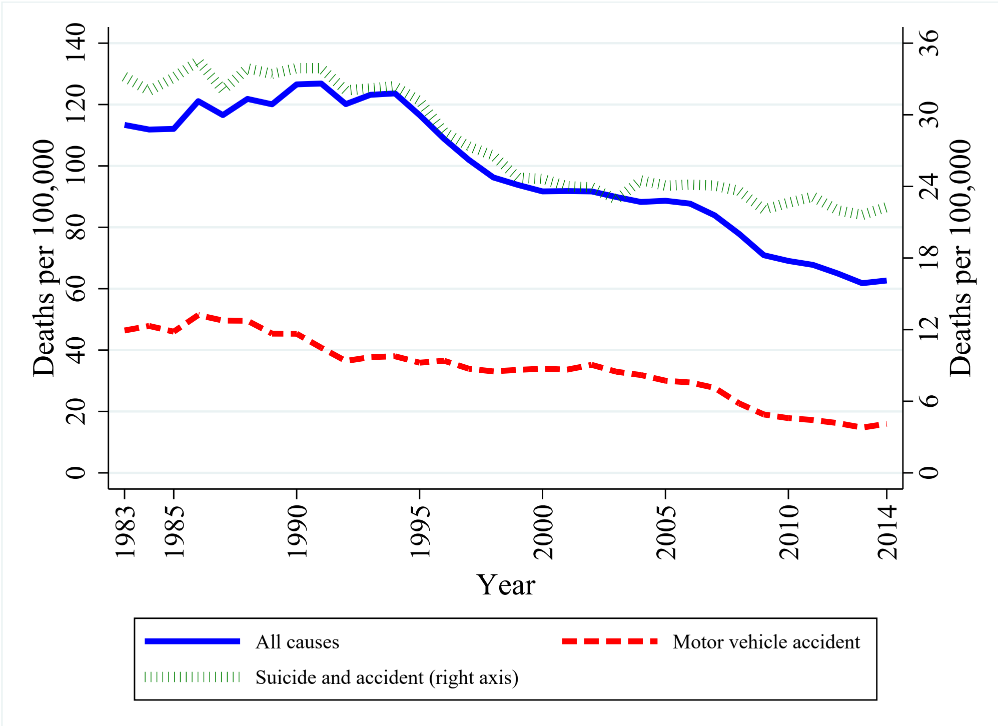
Figure B.2: Average annual vehicle miles traveled, ages 16–19



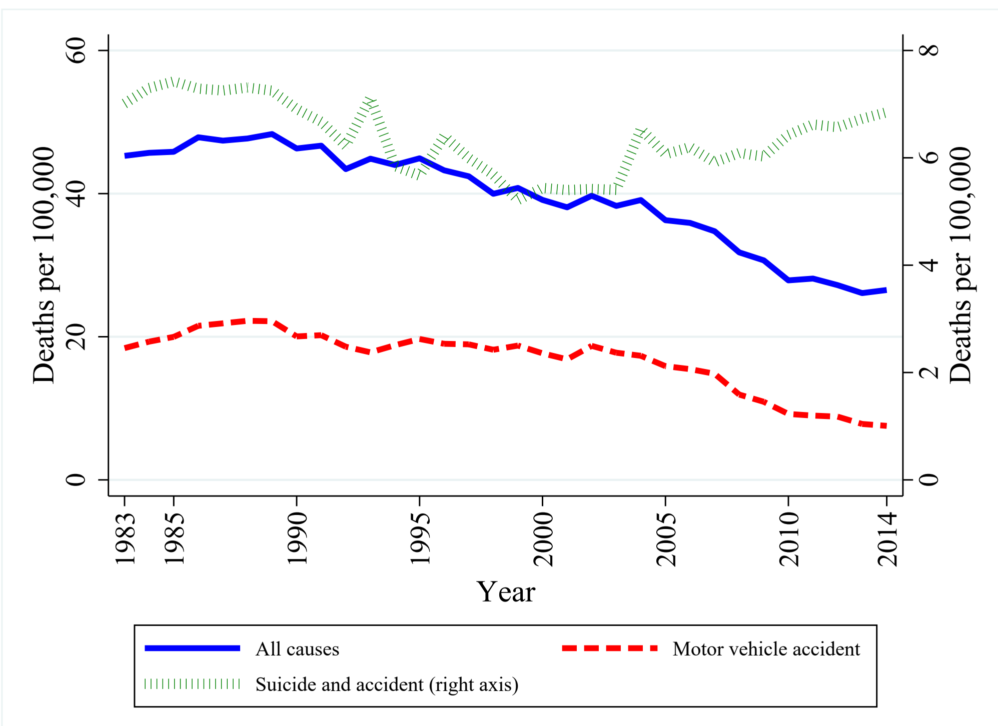
Notes: The figure plots self-reported average annual vehicle miles traveled for licensed teenagers ages 16–19. The data are obtained from Table 23 of McGuckin and Fucci (2018) and are available only for select years between 1983 and 2017.

Figure B.3: Aggregate trends in mortality rates for teenagers ages 15–19, by sex

(a) Males

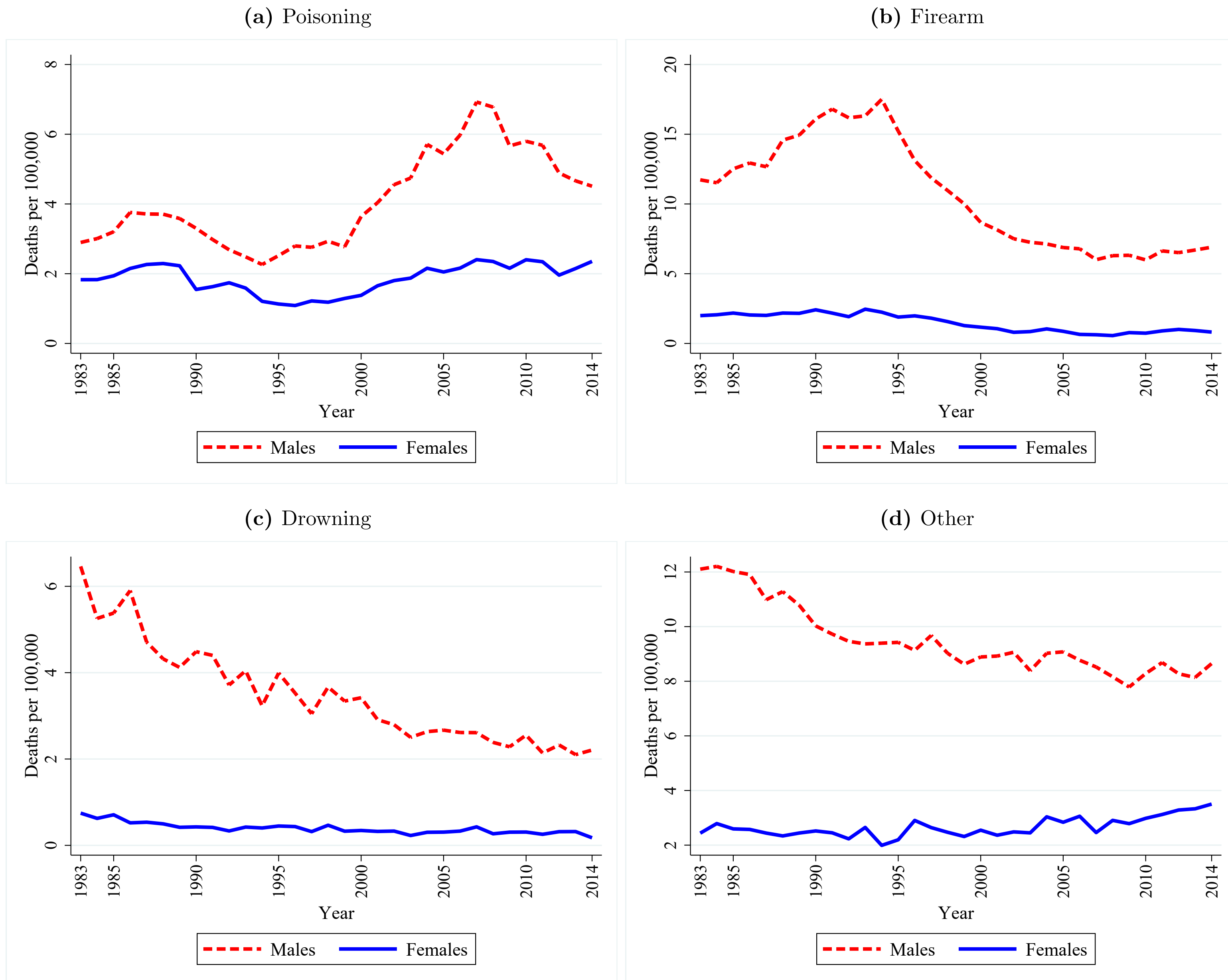


(b) Females



Notes: Figures show US death rates from all causes, suicides and accidents, and motor vehicle accidents for ages 15–19. Death counts are from the 1983–2014 National Vital Statistics, and population data are from the Surveillance, Epidemiology, and End Results (SEER) Program.

Figure B.4: Aggregate trends in deaths from suicides and accidents for teenagers ages 15–19, by category



Notes: Death counts are from the 1983–2014 National Vital Statistics, and population data are from the Surveillance, Epidemiology, and End Results (SEER) Program. Aggregate trends in deaths from all suicides and accidents are reported in Figure B.3.

Table B.1: US minimum driving age laws, 1983–2014

State	MDA 1	MDA 2 (date)	MDA 3 (date)	MDA 4 (date)
Alabama	16yr 0mo			
Alaska	16yr 0mo			
Arizona	16yr 0mo			
Arkansas	18yr 0mo	16yr 0mo (3/10/1993)		
California	16yr 0mo			
Colorado	16yr 0mo			
Connecticut	16yr 0mo	16yr 4mo (1/1/1997)		
Delaware	16yr 0mo	16yr 4mo (7/1/1999)	16yr 6mo (8/31/2006)	
District of Columbia	16yr 0mo	16yr 6mo (1/1/2001)		
Florida	16yr 0mo			
Georgia	16yr 0mo			
Hawaii	15yr 0mo	15yr 3mo (7/1/1997)	16yr 0mo (1/1/2001)	
Idaho	14yr 0mo	15yr 0mo (4/1/1990)		
Illinois	16yr 0mo			
Indiana	16yr 1mo	16yr 6mo (7/1/2010)		
Iowa	15yr 0mo	16yr 0mo (5/7/1991)		
Kansas	15yr 0mo			
Kentucky	16yr 0mo	16yr 6mo (10/1/1996)		
Louisiana	15yr 0mo	16yr 0mo (1/1/1998)		
Maine	16yr 0mo			
Maryland	16yr 0mo	16yr 1mo (7/1/1999)	16yr 3mo (10/1/2005)	16yr 6mo (10/1/2009)
Massachusetts	16yr 6mo			
Michigan	16yr 0mo			
Minnesota	16yr 0mo			
Mississippi	15yr 0mo	16yr 0mo (9/1/1995)	15yr 6mo (7/1/2000)	16yr 0mo (7/1/2009)
Missouri	16yr 0mo			
Montana	15yr 0mo			
Nebraska	16yr 0mo			
Nevada	16yr 0mo	15yr 9mo (7/1/2001)	16yr 0mo (10/1/2005)	
New Hampshire	16yr 0mo			
New Jersey	17yr 0mo			
New Mexico	15yr 0mo	15yr 6mo (1/1/2000)		
New York	16yr 0mo	16yr 6mo (9/1/2003)		
North Carolina	16yr 0mo			
North Dakota	14yr 0mo	14yr 6mo (4/4/1985)		
Ohio	16yr 0mo			
Oklahoma	16yr 0mo			
Oregon	16yr 0mo			
Pennsylvania	16yr 0mo	16yr 6mo (12/22/1999)		
Rhode Island	16yr 0mo	16yr 6mo (1/1/1999)		
South Carolina	15yr 0mo	15yr 3mo (7/1/1998)	15yr 6mo (3/5/2002)	
South Dakota	14yr 0mo	14yr 3mo (1/1/1999)		
Tennessee	16yr 0mo			
Texas	16yr 0mo			
Utah	16yr 0mo			
Vermont	16yr 0mo			
Virginia	16yr 0mo	16yr 3mo (7/1/2001)		
Washington	16yr 0mo			
West Virginia	16yr 0mo			
Wisconsin	16yr 0mo			
Wyoming	16yr 0mo			

Notes: The column labeled "MDA 1" lists the minimum driving age that was in effect on January 1, 1983 for each state. The next three columns provide information on when (month/day/year) the law changed and what the new minimum driving age became, up through December 31, 2014. Source: Insurance Institute for Highway Safety (http://www.iihs.org/iihs/topics/laws/graduatedlicenseintro?topicName=teenagers) for 1995–2014 and HeinOnline (https://home.heinonline.org/content/session-laws-library) for 1983–1994.

Table B.2: ICD-9 and ICD-10 codes for cause of death

Cause of death	**ICD-9 (1983–1998)**	**ICD-10 (1999–2014)**
Internal causes	001-799 (excl alcohol- and drug-related)	A00-R99 (excl alcohol- and drug-related)
External causes	E800-E996	V01-Y98
Motor vehicle accident	E810-E825	V01-V04, V06-V14, V16-V79, V80.0-V80.5, V80.7-V81.1, V82-V89
Suicide	E950-E959, E980-E989	X60-X84, Y10-Y34, Y87.0
Firearm	E955, E985	X72-X75, Y22-Y24
Poisoning	E950-E952, E980-E982	X60-X69, Y10-Y19
Drug overdose	E950, E980	X60-X65, X68-X69, Y10-15, Y18-Y19
Carbon monoxide and other gases	E951-E952, E981-E982	X66-X67, Y16-Y17
Drowning	E954, E984	X71, Y21
Other	E953, E956-E959, E983, E986-E989	X70, X76-X84, Y20, Y25-Y34, Y87.0
Accident	E800-E807, E826-E869, E880-E929	V05, V15, V80.6, V81.2-V81.9, V90-V99, W00-X59
Firearm	E922	W32-W34
Poisoning	E850-E869	X40-X49
Drug overdose	E850-E866	X40-X45, X48-X49
Carbon monoxide and other gases	E867-E869	X46-X47
Drowning	E910	W65-W70, W73-W74
Other	E800-E807, E826-E849, E880-E909, E911-E921, E923-E929	V05, V15, V80.6, V81.2-V81.9, V90-V99, W00-W31, W35-W64, W75-X39, X50-X59
Homicide	E960-E969	X85-X99, Y00-Y09
Other external	E808-E809, E870-E879, E930-E949, E970-E979, E990-E996, 291-292, 303-304, 305.0-305.9, 332.1, 357.5, 357.6, 425.5, 535.3, 571.0-571.3, 790.3	Y35-Y86, Y87.1-Y87.2, Y88-Y98, E24.4, F10-F19, F55, G31.2, G62.1, G72.1, I42.6, K29.2, K70, K85.2, K86.0, R78.0, T40-T43, T51

Notes: This table provides ICD-9 and ICD-10 codes used to categorize the cause of death. ICD-10 replaced ICD-9 starting in 1999. The following ICD-9 codes are for alcohol-related internal causes: 291, 303, 305.0, 357.5, 425.5, 535.3, 571.0-571.3, and 790.3. The following ICD-9 codes are for drug-related internal causes: 292, 304, 305.1-305.9, 332.1, and 357.6. The following ICD-10 codes are for alcohol-related internal causes: E24.4, F10, G31.2, G62.1, G72.1, I42.6, K29.2, K70, K85.2, K86.0, R78.0, and T51. The following ICD-10 codes are for drug-related internal causes: F11-F19, F55, and T40-T43.

Table B.3: Annual US deaths per 100,000 population, 1983–2014

	(1)	(2)	(3)	(4)
Cause of death	Ages 10–14	Ages 15–19	Ages 20–24	Ages 25–29
A. All				
All causes	20.57	68.63	98.49	106.12
Internal causes	9.52	14.94	23.30	37.52
External causes	11.06	53.69	75.18	68.60
Motor vehicle accident	4.84	25.10	28.82	20.98
Suicide and accident	4.80	17.11	28.11	30.79
Firearm	1.09	5.97	8.75	8.09
Poisoning	0.26	3.05	8.07	11.21
Drug overdose	0.18	2.45	7.17	10.14
Carbon monoxide and other gases	0.08	0.60	0.90	1.07
Drowning	0.95	1.95	1.96	1.67
Other	2.50	6.14	9.33	9.81
Homicide	1.30	10.99	16.97	14.40
Other external	0.12	0.49	1.27	2.43
B. Males				
All causes	24.97	96.70	146.46	153.01
Internal causes	10.27	17.27	27.04	45.07
External causes	14.70	79.44	119.41	107.94
Motor vehicle accident	5.96	33.28	43.32	31.68
Suicide and accident	6.94	27.30	45.94	49.37
Firearm	1.78	10.28	15.33	13.95
Poisoning	0.27	4.17	11.80	16.24
Drug overdose	0.18	3.29	10.35	14.50
Carbon monoxide and other gases	0.09	0.87	1.45	1.74
Drowning	1.43	3.43	3.44	2.88
Other	3.46	9.43	15.37	16.30
Homicide	1.66	18.11	28.19	23.33
Other external	0.14	0.75	1.95	3.56
C. Females				
All causes	15.96	39.05	48.68	58.60
Internal causes	8.73	12.49	19.42	29.87
External causes	7.23	26.55	29.26	28.74
Motor vehicle accident	3.66	16.48	13.77	10.14
Suicide and accident	2.54	6.37	9.60	11.96
Firearm	0.36	1.43	1.92	2.16
Poisoning	0.25	1.87	4.20	6.12
Drug overdose	0.19	1.57	3.87	5.73
Carbon monoxide and other gases	0.07	0.30	0.33	0.40
Drowning	0.44	0.39	0.43	0.44
Other	1.49	2.68	3.05	3.24
Homicide	0.93	3.48	5.33	5.35
Other external	0.09	0.23	0.56	1.29

Notes: Death counts come from the National Vital Statistics. Population estimates come from the Surveillance, Epidemiology, and End Results (SEER) Program.

Table B.4: Add Health variable definitions and codings

Description	Variable	Survey Question	Formula
Interview month	imonth	N/A	N/A
Interview year	iyear	N/A	N/A
Birth month	bmonth	N/A	N/A
Birth year	byear	N/A	N/A
Sex	bio_sex	N/A	N/A
Pseudo state identifier	w1state; w2state	N/A	"State" = w1state if iyear = 95; "State" = w2state if iyear = 96
Sample weight	gswgt1; gswgt2	N/A	"Weight" = gswgt1 if iyear = 95; "Weight" = gswgt2 if iyear = 96
Race	h1gi6a	What is your race?	White (= 1)
Driver's license	h1ee10; h2ee10	Do you have a valid driver's license (not a driver's permit)?	Yes (= 1)
Vehicle miles driven (baseline)	h1ee11; h2ee11	About how many miles do you drive each week?	0 (= 1); 25 miles (= 2); 75 miles (= 3); 150 miles (= 4)
Vehicle miles driven (alternate)	h1ee11; h2ee11	About how many miles do you drive each week?	0 (= 1); 25 miles (= 2); 75 miles (= 3); 265 miles (= 4)
Work for pay	h1ee3; h2ee3	In the last 4 weeks, did you work—for pay—for anyone outside your home? This includes both regular jobs and things like baby-sitting or yard work.	Yes (= 1)
Not enrolled nor graduated	h1gi21; h2gi10	Why aren't/weren't you going to school?	For any reason other than graduation (= 1, 2, 3, 5 or 6 if iyear = 95; = 1, 2, 3, 4, 5, 7 or 8 if iyear = 96)

Notes: This table lists the codings and definitions from Wave I (1995) and Wave II (1996) of Add Health that were used in the analysis. Responses were coded as missing if the respondent answered "don't know" or "refused" to a question. Detailed survey documents are available at: https://www.cpc.unc.edu/projects/addhealth/documentation/restricteduse/datasets.