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 motor vehicle fatalities rise by 40% at the minimum legal driving age cutoff, implying a mortality risk per additional mile driven 6–9 times higher than the risk faced by adult drivers. We also find a stark 80% increase in female deaths from drug overdoses and carbon monoxide poisoning at the cutoff, caused by changes in both suicides and accidental deaths. Our analysis suggests driving regulations could be an effective tool to improve teenage health.

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1 Introduction

Suicides and motor vehicle accidents are the two leading causes of death for U.S. teenagers (CDC, 2018). 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. Identifying the effects of driving on teenage outcomes is challenging, however. 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. Likewise, exploiting variation due to changes in state regulations is complicated due to challenges such as omitted variable bias and reverse causality. 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 intent-to-treat 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

[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.

of 0.646 per 100,000 (78%) and an accompanying rise in female carbon monoxide poisoning deaths of 0.127 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.

We identify the local average treatment effect of driving on motor vehicle fatalities by incorporating Add Health survey data on license status and vehicle miles driven into our analysis. We estimate that a new teenage driver faces a risk of dying in a motor vehicle accident equal to 10.1–14.5 per 100 million additional vehicle miles driven, 6–9 times higher than the national average of 1.7. This additional risk declines modestly to 6.0–8.3 deaths per 100 million vehicle miles driven (4–5 times higher than the average) during the first year of driving, indicating that teenagers learn how to drive more safely after obtaining their license.

Finally, we calculate that raising the MDA by one year during the time period we study would have saved 282 lives per year, which is worth $2.5 billion annually using conventional estimates of the value of statistical life. This mortality reduction is similar to estimates of the effect of raising the minimum legal drinking age by one year (Carpenter and Dobkin, 2009). This counterfactual exercise requires applying our estimated treatment effect—which is local to the cutoff threshold—to ages up to one year above the threshold. We argue that this extrapolation is reasonable because the derivative of our estimated treatment effect with respect to the running variable at the cutoff is nonnegative (Dong and Lewbel, 2015).

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 cutoff. Moreover, our main results hold 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.

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

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

[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,

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 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 teenage females. Importantly, our findings imply that policymakers interested in reducing teenage drug abuse should consider increasing the MDA.

We are unaware of any quasi-experimental studies on the effects of the MDA.[4] The prior economics literature on driving policy has focused on laws addressing drunk driving (Evans, Neville and Graham, 1991; Ruhm, 1996; Levitt and Porter, 2001; Carpenter, 2004; Hansen, 2015), child safety seats (Jones and Ziebarth, 2017), seat belts (Peltzman, 1975; Evans, 1986; Cohen and Einav, 2003), traffic safety messages (Hall and Madsen, 2020), and speed limits (Dee and Sela, 2003). Studies have also investigated the effects of Graduated Driver Licensing (GDL) laws on motor vehicle fatalities (Dee, Grabowski and Morrisey, 2005; Morrisey et al., 2006; Karaca-Mandic and Ridgeway, 2010; Gilpin, 2019) and crime (Deza and Litwok, 2016). We advance this literature by quantifying the mortality consequences of changing the MDA, a regulation that affects all teenage drivers in the United States.

Our paper is also related to studies in the transportation literature that quantify crash risk per driver as a function of time since licensure for a small number of states and years (Foss et al., 2011; Chapman, Masten and Browning, 2014; Curry et al., 2015). Our quasi-experimental study advances this literature by employing 32 years of administrative death records for all 50 states, combining it with nationally representative survey data to estimate risk per mile driven, and imposing a weaker identifying assumption.[5] To our knowledge, we are the first to investigate the causal effect of teenage driving on drug-related outcomes.

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, Section 6 describes policy implications, and Section 7 concludes.

however, are mostly caused by opioids (both illegal and prescription) and sedatives.

[4]By contrast, a large quasi-experimental literature investigates the effects of the minimum legal drinking age on health, drug use, and crime (Kaestner, 2000; Carpenter and Dobkin, 2009; Crost and Rees, 2013; Carpenter and Dobkin, 2015, 2017; Fletcher, 2018).

[5]Our research design does not require assuming that the timing of the voluntary decision to obtain a license is unrelated to crash risk. The transportation literature finds—like we do—that crash risk declines significantly during the first year of driving, although its estimates are not directly comparable to ours because it measures risk per driver, rather than per capita, and generally focuses on all crashes rather than on fatal crashes.

2 Background

Every U.S. 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. The minimum age for taking the driving test ranges from 14 to 18 during our sample period. Beginning in 1996, states began adopting GDL programs, which 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 vehicles.

Our study focuses on the age at which teenagers become eligible to take their state's driving test. Before 1996, passing this test earned a full driver's license. In more recent years, it may earn only a restricted driver's license, depending on whether the state has implemented a GDL program.[6] The fraction of teenagers with a license has declined over our 1983–2014 sample period (Figure B.1).

Suicides and motor vehicle accidents (MVAs) are the leading and second-leading causes of death for teenagers, respectively (CDC, 2018). About 25% of teenage motor vehicle fatalities are alcohol-related, and over 50% occur during nighttime (Dee and Evans, 2001). Accidental poisonings are the leading cause of death for people under age 30 (13,157 deaths in 2018) (CDC, 2018). Two-thirds of drug overdose deaths for 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).

[6] Our age-based RD design can also be used to investigate the effect of gaining a learner's permit or a full (unrestricted) driver's license. We find no mortality increase at the age cutoff for a learner's permit, and a small positive increase at the age cutoff for an unrestricted driver's license (Table A.3). The latter result suggests that implementing GDL licenses may reduce motor vehicle fatalities.

3 Data

3.1 Minimum driving age laws

We obtain 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 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, and sex. We obtained a restricted-use version 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.[7] Our final dataset includes information on 501,193 teenage deaths.

Our main results 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 also report estimates separately for suicides and accidents in a later analysis.

Figure B.2 reports annual teenage death rates for the years 1983–2014, separately for males and females. Male death rates are about twice as large as female death rates. Motor vehicle fatality rates decline significantly during this time period for both groups.[8] Poisoning deaths decline in the early 1990s and climb significantly during the early 2000s for both groups. The trends then diverge, with the male poisoning death rate falling while the female poisoning death rate remains steady. 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.

[7]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.

[8]Dee and Evans (2001) attribute the decline in motor vehicle fatalities during the 1990s to a reduction in drunk driving and to an increase in seat belt use. 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.

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.3). 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 a more conservative 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 consider those outcomes in the main text because the survey's small sample size combined with the low prevalence of the outcomes we are most interested in–suicide attempts and illegal drug consumption–cause the analysis to be underpowered. Instead, we present the results of that analysis in Appendix C.

4 Empirical strategy

We employ a fuzzy RD design to identify the effect of driving eligibility on teenage behaviors and mortality. Eligibility depends on 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:

$$Y_a = \alpha_1 AGE_a + \beta POST_a + \gamma_1(POST_a \times AGE_a) + \delta_1 D_a + \varepsilon_a \tag{1}$$

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).

We interpret the parameter β in equation (1) as the intent-to-treat effect of licensed driving on the outcome Y_a. We estimate the first-stage effect using the following model:

$$DRIVE_a = \alpha_2 AGE_a + \theta POST_a + \gamma_2(POST_a \times AGE_a) + \delta_2 D_a + \varepsilon_a \tag{2}$$

The dependent variable, $DRIVE_a$, is either the fraction of teenagers with a driver's license or average vehicle miles driven for the one-month age cell a. The other variables are defined as in equation (1). The parameter of interest, θ, is the effect of driving eligibility on driving behavior.

We interpret the ratio $\lambda = \beta/\theta$ as the local average treatment effect (LATE) of teenage driving on the outcome, Y_a (Hahn, Todd and Van der Klaauw, 2001). This ratio corresponds to the average causal effect for the subset of teenagers who are compliers, i.e., for teenagers who are induced to drive upon reaching the MDA (Angrist, Imbens and Rubin, 1996). The LATE is identified under the assumption that teenagers above the MDA cutoff are not less likely to drive. This monotonicity assumption is satisfied in our setting because—with rare exception—teenagers cannot obtain driver's licenses prior to age eligibility. This assumption also has a testable implication when instruments are multivalued (Angrist and Imbens, 1995). Figure A.1 presents evidence that this implication is satisfied for our vehicle miles driven instrument.

All of our regressions employ a triangular kernel. Our preferred specification employs a mean-squared error (MSE) optimal bandwidth that varies for each outcome and reports 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.[9] We define a family that includes all 13 mortality

[9]This correction is conservative because it does not account for the significant collinearity among our

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 (first stage)

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. This increase 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.

The first three rows of Panel A in Table 1 report RD estimates of θ from equation (2) for our first-stage 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 by 375 miles using the baseline definition of average vehicle miles driven, or by 575 miles using the alternate definition (Figure A.2). 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

Panel B in Table 1 reports estimates of β from equation (1) for different causes of death.[10] 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 $p = 0.0523$). While the 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%) (Figure A.3).

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.

[10]Because bandwidths vary by outcome, estimates for specific causes of death do not add up to the estimate for total deaths. Table A.13 reports estimates from a specification that uses a constant bandwidth of 24 months. In that table, subcategory estimates add up to the total estimate.

Table 1 decomposes deaths due to external causes into its four main subcategories: MVAs, 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. Figure 1b confirms these results by showing that motor vehicle fatalities increase sharply within the first two months of gaining driving eligibility for both males and females. There is little change in the overall trend: motor vehicle fatalities increase with age at about the same rate in the periods before and after the age cutoff. 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 carbon monoxide poisoning deaths.[11] 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 $p < 0.0001$). Figure 2a illustrates this stark increase in female poisoning deaths. Figure 2b shows that the increase can be attributed primarily to a 0.646 per 100,000 (78%) increase in drug overdose deaths (family-wise $p < 0.0001$). Figure 2c shows a visible increase of 0.127 per 100,000 (82%) in carbon monoxide poisoning deaths, although this effect is not statistically significant after accounting for multiple hypothesis testing (family-wise $p = 0.163$).

By contrast, trends in male poisoning deaths appear continuous at the age cutoff (Figure A.4), and this result is confirmed by the small and statistically insignificant male poisoning estimates reported in Table 1. We do estimate a statistically significant decrease in drownings of 0.690 per 100,000 (26%) for males (Figure A.5a). Unlike the change in female poisoning deaths shown in Figure 2a, this change in male drownings is short-lived. Likewise, while Table 1 reports a statistically significant estimate for female deaths due to "other external" causes, the RD plot does not provide compelling evidence of an effect (Figure A.6b).

Table 2 decomposes the female poisoning death estimates into those classified as suicides versus accidents. A few results stand out in this exploratory analysis. First, the increase in drug overdose deaths is caused by both accidents and suicides. Second, although most carbon monoxide poisoning deaths among female teenagers are accidental, the increase in

[11] Carbon monoxide poisonings are a subcategory of gas poisonings. However, nearly 90% of gas poisoning deaths are caused by carbon monoxide, so we refer to the category as carbon monoxide poisoning rather than gas poisoning.

these deaths following driving eligibility is driven by suicides. Finally, the net effect on total suicides is small and statistically insignificant because of an offsetting reduction in firearm suicides, suggesting that female teenagers who commit suicide substitute away from using firearms and toward using drugs and carbon monoxide poisoning upon gaining access to a car.

We caution that the reliability of these classifications 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 suicide estimate might reflect a compositional shift in the method of suicide.

Finally, we assess how our estimates change over time by estimating our model for different four-year bins. Figures 3a and 3c reveal a steady decline in our estimated effect for motor vehicle fatalities beginning in the mid-1990s, which likely reflects the significant reduction in teenage licensure rates in recent years (Figure B.1). Figures 3b and 3d show estimates over time for poisoning deaths. The male estimates are centered around zero throughout our sample period. By contrast, the female estimates follow a U-shape pattern, which mirrors the aggregate fall and rise in poisoning deaths observed nationwide for teenage females (Figure B.2b). The recent increase in female poisoning deaths is statistically significant and suggests that contemporaneous (post-2014) effects may be larger than what we report in this study.[12]

5.3 Local average treatment effects

The local average treatment effect (LATE) of driving on teenage mortality is the ratio of the intent-to-treat and first-stage effects. To identify LATE, we shall assume that driving eligibility affects outcomes only through the receipt of a driver's license. We therefore focus on motor vehicle fatalities, the outcome most likely to satisfy this exclusion restriction. As described in Appendix A.1, we impose a uniform bandwidth when estimating LATE, which means the estimate is not exactly equal to the ratio of the intent-to-treat and first-stage estimates reported in Table 1 (Imbens and Lemieux, 2008).

We have three different first-stage measures of driving behavior, so we estimate three corresponding LATEs (Table A.14). Gaining a driver's license increases motor vehicle fatalities

[12]We strongly reject the equality of the five coefficients corresponding to the 1995–2014 time period in Figure 3d (p-value < 0.001).

by 29.9 per 100,000, an increase of 267% relative to the mean of 11.2. Our two measures of vehicle miles driven yield LATE estimates of 10.1–14.5 deaths per 100 million vehicle miles driven. By way of comparison, the national average for 1995–1996 is 1.7 deaths per 100 million vehicle miles driven (Insurance Institute for Highway Safety, 2018). In other words, a new teenage driver faces a mortality risk 6–9 times higher per additional vehicle mile driven than the typical driver.

Quantifying how quickly teenagers learn to drive more safely requires strengthening the usual "local" randomization assumption to include inframarginal compliers (Angrist and Rokkanen, 2015). Figure A.11 plots nonparametric approximations of the average treatment effect for both marginal and inframarginal compliers. Figures A.11b and A.11c illustrate a declining trend for the effect of vehicle miles driven on motor vehicle fatalities: twelve months after driving eligibility, the risk has fallen to 6.0–8.3 per 100 million vehicle miles driven, or 4–5 times higher than the typical driver. This decline suggests that teenagers learn to drive more safely within the first year of obtaining their license.

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.7). Moreover, our results are similar when we limit our analysis to states with an MDA that is not 16 years (Tables A.1 and A.2).[13] Because the MDA differs from the minimum working and school leaving ages in this subsample (Appendix B.4), 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.

Tables A.5–A.8 report our results separately by race and sex. 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 first-stage effect is reflected in the

[13]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).

second-stage 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. Figure A.8 also suggests some modest seasonality in our estimate for motor vehicle fatalities, with effect sizes peaking during the summer months in both absolute and relative terms.

Tables A.11–A.13 show that our intent-to-treat estimates are not sensitive to using different bandwidth selection procedures or polynomial approximations, or to imposing a uniform bandwidth of 24 months. Columns (2), (4), and (6) of Table A.14 show that 2SLS estimates of LATE are similar to our MSE-optimal estimates. Figure A.10 shows that estimates using placebo cutoffs are centered around 0, and that our motor vehicle fatality and female poisoning death estimates lie well outside the distribution of placebo estimates.

6 Policy implications

The mortality consequences of raising the MDA depend on how one extrapolates the RD treatment effect estimate to ages above the cutoff. It is not clear a priori whether the treatment effect should increase, decrease, or remain the same for those older ages. It could be smaller if older teenagers are more careful drivers, or larger if older teenagers are more likely to drink and drive.

We investigate the external validity of our local RD estimate by estimating the treatment effect derivative, i.e., the change in the slope of the trendline at the age cutoff (Dong and Lewbel, 2015). Panel A of Table A.4 presents estimates for all-cause mortality, our primary outcome of interest for this policy exercise, and Panel B presents estimates for motor vehicle fatalities, which drive the majority of the increase in all-cause mortality. Column (1) estimates a positive but statistically insignificant treatment effect derivative of 0.217 deaths per 100,000. Columns (2) and (3) show that this estimate remains positive and statistically insignificant when estimated separately for males and females. A positive estimate implies that the slope of the trendline increases after crossing the age cutoff, as can be confirmed from close visual inspection of the fitted lines in Figure 1b. Because our estimate of the treatment effect derivative is small and statistically insignificant, we proceed below under the assumption that it is equal to zero, i.e., we assume our local RD estimate also applies to older ages. This assumption is likely conservative: if we instead assumed a positive treatment effect derivative, as suggested by the point estimates in Table A.4, we would apply a larger treatment effect to older ages, which would increase our estimate of the number of lives saved from raising the MDA.

We estimated previously that driving eligibility increases mortality by 5.84 deaths per 100,000 (Table 1) over the 1983–2014 time period. The social cost of these deaths depends on the teenage value of a statistical life (VSL), which we set equal to $9 million (Murphy and Topel, 2006). Applying this value to our empirical estimate yields an estimated annual cost of $526 per capita (= $9 million$\times$5.84/100000) for the affected population. There was an average of 3.9 million 16-year-olds alive in the United States during 1983–2014, so this estimate implies that a one-year increase in the MDA would have saved 228 lives annually during our sample period, producing an annual value of $2.0 billion. This value, while large, does not necessarily imply that driving eligibility should be curtailed since driving also confers significant benefits. Indeed, if teenage drivers are rational, then the net private value of driving must remain positive for teenagers who choose to drive.

However, teenage drivers also risk the lives of other passengers on the road. According to our analysis of data published by the Fatal Accident Reporting System for the years 1983–2014, for every car accident that involved the death of at least one teenage driver in her first year of driving eligibility, an additional 0.24 people died on average. Assuming again a $9 million VSL, these additional deaths imply a negative externality of $490 million annually. When added to our previous result, we calculate that increasing the MDA by one year would have saved 282 lives per year, or $2.5 billion, which is comparable to the effect of increasing the minimum legal drinking age by one year.[14]

These estimates apply to the 1983–2014 sample period. Figures 3a and 3c show declining trends in our motor vehicle fatalities estimates over time, suggesting that contemporaneous increases in the MDA may have small effects on mortality. By contrast, Figure 3d shows an increasing trend in our female poisoning deaths estimates beginning in 1995, suggesting that an increase in the MDA may reduce poisoning deaths by more than what we estimate in this study.

7 Conclusion

This study investigates the effect of teenage driving on mortality and risky behaviors. We estimate that new teenage drivers are 6–9 times more likely to die per additional mile driven than a typical adult driver and that raising the MDA by one year would have saved nearly 300 lives annually during our sample period. Our estimate is similar to the estimated benefits of raising the minimum legal drinking age.

We find that female poisoning deaths increase by about 80% in the months following driving eligibility. These deaths reflect changes in both accidents and suicides, but the

[14] Carpenter and Dobkin (2009) estimate that reducing the minimum legal drinking age from 21 to 20 would result in 337 additional deaths per year, including other people killed by drunk drivers. This estimate is statistically indistinguishable from ours.

specific behavioral mechanisms underlying our results remain unclear. Driving may enable teenagers to purchase or consume drugs more easily, and may affect mental health by altering social environments. Further research is required to investigate these different possibilities. Nevertheless, our results imply that increasing the MDA may be an effective way to curb poisoning deaths among teenagers.

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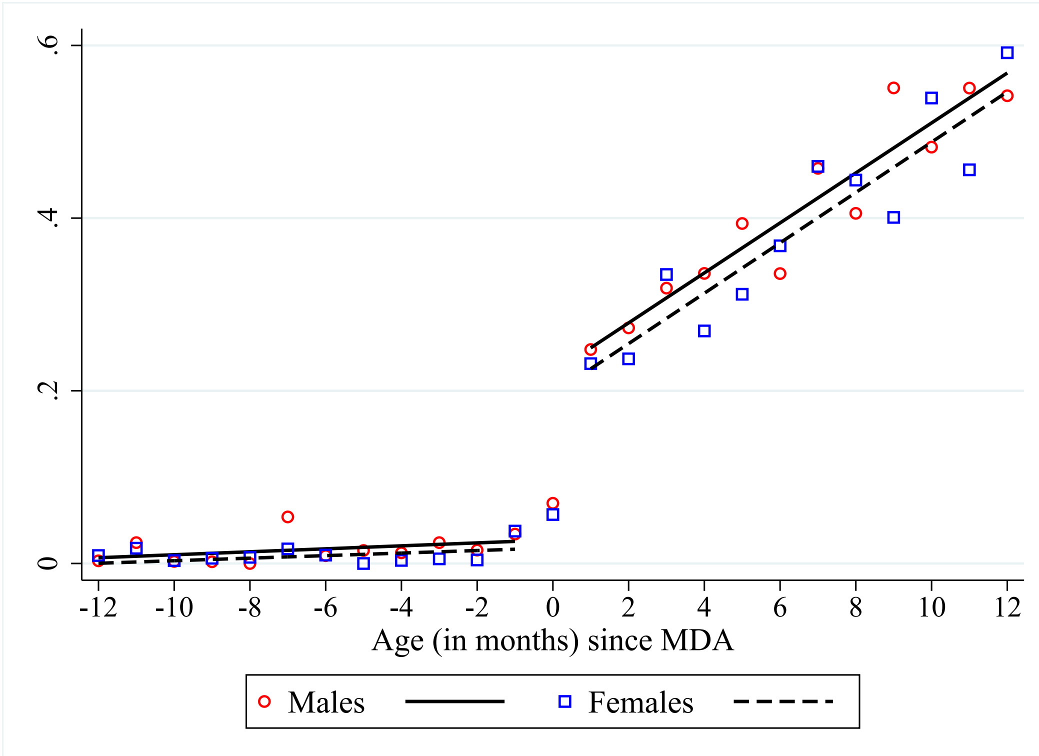
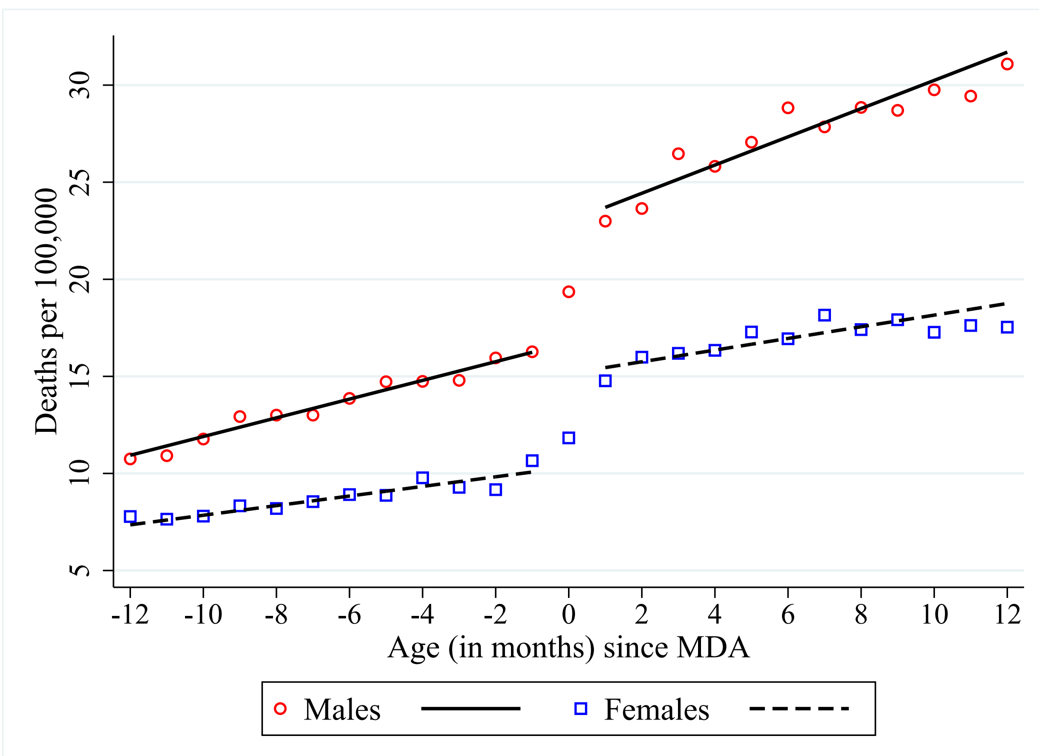
Figure 1: Teenage driver's licensing rates and motor vehicle fatalities

(a) Proportion with a driver's license



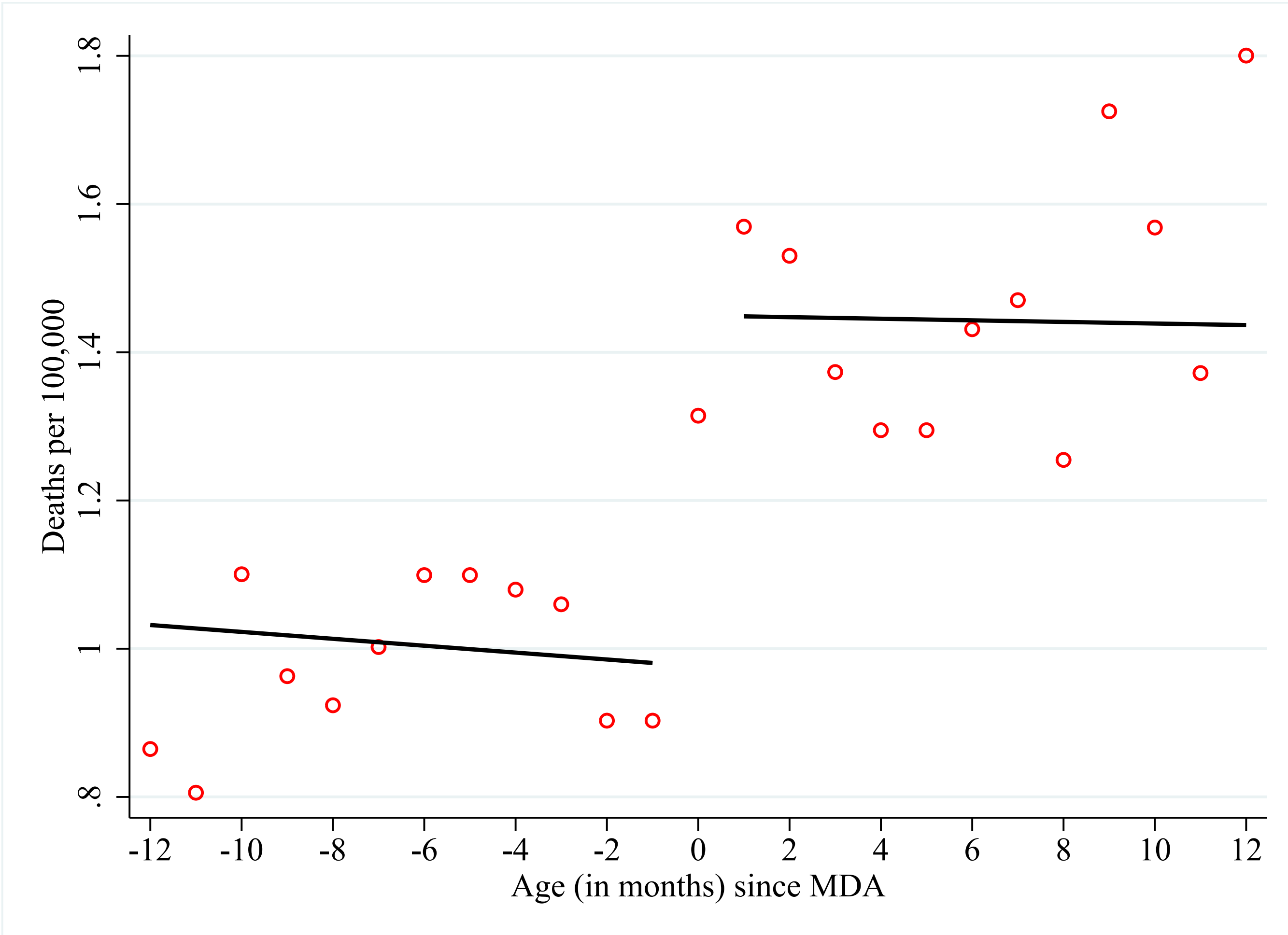
(b) Motor vehicle fatalities



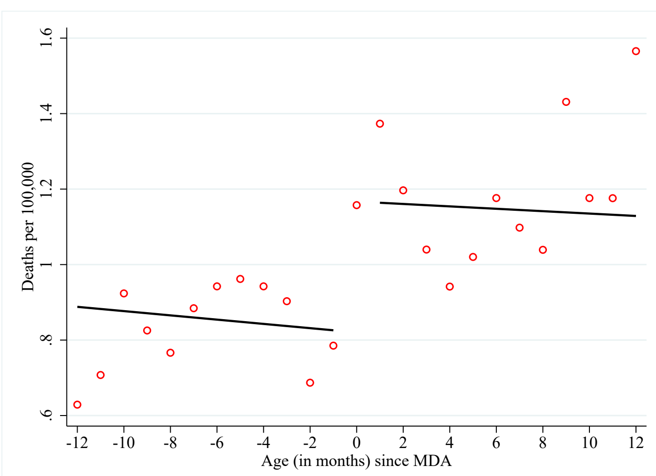
Notes: The figure shows the proportion of teenagers with a driver's license and motor vehicle fatality rates by age, relative to the minimum driving age (MDA). Estimates in panel (a) are based on weighted responses to the 1995–1996 Add Health surveys. Estimates in panel (b) are based on data from the 1983–2014 National Vital Statistics. The fitted lines in panels (a) and (b) are estimated using equations (2) and (1), respectively, with a bandwidth of 24 months. Table 1 provides RD estimates.

Figure 2: Female poisoning deaths, 1983–2014

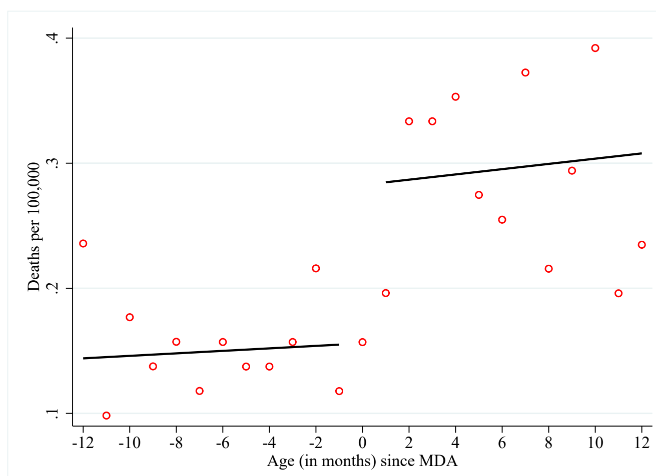
(a) Poisoning deaths



(b) Drug overdose deaths

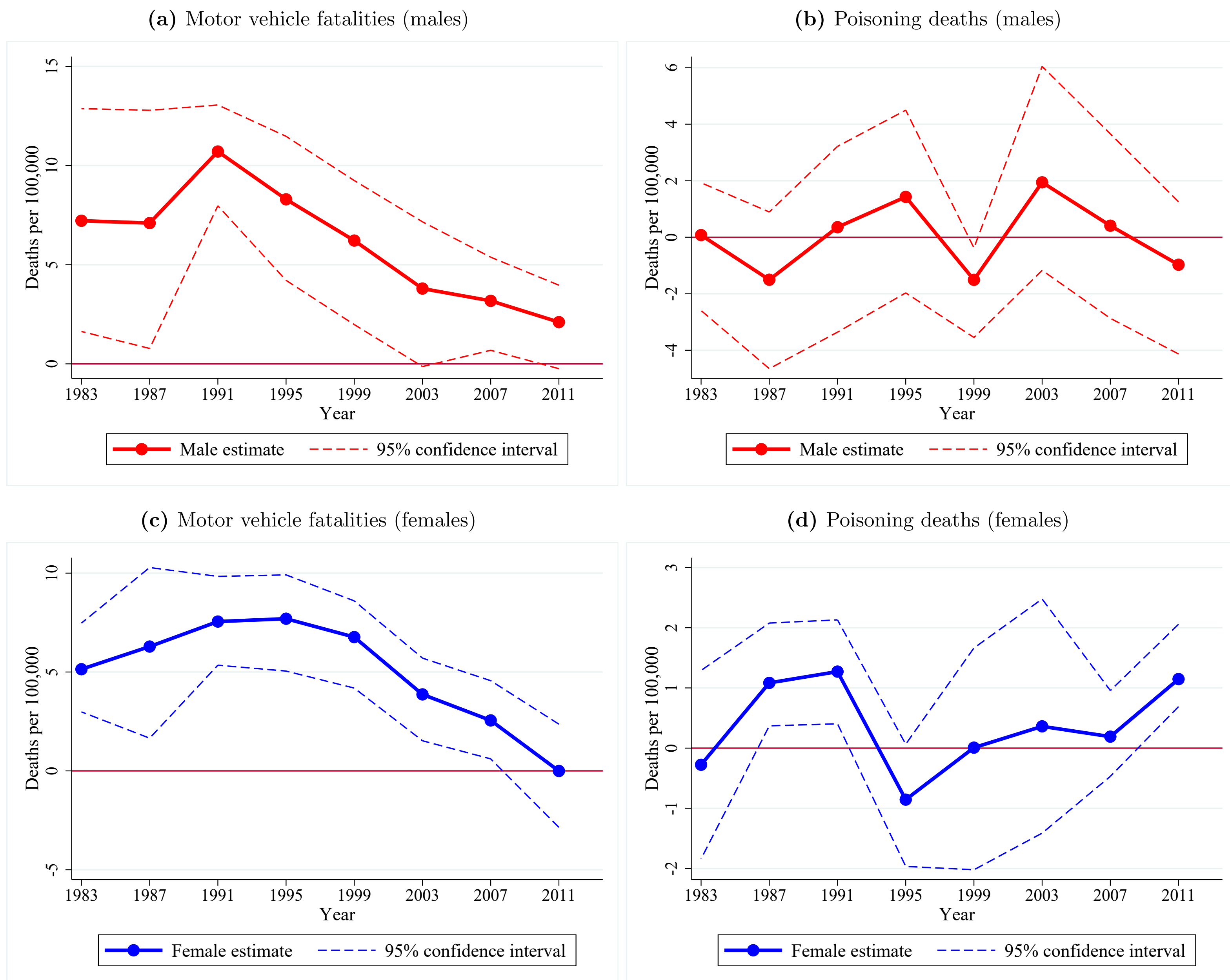


(c) Carbon monoxide poisoning deaths



Notes: The figure shows female U.S. death rates for different causes of death by age, relative to the minimum driving age (MDA). Poisoning deaths equal the sum of drug overdose and carbon monoxide poisoning deaths. The fitted lines are estimated using equation (1) with a bandwidth of 24 months. Table 1 provides RD estimates for these outcomes.

Figure 3: Trends in the effect of driving eligibility on motor vehicle fatalities and poisoning deaths



(a) Motor vehicle fatalities (males)

(b) Poisoning deaths (males)

(c) Motor vehicle fatalities (females)

(d) Poisoning deaths (females)

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 (first stage)						
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	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: Driving outcomes come from the 1995–1996 Add Health surveys. Mortality outcomes come from the 1983–2014 National Vital Statistics and 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 (2), (4), and (6) report MSE-optimal estimates of β from equation (1) in Panel B and θ from equation (2) in Panel A. Robust, bias-corrected 95-percent 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.

Table 2: 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	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-percent 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.

Online Appendix

"Teenage Driving, Mortality, and Risky Behaviors"

Jason Huh and Julian Reif

A Supplementary results

Figure A.1 displays cumulative distribution functions (CDFs) of vehicle miles driven for teenagers one month below and one month above the MDA. This result provides evidence in favor of the monotonicity assumption (Angrist and Imbens, 1995).

Tables A.1 and A.2 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. The estimates for female poisoning deaths are statistically indistinguishable from each other. Table A.3 reports estimates of the effect of becoming eligible for a learner's permit and full driver's license on motor vehicle fatalities. Table A.4 reports estimates of the treatment effect derivative for deaths from all causes and for deaths from MVAs (Dong and Lewbel, 2015).

Plots of additional outcomes, by age in months:

- Figure A.2: vehicle miles driven
- Figure A.3: deaths from all causes, external causes, and internal causes
- Figure A.4: poisoning deaths for males
- Figure A.5: drowning deaths
- Figure A.6: deaths from other external causes
- Figure A.7: working for pay and school enrollment

Heterogeneity by race and sex:

- Table A.5: driver's licensing rates
- Table A.6: vehicle miles driven
- Table A.7: motor vehicle fatalities
- Table A.8: poisoning deaths

Heterogeneity by month of birth:

- Table A.9: motor vehicle fatalities (see also Figure A.8)
- Table A.10: female drug overdose deaths (see also Figure A.9)

Alternative specifications and robustness checks:

- Table A.11: different bandwidth selection procedures
- Table A.12: different polynomial approximations

- Table A.13: constant bandwidth of 24 months (OLS)
- Figure A.10: placebo tests
- Figure A.11: nonparametric estimates of the average treatment effect

A.1 Local average treatment effect estimates

As described in Section 4, the parameter β in equation (1) is the intent-to-treat effect of licensed driving on the outcome Y_a and the parameter θ in equation (2) is the effect of driving eligibility on driving behavior. We interpret their ratio, $\lambda = \beta/\theta$, as the local average treatment effect (LATE) of teenage driving on the outcome, Y_a (Hahn, Todd and Van der Klaauw, 2001). We follow Imbens and Lemieux (2008) and estimate LATE using an MSE-optimal bandwidth that is constant across the first and second stages.

We report our preferred LATE estimates for motor vehicle fatalities in Columns (3), (5), and (7) of Table A.14. These estimates are approximately, but not exactly, equal to the ratio of the intent-to-treat and first-stage estimates reported in Table 1 because of differences in the bandwidths.

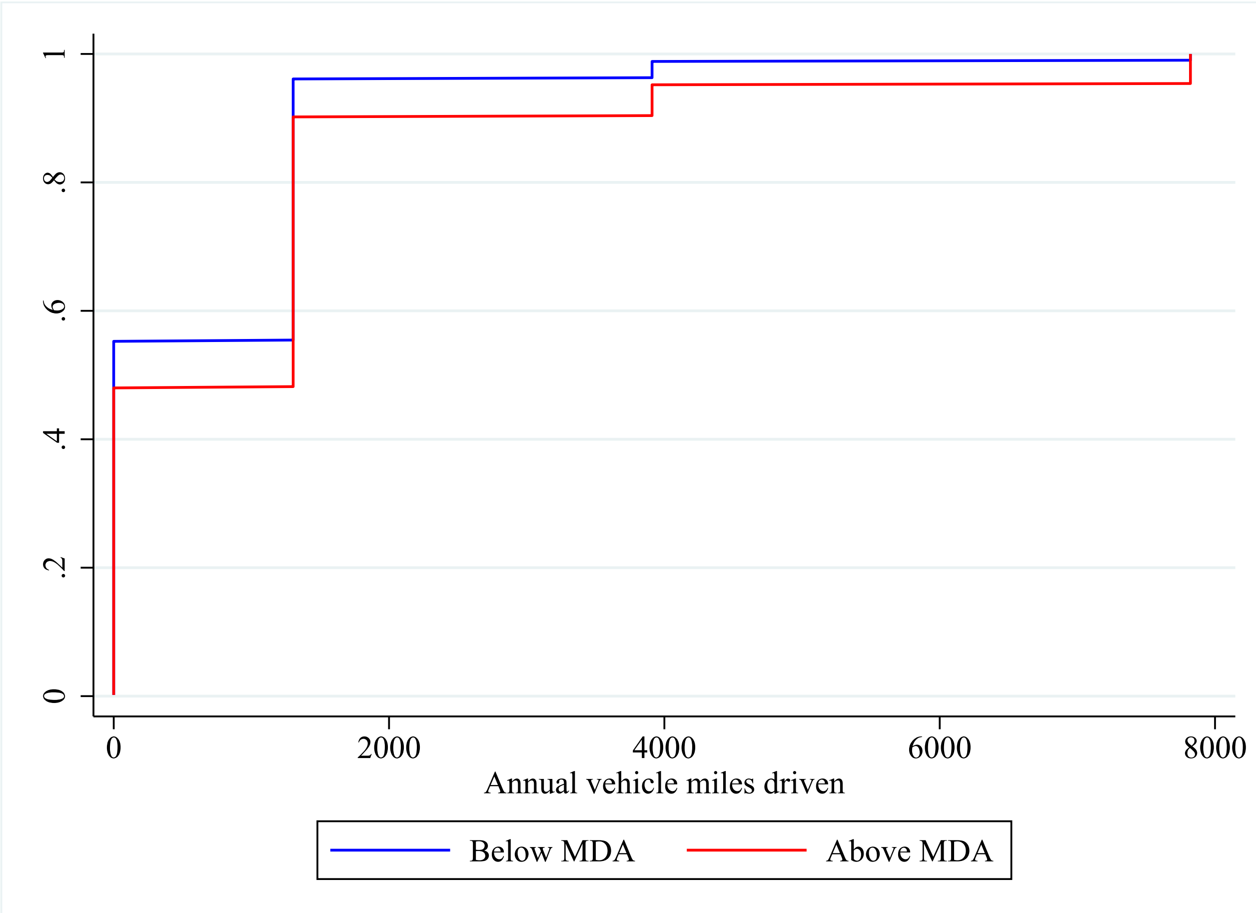
LATE can alternatively be estimated using two-stage least squares (2SLS), where the second stage is given by:

$$Y_a = \alpha_3 AGE_a + \lambda DRIVE_a + \gamma_3(POST_a \times AGE_a) + \delta_3 D_a + \varepsilon_a \tag{3}$$

We instrument for $DRIVE_a$ using the post-MDA indicator, $POST_a$.[1] These 2SLS estimates, reported in Columns (2), (4), and (6) of Table A.14, are very similar to the MSE-optimal estimates. Unlike the MSE-optimal estimates, the 2SLS estimates are exactly equal to the ratios of their corresponding intent-to-treat and first-stage estimates. This equality can be confirmed by forming ratios of the appropriate OLS estimates from Table A.13 to replicate the 2SLS estimates.

[1]One could alternatively include the interaction $(DRIVE_a \times AGE_a)$ instead of $(POST_a \times AGE_a)$ in (3), which requires additionally instrumenting for the interaction using $(POST_a \times AGE_a)$ (Angrist and Pischke, 2008). That alternative specification produces similar estimates.

Figure A.1: Vehicle miles driven CDF, for teenagers below and above the MDA



Notes: The figure reports the average vehicle miles driven per year for teenagers one month below and one month above the minimum driving age (MDA). Annual vehicle miles driven are calculated by assigning midpoints to the number range reported by Add Health survey respondents. Respondents were asked whether they drive 0 miles per week, drive 1–50 miles per week, drive 51–100 miles per week, or drive over 100 miles per week. For the last bin ("over 100"), we assigned a value of 150.

Figure A.2: Annual vehicle miles driven, 1995–1996

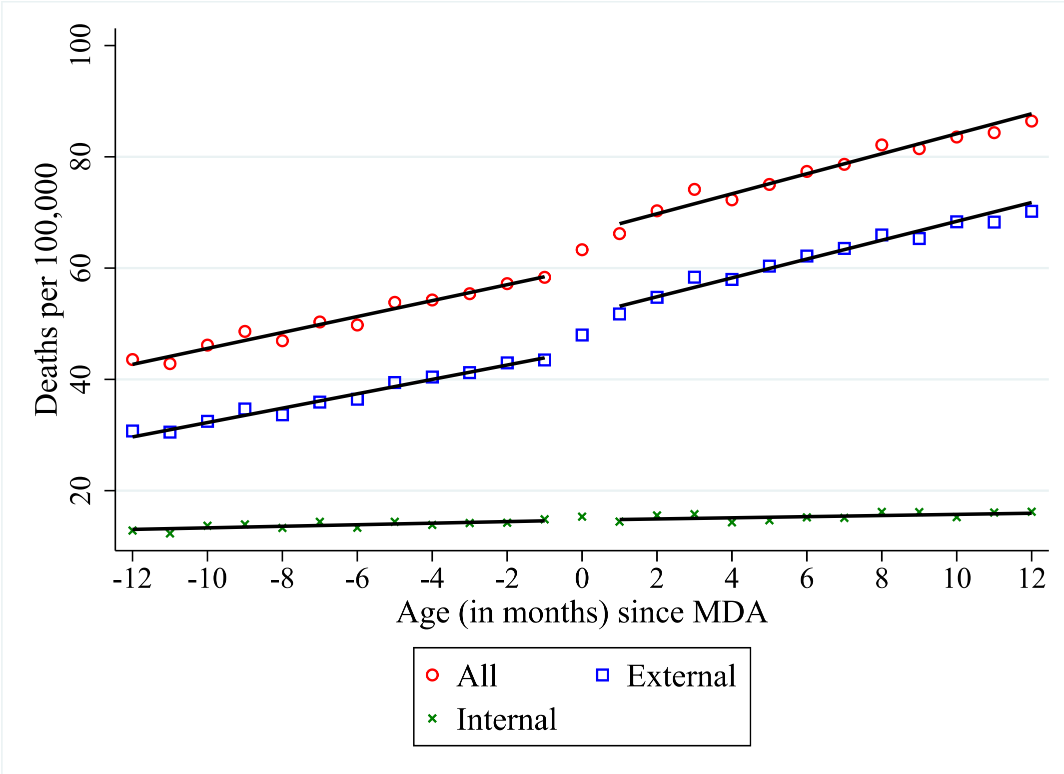
(a) Baseline specification

(b) Alternate specification

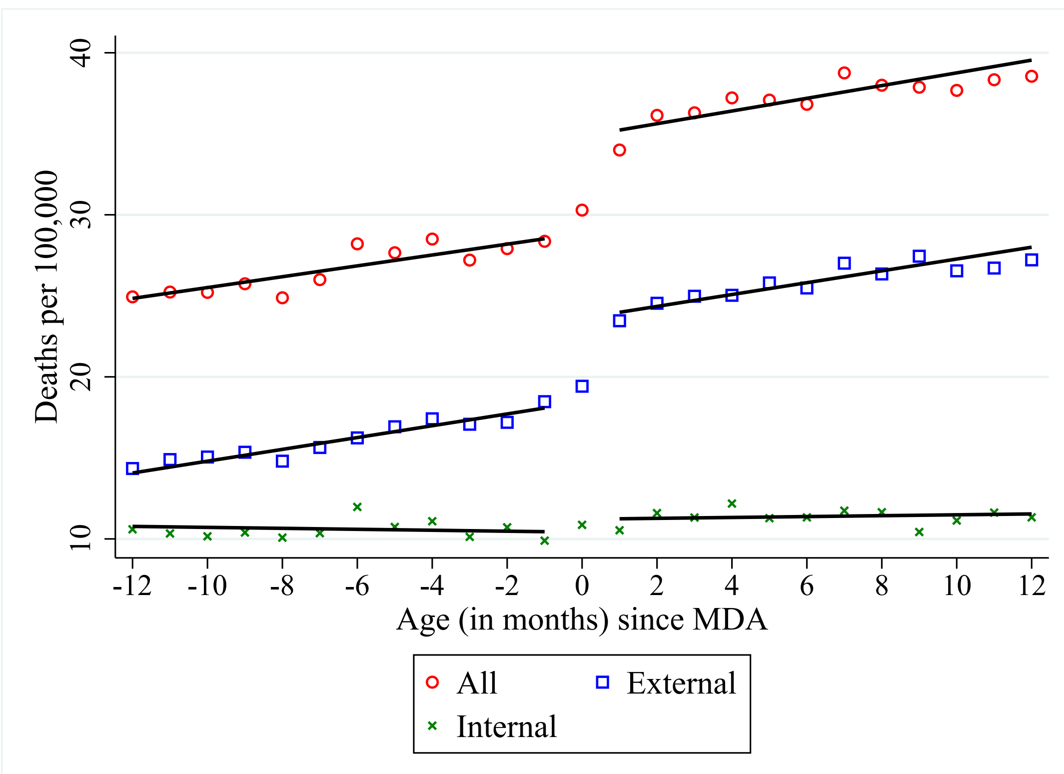
Notes: These figures show average annual vehicle miles driven by age, relative to the minimum driving age (MDA). Estimates are weighted using Add Health's cross-sectional weights. The fitted lines are estimated using equation (2) with a bandwidth of 24 months. The baseline specification assigns a value of 150 to respondents who report driving "over 100" miles per week. The alternative specification assigns a value of 265.

Figure A.3: Teenage mortality rates for different causes of death, 1983–2014

(a) Males



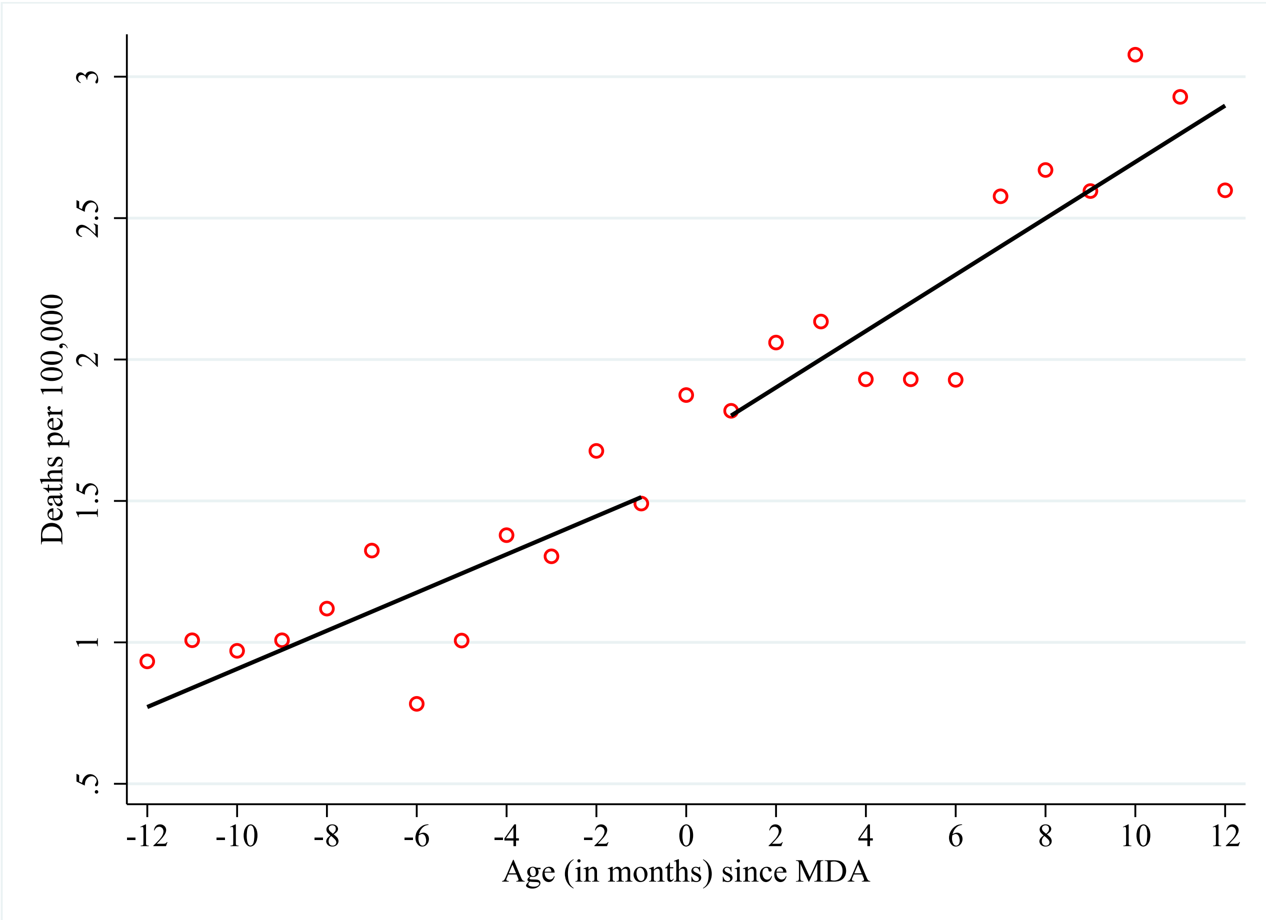
(b) Females



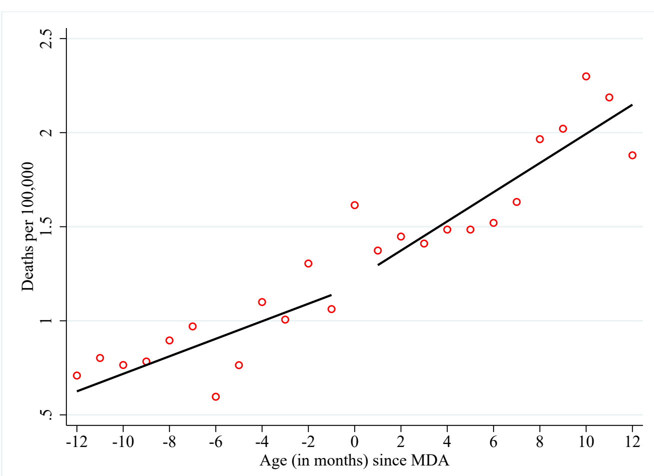
Notes: The figure shows U.S. death rates by age, relative to the minimum driving age (MDA). The fitted lines are estimated using equation (1) with a bandwidth of 24 months.

Figure A.4: Male poisoning deaths, 1983–2014

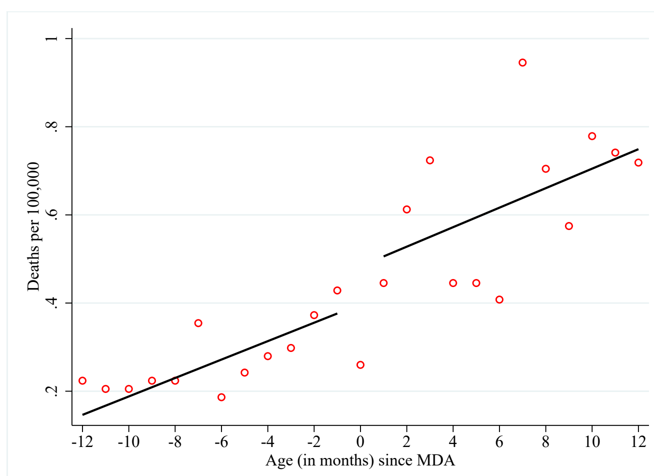
(a) Drug overdose and carbon monoxide poisoning deaths



(b) Drug overdose deaths



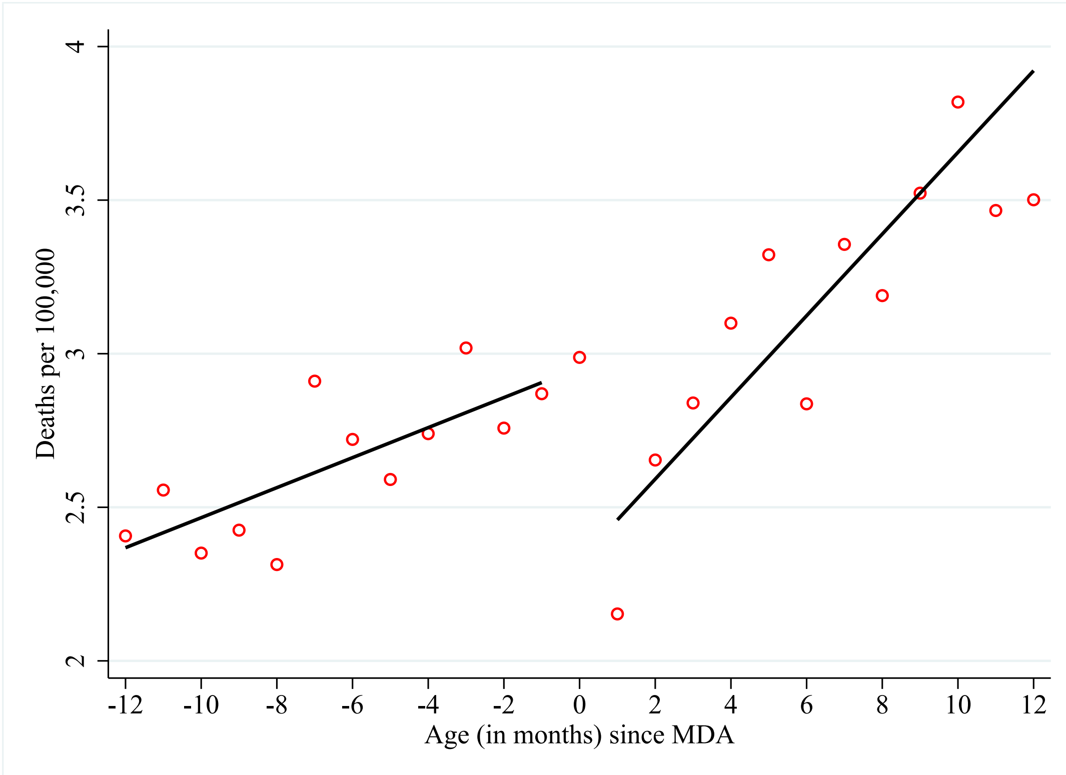
(c) Carbon monoxide poisoning deaths



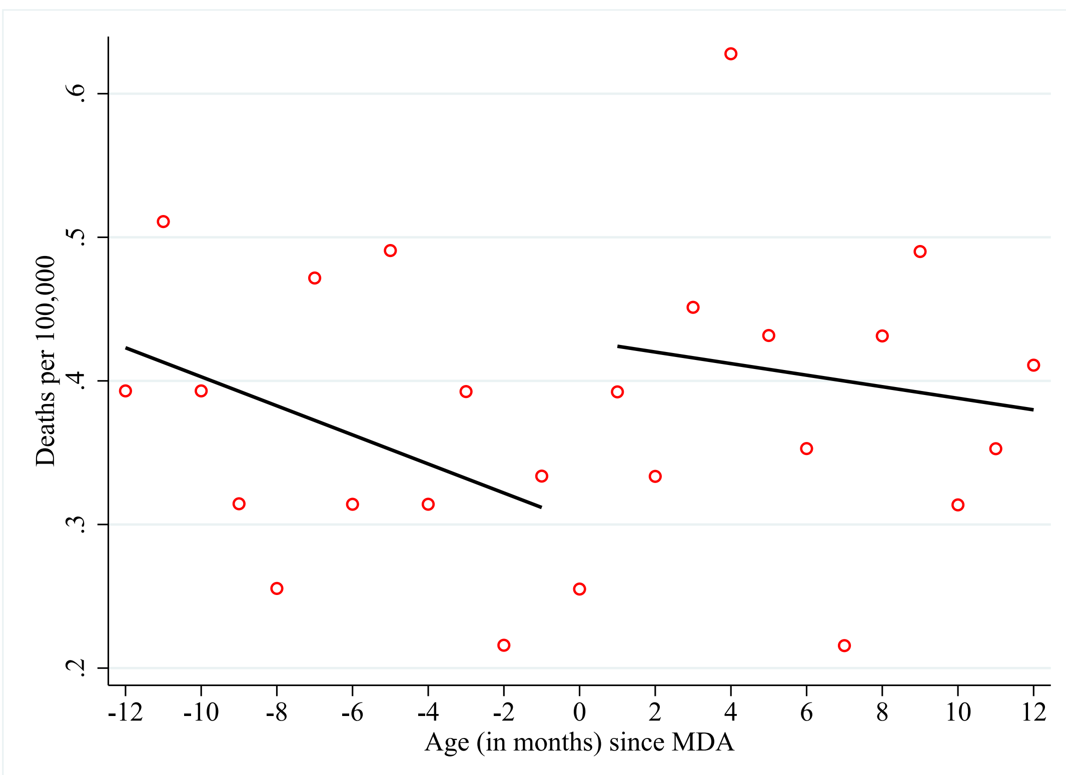
Notes: The figure shows death rates by age, relative to the minimum driving age (MDA). The fitted lines are estimated using equation (1) with a bandwidth of 24 months.

Figure A.5: Teenage drowning deaths, 1983–2014

(a) Males



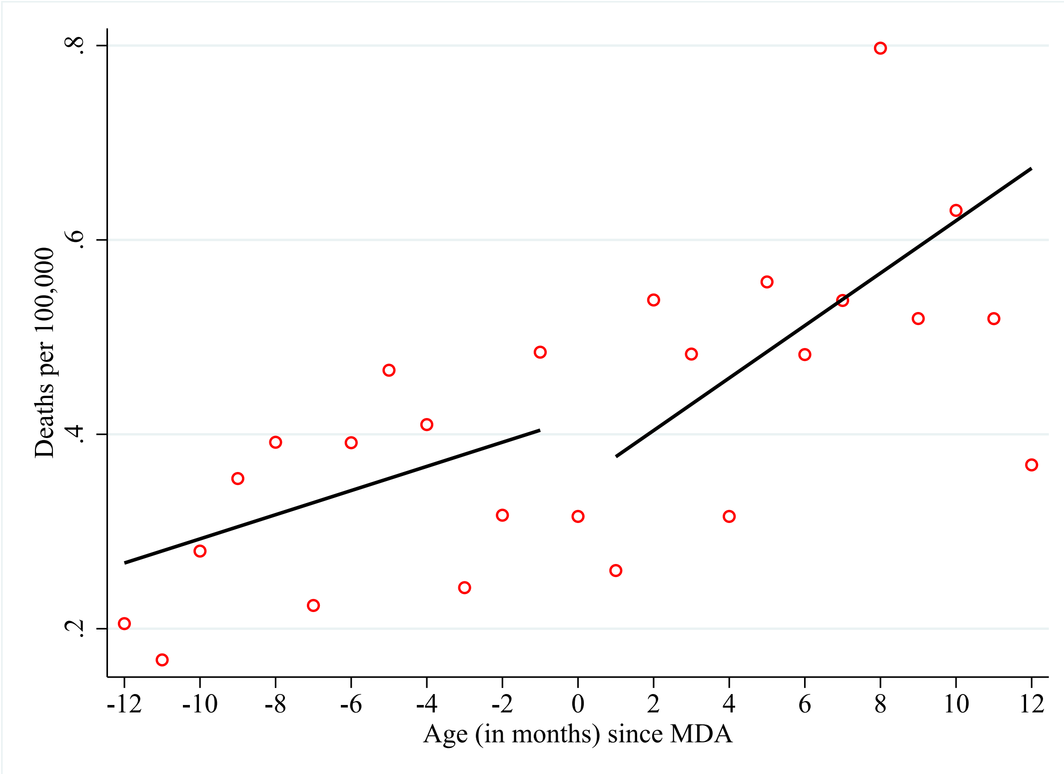
(b) Females



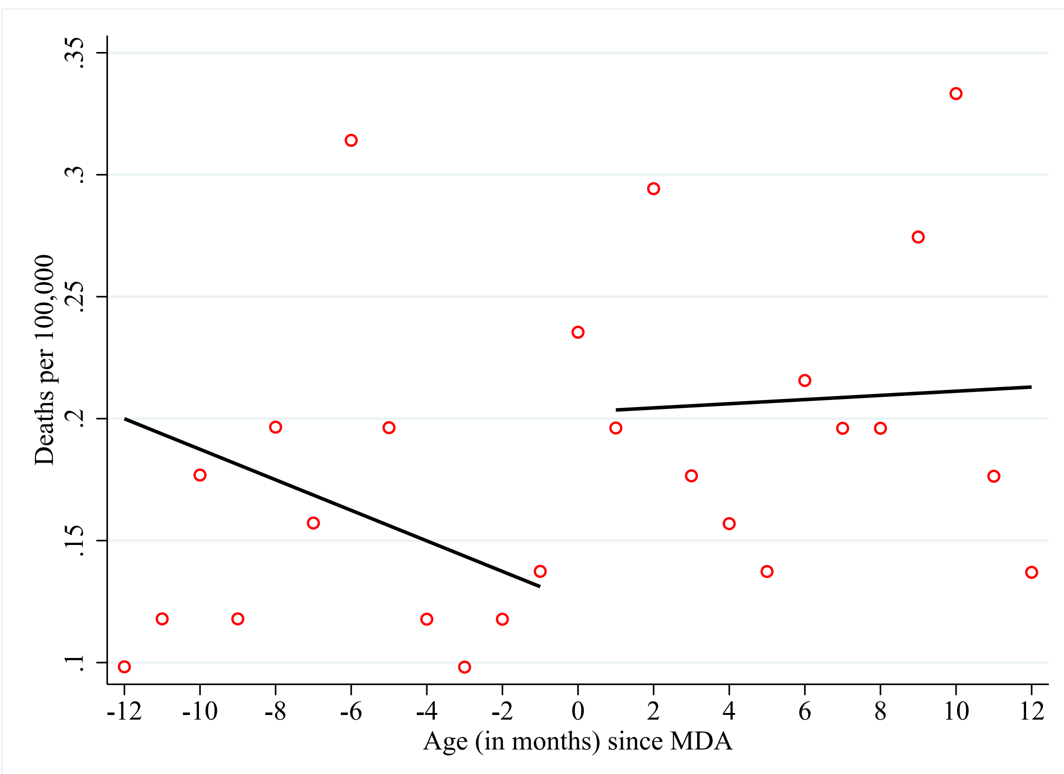
Notes: The figure shows U.S. death rates by age, relative to the minimum driving age (MDA). The fitted lines are estimated using equation (1) with a bandwidth of 24 months.

Figure A.6: Teenage deaths categorized as "other external", 1983–2014

(a) Males



(b) Females

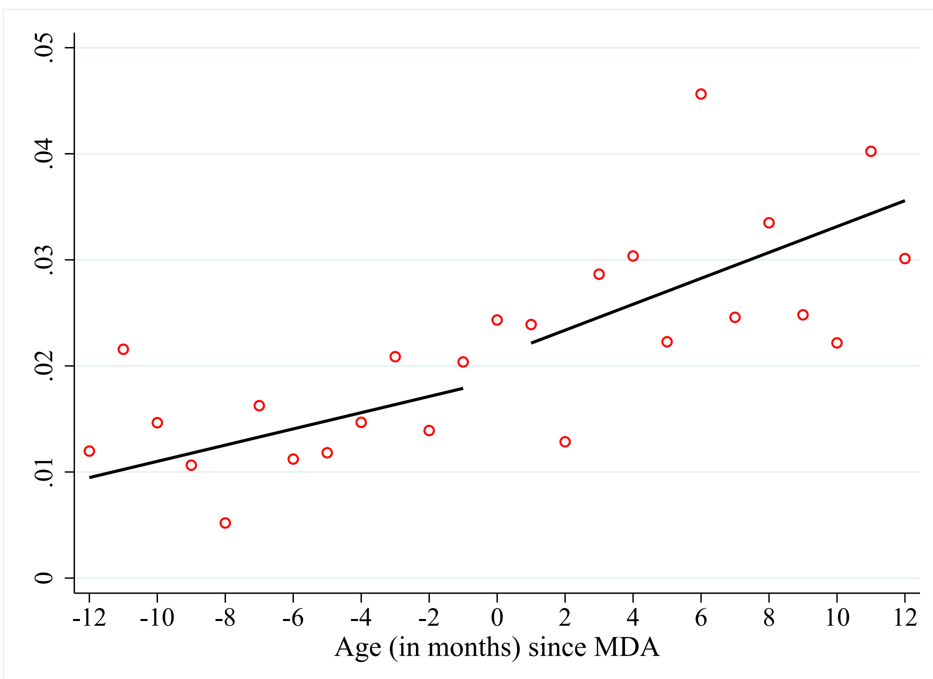


Notes: The figure shows U.S. death rates by age, relative to the minimum driving age (MDA). The fitted lines are estimated using equation (1) with a bandwidth of 24 months.

Figure A.7: Proportion of teenagers working for pay and proportion not enrolled in school, 1995–1996

(a) Working for pay during last four weeks

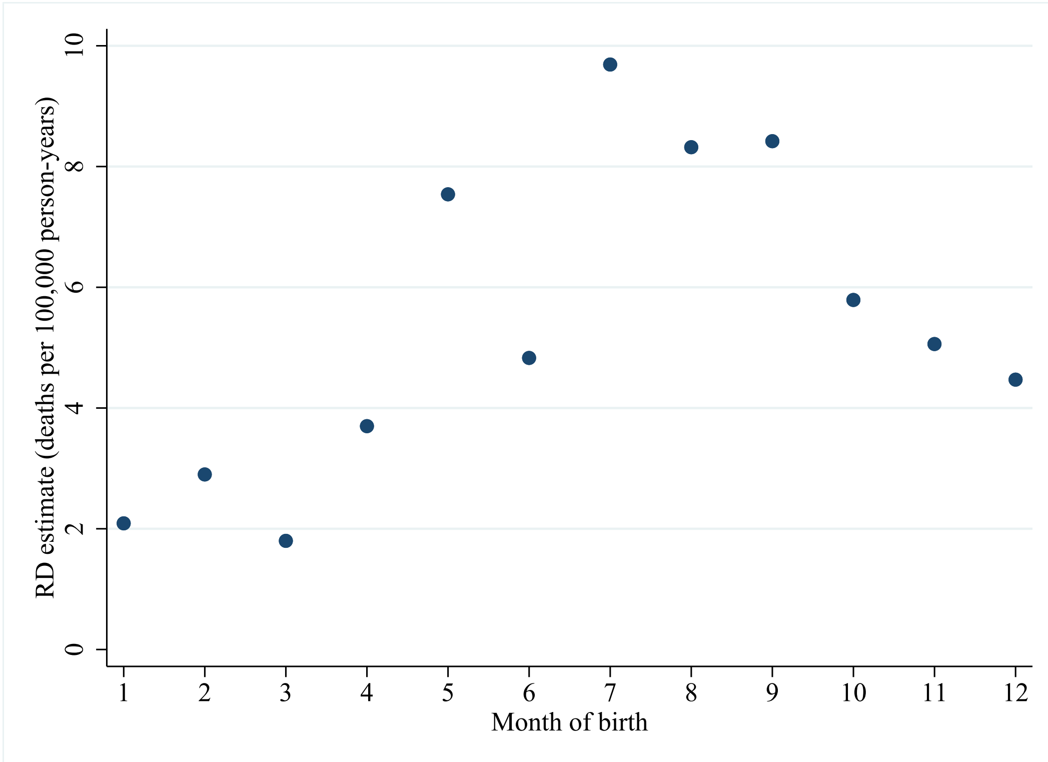
(b) Not enrolled in school



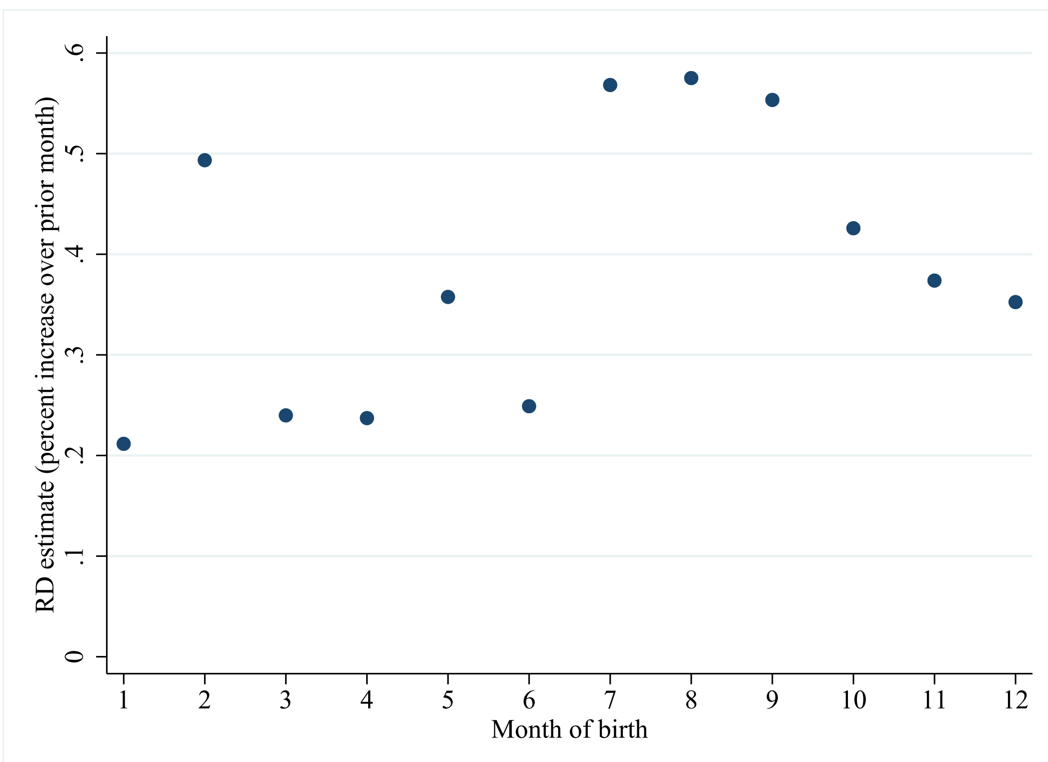
Notes: Panel (a) reports the proportion of teenagers who report ever working for pay during the last four weeks by age, relative to the minimum driving age (MDA). Working includes both formal jobs and informal jobs like babysitting or yard work. Panel (b) reports the proportion who report not being enrolled 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]. Data source: Add Health.

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

(a) Motor vehicle fatalities



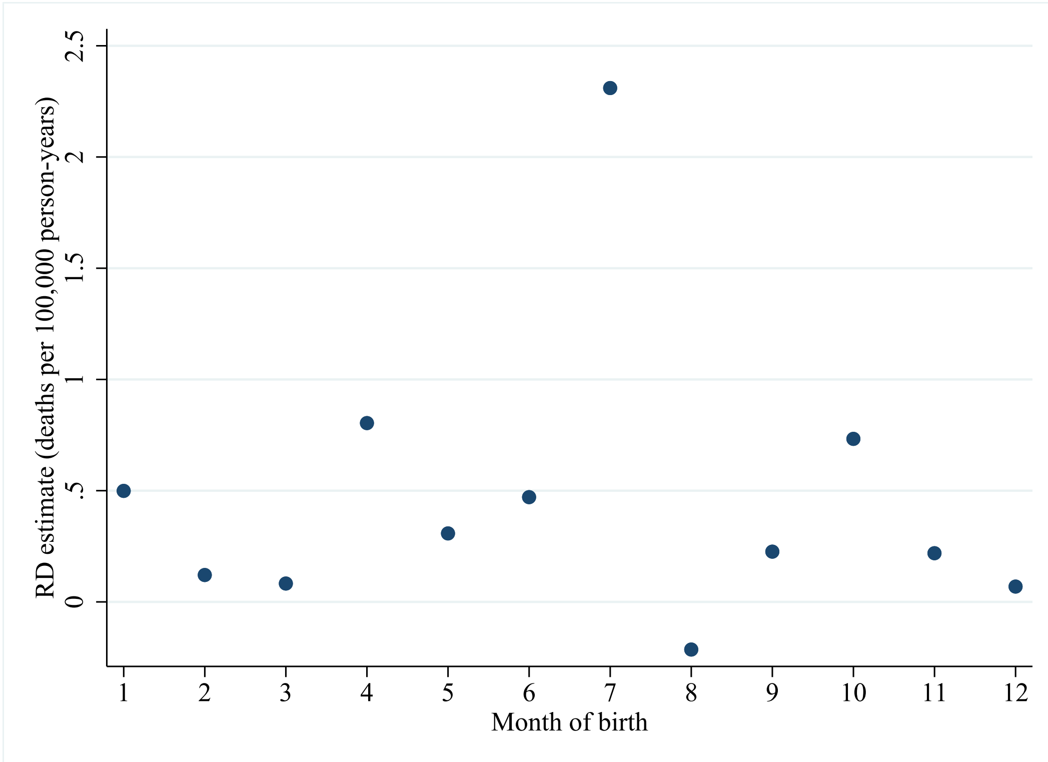
(b) Motor vehicle fatalities (relative to monthly mean)



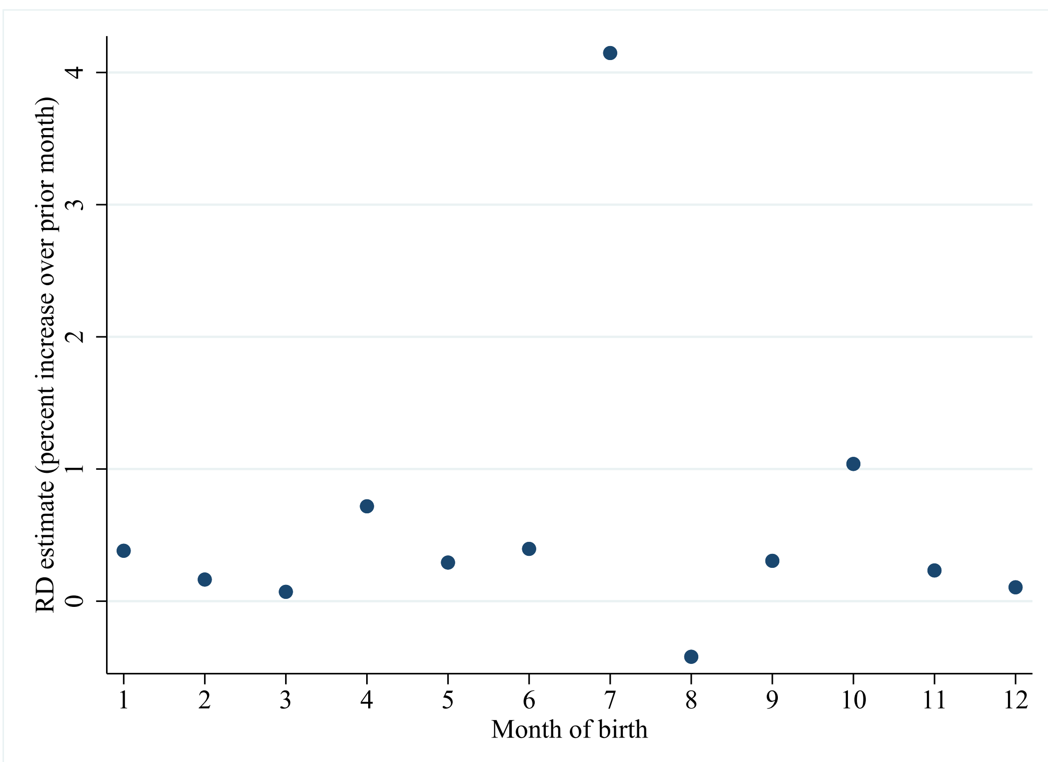
Notes: Panel (a) plots estimates from Table A.9. Panel (b) normalizes the point estimates by the mean reported in Column (1) of those tables. January is denoted as month 1.

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

(a) Poisoning deaths



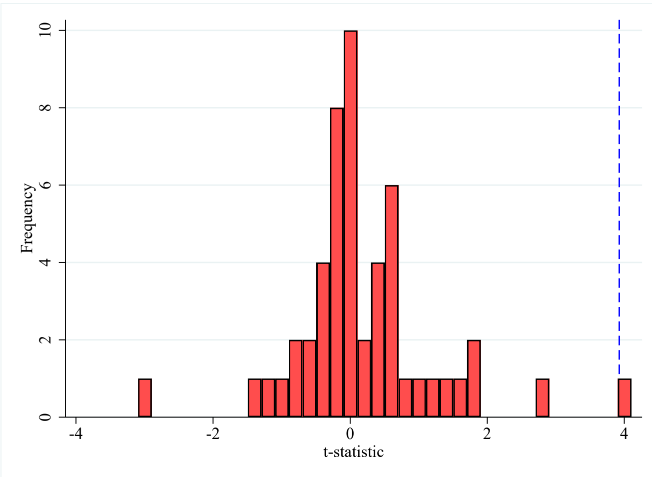
(b) Poisoning deaths (relative to monthly mean)



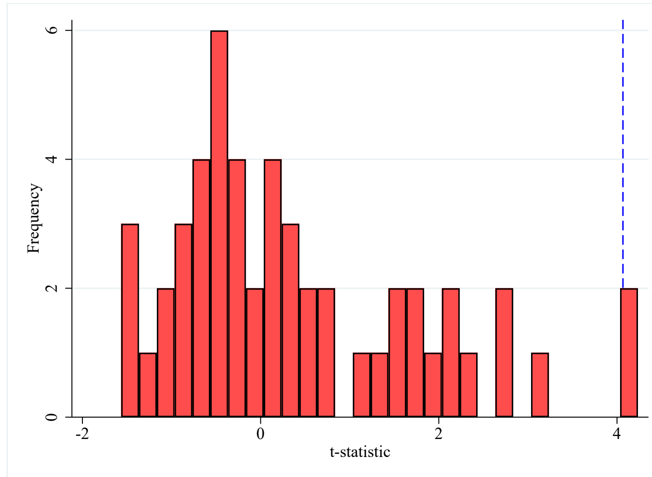
Notes: Panel (a) plots estimates from Table A.10. Panel (b) normalizes the point estimates by the mean reported in Column (1) of that table. January is denoted as month 1.

Figure A.10: Placebo estimates for motor vehicle fatalities and poisoning deaths

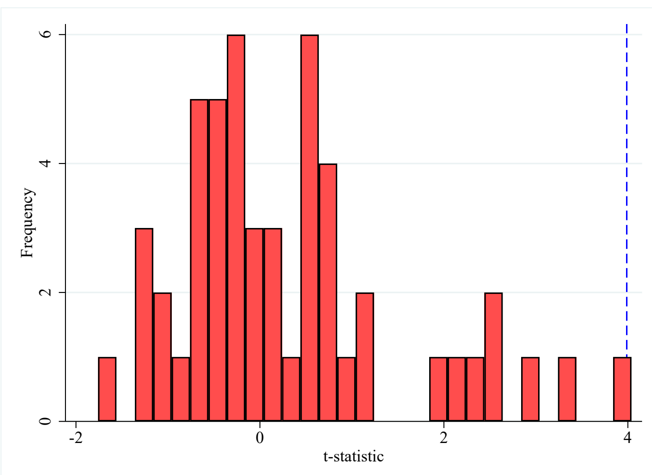
(a) Full sample: Motor vehicle fatalities



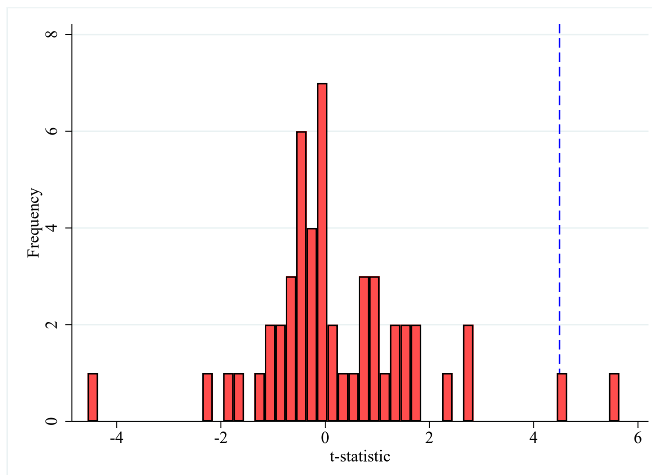
(b) Full sample: Poisoning deaths



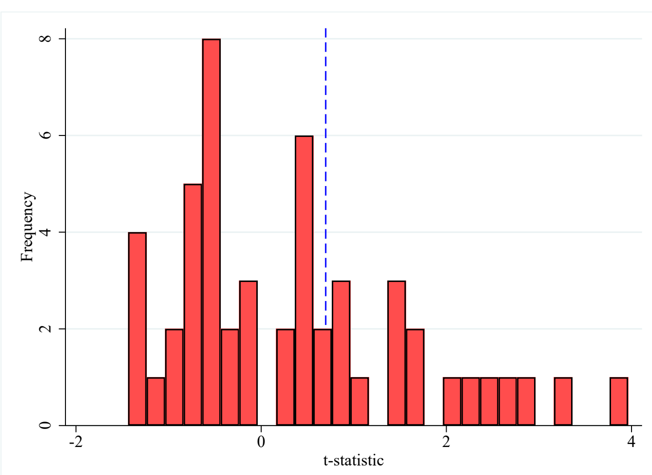
(c) Male: Motor vehicle fatalities



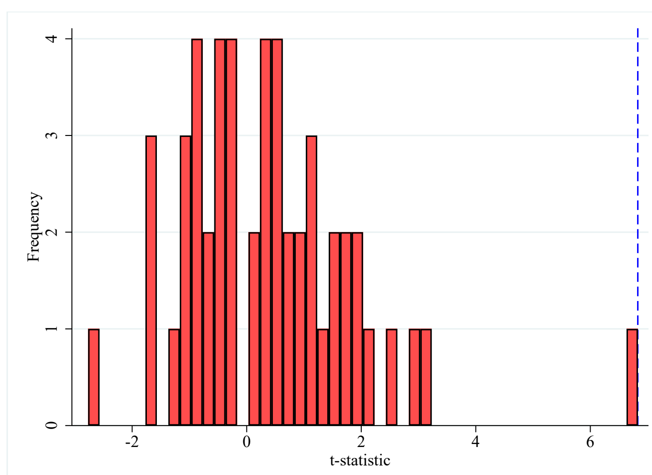
(d) Female: Motor vehicle fatalities



(e) Male: Poisoning deaths



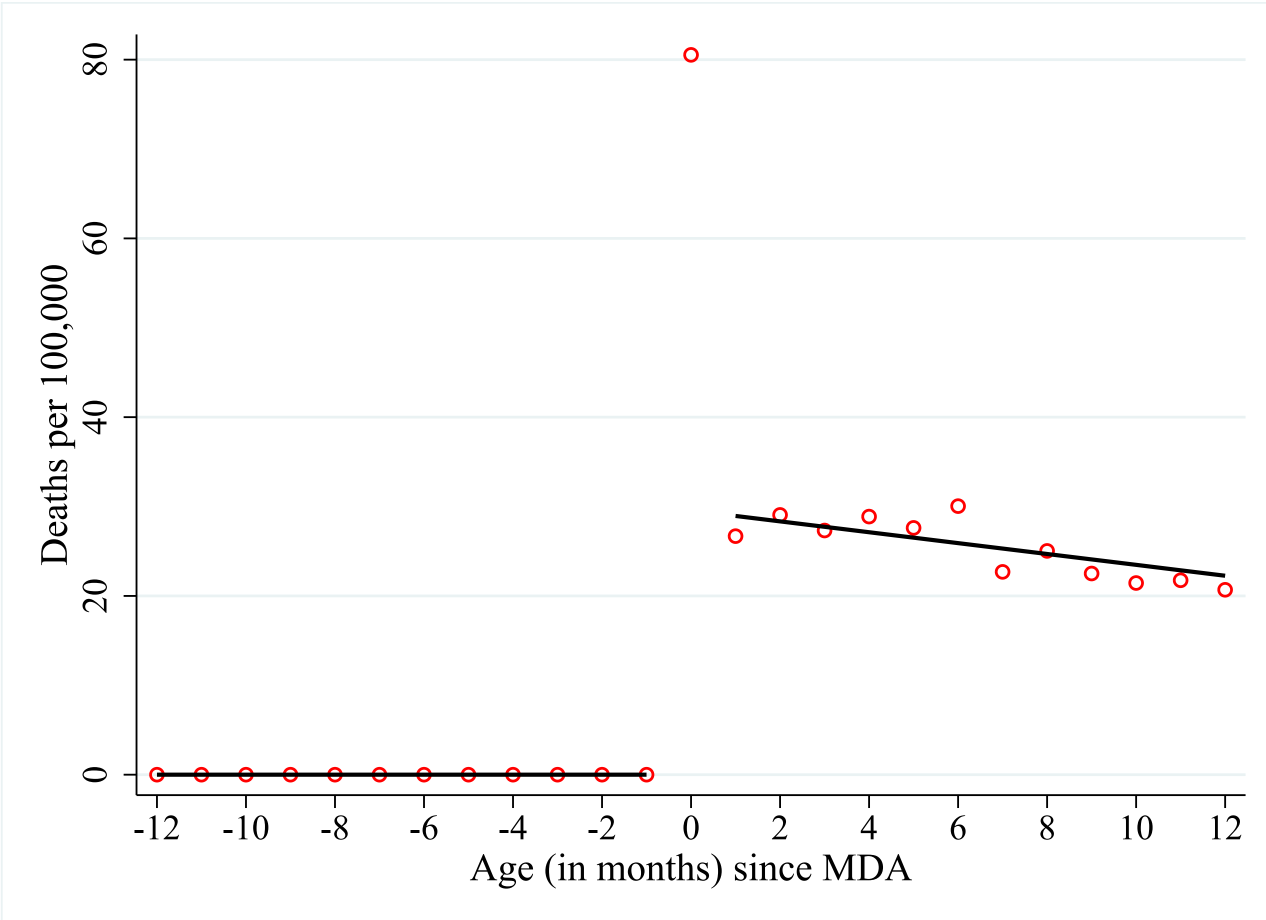
(f) Female: Poisoning deaths



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.

Figure A.11: Average treatment effects of driving on motor vehicle fatalities for inframarginal compliers

(a) Treatment: has driver's license



(b) Treatment: 100M vehicle miles driven per year (baseline)

(c) Treatment: 100M vehicle miles driven per year (alternate)

Notes: The figure plots $\lambda(a) = \frac{Y_a - Y_{-1}}{DRIVE_a - DRIVE_{-1}}, a \geq 0$, where with a slight abuse of notation, $\lim_{a \to 0} \lambda(a)$ provides a nonparametric approximation of λ, the local average treatment effect in equation (3). The numerator variable Y_a is mortality (deaths per 100,000) for age cell a. The denominator variable $DRIVE_a$ is either proportion of teenagers with a license or average annual vehicle miles driven (measured in hundreds of millions). The point estimate at the age cutoff is inflated due to the attenuation bias caused by measurement error in estimates of licensing status and vehicle miles driven at the cutoff (e.g., see Figure 1a). For illustrative purposes, point estimates below the cutoff are set equal to zero.

Table A.1: 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.2: 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.3: Effect of driving eligiblity on motor vehicle fatalities, for different stages of licensing

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample		Male		Female	
Eligibility type	Mean	RD	Mean	RD	Mean	RD
Restricted license	11.2	4.92**	13.6	5.67**	8.75	4.46**
		[2.36, 7.07]		[2.76, 8.10]		[2.41, 6.14]
Learner's permit	7.17	0.672	8.58	0.681	5.69	0.346
		[–0.267, 1.92]		[–0.953, 2.66]		[–0.342, 1.27]
Full license	15.7	1.08*	19.3	1.43	11.8	0.702
		[0.223, 2.26]		[–0.211, 3.34]		[–0.0248, 1.72]

Notes: 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 age for different stages of licensing. Columns (2), (4), and (6) report MSE-optimal estimates of β from equation (1). Estimates reported in the first row reproduce the estimates from Table 1. The second row reports estimates of the effect of becoming age-eligible for a learner's permit. The third row reports estimates of the effect of becoming age-eligible for a full, unrestricted driver's license in states with GDL laws. The sample used in the first row includes 1,632 state-year observations between 1983–2014. Our data on laws for learner's permits start in 1991, which yield 1,224 state-year observations for the sample used in the second row. Estimates for the effects of full licensure in the third row are based on the subsample of 716 state-year observations that have GDL laws in place. Robust, bias-corrected 95-percent confidence intervals are reported in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.4: Estimates of the treatment effective derivative (TED) for mortality outcomes

	(1)	(2)	(3)
	Full sample	Male	Female
A. All deaths			
POST	6.16**	6.29**	5.98**
	(0.934)	(1.23)	(0.758)
AGE	0.898**	1.43**	0.335**
	(0.0506)	(0.0771)	(0.0524)
POST X AGE (TED)	0.217	0.365	0.0576
	(0.140)	(0.183)	(0.118)
B. Motor vehicle fatalities			
POST	5.57**	6.25**	4.83**
	(0.492)	(0.636)	(0.564)
AGE	0.368**	0.482**	0.247**
	(0.0303)	(0.0272)	(0.0557)
POST X AGE (TED)	0.152	0.245*	0.0530
	(0.0748)	(0.0934)	(0.0856)

Notes: This table presents estimates of equation (1) for two mortality outcomes: deaths from all causes and deaths from motor vehicle accidents. The dependent variable is deaths per 100,000 person-years. The model is estimated using OLS with a bandwidth of 24 months. The estimated coefficient on POST is the OLS RD estimate (see also Column (2) of Table A.13). The estimated coefficient on AGE corresponds to the slope of the trendline for ages below the MDA (see, e.g., the left halves of the fitted lines shown in Figures A.3 and 1b). The estimated coefficient on POST X AGE is the treatment effect derivative (TED). It is equal to the change in the slope of the trendline before and after the age cutoff. Robust standard errors are reported in parentheses. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.5: 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 θ from equation (2) 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.6: 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 θ from equation (2) 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.7: 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.8: 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.9: 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.10: 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.11: 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-percent 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.12: 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-percent confidence intervals are reported in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

Table A.13: 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 (first stage)						
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	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) in Panel B and θ from equation (2) in Panel A. 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.

Table A.14: Local average treatment effect of driving on teenage motor vehicle fatalities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		First-stage outcome					
		Has license		Miles driven (thousands miles/yr) (baseline)		Miles driven (thousands miles/yr) (alternate)	
Cause of death	Mean	2SLS	MSE optimal	2SLS	MSE optimal	2SLS	MSE optimal
Motor vehicle accident	11.2	29.9**	29.9**	15.0**	14.5**	9.58**	10.1**
		(2.23)	[24.9, 35.4]	(2.24)	[10.1, 20.1]	(1.55)	[6.22, 14.1]

Notes: This table reports estimates of λ, the local average treatment effect. The dependent variable in the second stage is deaths per 100,000 person-years. In Columns (2)–(3), the outcome variable in the first stage is the proportion of teenagers with a driver's license. In Columns (4)–(5), the outcome variable in the first stage is average annual vehicle miles driven, assuming a value of 150 for the respondents who report driving "over 100" miles per week. In Columns (6)–(7), we alternatively assume a value of 265 for that survey response. Column (1) reports the mean of the dependent variable one year before reaching the minimum driving age (MDA). Columns (2), (4), and (6) report two-stage least squares (2SLS) estimates of λ from equation (3) from a model employing a bandwidth of 24 months and report robust standard errors in parentheses. Columns (3), (5), and (7) employ an MSE-optimal bandwidth selection and report robust, bias-corrected 95-percent confidence intervals in brackets. A */** indicates significance at the 5%/1% level using conventional inference.

B Data and additional background information

B.1 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.[2] 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.[3] 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.

Most states have hardship exemptions that allow teenagers below the MDA to obtain a limited license for certain occupational, medical, and educational purposes.[4] 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.2 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 dataset. (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 for different five-year age groups during our sample period. Figure B.2 reports annual teenage death rates for the years 1983–2014, separately for males and females. Male death rates are about twice as large as female death rates. Motor vehicle fatality rates decline significantly during this time period for both groups.

[2] 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.

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

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

B.3 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. 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 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.4 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 percent of our state-year observations have a minimum school leaving age equal to 16 years. The MDA in 31 percent 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.

B.5 Background information on teenage driver's licenses

Figure B.1 shows the proportion of teenagers with a restricted or full driver's license during our 1983–2014 sample period. Below, we provide details about the teenage driver's licensing process.

B.5.1 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.[5]

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.5.2 Restricted driver's license

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 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. 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 have 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.

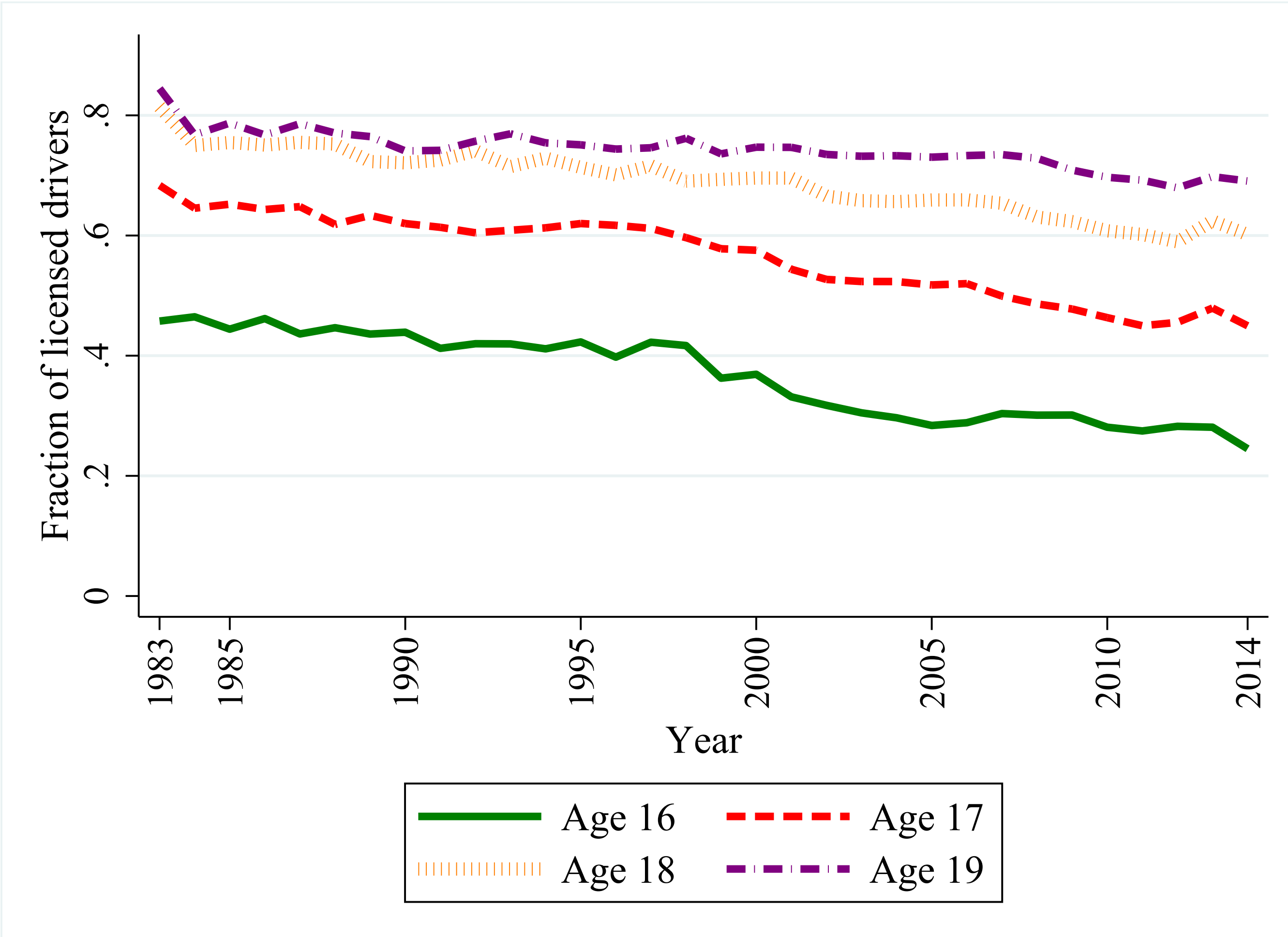
Two types of driving restrictions were adopted or modified during our sample period: nighttime restrictions (42 states plus DC) and passenger restrictions (44 states plus DC). By the end of our sample period, 42 states plus DC had both nighttime and passenger restrictions. The night driving restrictions 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.

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

B.5.3 Full driver's license

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.

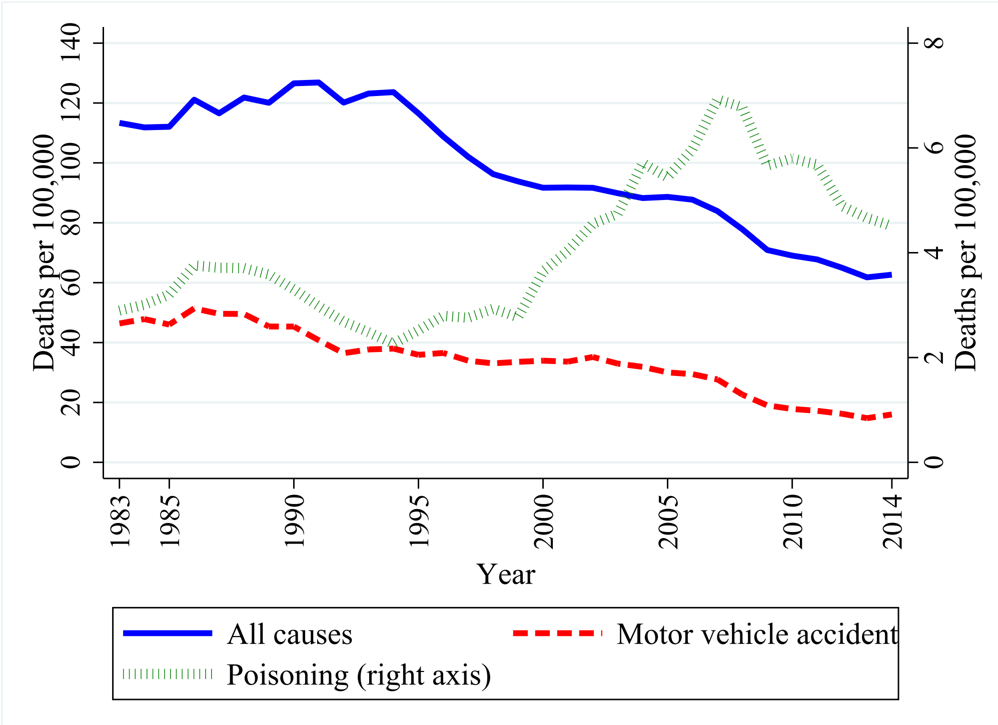
Figure B.1: Proportion of U.S. teenagers with a driver's license, 1983–2014



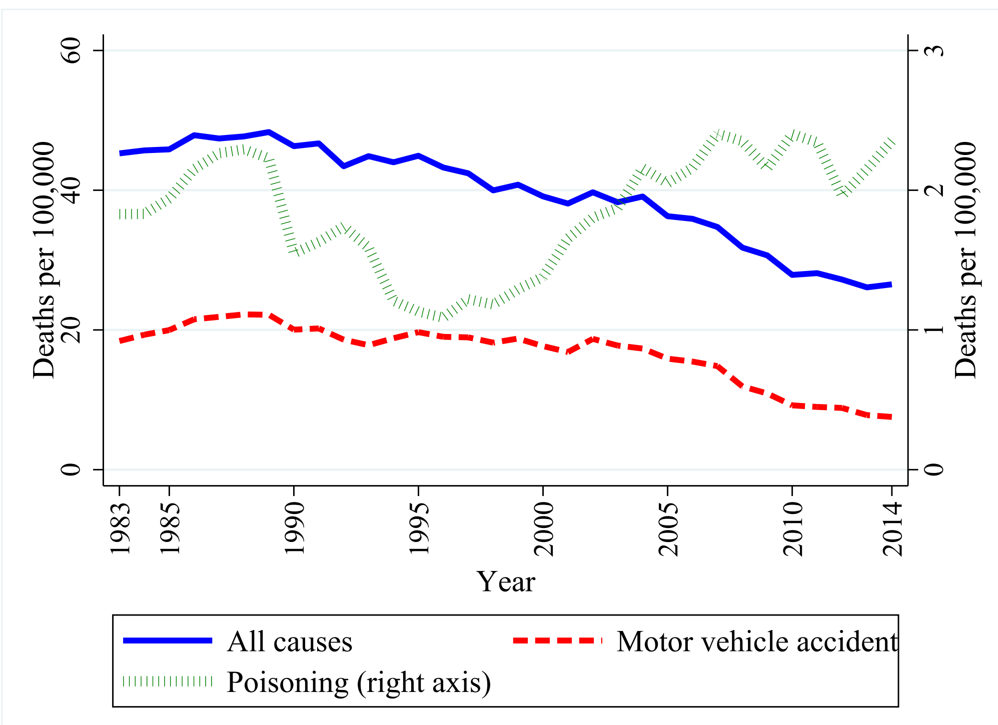
Notes: The figure reports the proportion of U.S. teenagers with a restricted or full driver's license. Counts of licensed drivers are obtained from the Federal Highway Administration (FHWA). A small number of the state-year counts in the FHWA data are incorrect (Curry, Kim and Pfeiffer, 2014; Gilpin, 2019). We replaced obvious anomalies with interpolated values during our data construction process. Population estimates come from the Surveillance, Epidemiology, and End Results (SEER) Program. FHWA data are available from: www.fhwa.dot.gov/policyinformation/quickfinddata/qfdrivers.cfm

Figure B.2: Aggregate trends in mortality rates for teenagers ages 15–19

(a) Males



(b) Females



Notes: Figures show U.S. death rates from all causes, poisonings, and motor vehicle accidents for ages 15–19. Poisonings include deaths from drug overdoses and carbon monoxide. Death counts are from the 1983–2014 National Vital Statistics, and population data are from the Surveillance, Epidemiology, and End Results (SEER) Program.

Table B.1: U.S. 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
Firearms	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	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
Firearms	E922	W32-W34
Poisoning	E850-E869	X40-X49
Drug overdose	E850-E866	X40-X45, X48-X49
Carbon monoxide	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 U.S. 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
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	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

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

C Drug consumption and mental health analysis

The Add Health surveys ask several questions about drug consumption and mental health. This section estimates the effect of driving eligibility on those outcomes. We do not consider those outcomes in the main text because the survey's small sample size combined with the low prevalence of the outcomes we are most interested in–suicide attempts and illegal drug consumption–cause this analysis to be underpowered. Table C.1 provides the exact definitions for the Add Health variables used in this supplemental analysis.

Panels B and C of Table C.2 report estimates of the effect of driving eligibility on self-reported drug consumption and mental health, as measured using the 1995–1996 Add Health surveys. One estimate remains significant after accounting for multiple hypothesis testing: males are 6.38 percentage points (55%) less likely to report that their life had been a failure (family-wise $p < 0.01$).

Our null estimates are meaningfully precise for prevalent outcomes. Our 95% confidence intervals rule out a 2.97 percentage point (6.5%) increase in self-reported female depression and a 7.59 percentage point (13.4%) increase in self-reported female sadness. Our null estimates are less precise for self-reported suicidal thoughts, suicide attempts, and illegal drug consumption, three outcomes of particular interest given our previous findings of an increase in suicidal and accidental drug overdoses. Our 95% confidence intervals rule out a 4.50 percentage point (24.7%) increase in suicidal thoughts and a 3.80 percentage point (92.5%) increase in illegal drug consumption among females.

Table C.3 provides results for the remaining 15 mental health outcomes from Add Health. Most estimates are statistically insignificant. Females are 2.26 percentage points less likely to report enjoying life at the cutoff (family-wise $p = 0.0359$). They are also 8.81 percentage points more likely to report being unusually bothered in the past week (family-wise $p = 0.125$). Figure C.1 illustrates that result.

Overall, while these estimates do not contradict the poisoning death results from Section 5.2, they do not point to a clear mechanism underlying those results either. In particular, the estimates from Table C.2 are consistent with the possibility of large (relative) changes in illegal drug consumption and serious mental health disorders, but unfortunately they are too noisy to confirm that hypothesis.

Figure C.1: Proportion of teenagers reporting they are unusually bothered in past week, 1995–1996

(a) Males

(b) Females

Notes: Panels (a) and (b) illustrate the proportion of teenagers who report being bothered by things that usually don't bother them in the past week 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.

Table C.1: Add Health variable definitions and codings

Description	Variable	Survey Question	Formula	Confidential?
Interview month	imonth	N/A	N/A	No
Interview year	iyear	N/A	N/A	No
Birth month	bmonth	N/A	N/A	No
Birth year	byear	N/A	N/A	No
Sex	bio_sex	N/A	N/A	No
Pseudo state identifier	w1state; w2state	N/A	"State" = w1state if iyear = 95; "State" = w2state if iyear = 96	No
Sample weight	gswgt1; gswgt2	N/A	"Weight" = gswgt1 if iyear = 95; "Weight" = gswgt2 if iyear = 96	No
Driver's license	h1ee10; h2ee10	Do you have a valid driver's license (not a driver's permit)?	Yes (= 1)	No
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)	No
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)	No
Alcohol	h1to15; h2to19	During the past 12 months, on how many days did you drink alcohol?	At least once (≤ 6)	Yes
Cigarette	h1to5; h2to5	During the past 30 days, on how many days did you smoke cigarettes?	At least once (≥ 1)	Yes
Marijuana	h1to32; h2to46	During the past 30 days, how many times did you use marijuana?	At least once (≥ 1)	Yes
Cocaine	h1to36; h2to52	During the past 30 days, how many times did you use cocaine?	At least once (≥ 1)	Yes
Inhalant	h1to39; h2to56	During the past 30 days, how many times did you use inhalants?	At least once (≥ 1)	Yes
Illegal drugs (excl cocaine/marijuana)	h1to42; h2to60	During the past 30 days, how many times did you use any of these types of illegal drugs? (Such as LSD, PCP, ecstasy, mushrooms, speed, ice, heroin, or pills, without a doctors prescription)	At least once (≥ 1)	Yes
Suicidal thoughts	h1su1; h2su1	During the past 12 months, did you ever seriously think about committing suicide?	Yes (= 1)	Yes
Suicide attempts	h1su2; h2su2	During the past 12 months, how many times did you actually attempt suicide?	Yes (= 1)	Yes
Depressed	h1fs6; h2fs6	You felt depressed. (During the past week)	At least sometimes (≥ 1)	No
Sad	h1fs16; h2fs16	You felt sad. (During the past week)	At least sometimes (≥ 1)	No

Table C.1: Add Health variable definitions and codings

Description	Variable	Survey Question	Formula	Confidential?
Life was a failure	h1fs9; h2fs9	You thought your life had been a failure. (During the past week)	At least sometimes (≥ 1)	No
Life not worth living	h1fs19; h2fs19	You felt life was not worth living. (During the past week)	At least sometimes (≥ 1)	No
Unusually bothered	h1fs1; h2fs1	You were bothered by things that usually don't bother you. (During the past week)	At least sometimes (≥ 1)	No
Poor appetite	h1fs2; h2fs2	You didn't feel like eating, or your appetite was poor. (During the past week)	At least sometimes (≥ 1)	No
Feel blue	h1fs3; h2fs3	You felt that you could not shake off the blues, even with help from your family and your friends. (During the past week)	At least sometimes (≥ 1)	No
As good as others	h1fs4; h2fs4	You felt that you were just as good as other people. (During the past week)	At least sometimes (≥ 1)	No
Difficulty in continuing	h1fs5; h2fs5	You had trouble keeping your mind on what you were doing. (During the past week)	At least sometimes (≥ 1)	No
Tired	h1fs7; h2fs7	You felt that you were too tired to do things. (During the past week)	At least sometimes (≥ 1)	No
Hopeful	h1fs8; h2fs8	You felt hopeful about the future. (During the past week)	At least sometimes (≥ 1)	No
Fearful	h1fs10; h2fs10	You felt fearful. (During the past week)	At least sometimes (≥ 1)	No
Happy	h1fs11; h2fs11	You were happy. (During the past week)	At least sometimes (≥ 1)	No
Talk less	h1fs12; h2fs12	You talked less than usual. (During the past week)	At least sometimes (≥ 1)	No
Lonely	h1fs13; h2fs13	You felt lonely. (During the past week)	At least sometimes (≥ 1)	No
Unfriendly	h1fs14; h2fs14	People were unfriendly to you. (During the past week)	At least sometimes (≥ 1)	No
Enjoy life	h1fs15; h2fs15	You enjoyed life. (During the past week)	At least sometimes (≥ 1)	No
Disliked	h1fs17; h2fs17	You felt that people disliked you. (During the past week)	At least sometimes (≥ 1)	No
Difficulty in getting started	h1fs18; h2fs18	It was hard to get started doing things. (During the past week)	At least sometimes (≥ 1)	No

Table C.1: Add Health variable definitions and codings

Description	**Variable**	**Survey Question**	**Formula**	**Confidential?**
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)	No
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)	No

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. Confidential or sensitive questions were pre-recorded and asked over earphones instead of being asked directly by the interviewer. Detailed survey documents are available at: https://www.cpc.unc.edu/projects/addhealth/documentation/restricteduse/datasets.

Table C.2: Effect of driving eligibility on teenage driving, drug consumption, and mental health, 1995–1996

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample		Male		Female	
Outcome variable	Mean	RD	Mean	RD	Mean	RD
A. Driving (first stage)						
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. Drug consumption						
Alcohol	0.444	–0.0746* [–0.144, -0.00301] {0.222}	0.409	–0.0609 [–0.160, 0.0309] {0.805}	0.481	–0.0865* [–0.166, -0.00909] {0.275}
Cigarettes	0.295	–0.0255 [–0.0624, 0.0166] {0.587}	0.264	–0.0318 [–0.106, 0.0295] {0.887}	0.328	–0.0126 [–0.0594, 0.0576] {0.976}
Marijuana	0.154	–0.0248* [–0.0434, -0.000766] {0.222}	0.151	–0.0623** [–0.102, -0.0188] {0.0515}	0.156	0.00714 [–0.0264, 0.0530] {0.903}
Cocaine	0.0122	–0.00366 [–0.0144, 0.00794] {0.814}	0.0164	–0.0103 [–0.0342, 0.0128] {0.903}	0.00750	0.0108 [–0.00150, 0.0290] {0.552}
Inhalant	0.0230	–0.000142 [–0.0105, 0.0136] {0.814}	0.0212	–0.00516 [–0.0301, 0.0146] {0.903}	0.0246	0.00897 [–0.0121, 0.0401] {0.887}
Illegal drugs (excl cocaine/marijuana)	0.0403	0.0158 [–0.00123, 0.0413] {0.235}	0.0388	0.00898 [–0.0177, 0.0435] {0.903}	0.0411	0.0127 [–0.00603, 0.0380] {0.779}
C. Mental health						
Suicidal thoughts	0.131	0.00371 [–0.0120, 0.0250] {0.936}	0.0791	–0.000964 [–0.0335, 0.0294] {0.996}	0.182	0.0111 [–0.00893, 0.0450] {0.815}
Suicide attempts	0.0451	0.00342 [–0.0205, 0.0337] {0.936}	0.0253	–0.0101 [–0.0539, 0.0322] {0.992}	0.0650	0.0210 [–0.00287, 0.0604] {0.606}
Depressed	0.367	–0.0336 [–0.0784, 0.0000198] {0.302}	0.278	–0.00456 [–0.0646, 0.0461] {0.996}	0.457	–0.0372 [–0.114, 0.0297] {0.866}
Sad	0.468	0.00428 [–0.0327, 0.0597] {0.936}	0.372	0.0395 [–0.0168, 0.114] {0.792}	0.565	–0.0266 [–0.104, 0.0759] {0.996}
Life was a failure	0.149	–0.0162 [–0.0531, 0.0223] {0.936}	0.116	–0.0638** [–0.116, -0.0345] {<0.01}	0.183	0.0418 [–0.00925, 0.126] {0.649}
Life not worth living	0.109	0.0231 [–0.00155, 0.0550] {0.327}	0.0806	0.000760 [–0.0243, 0.0206] {0.996}	0.138	0.0542* [0.0115, 0.117] {0.200}

Notes: 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) in Panels B–C and θ from equation (2) in Panel A. Robust, bias-corrected 95-percent 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.

Table C.3: Effect of driving eligibility on additional mental health outcomes, 1995–1996

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample		Male		Female	
Outcome variable	Mean	RD	Mean	RD	Mean	RD
Unusually bothered	0.394	0.0196 [–0.00775, 0.0642] {0.838}	0.298	–0.0201 [–0.0774, 0.0375] {1.00}	0.492	0.0881** [0.0318, 0.175] {0.125}
Poor appetite	0.347	–0.00907 [–0.0556, 0.0290] {0.999}	0.245	–0.0193 [–0.0644, 0.0374] {1.00}	0.449	0.0168 [–0.0329, 0.0770] {1.00}
Feel blue	0.265	–0.00239 [–0.0489, 0.0404] {0.999}	0.180	0.0436* [0.0103, 0.0845] {0.294}	0.350	–0.0368 [–0.113, 0.0303] {0.997}
As good as others	0.885	0.0229 [–0.0143, 0.0637] {0.945}	0.880	0.0423 [–0.00442, 0.0979] {0.851}	0.891	0.00141 [–0.0366, 0.0401] {1.00}
Difficulty in continuing	0.605	–0.0114 [–0.0763, 0.0613] {0.999}	0.569	0.00332 [–0.0551, 0.0621] {1.00}	0.642	–0.0228 [–0.112, 0.0850] {1.00}
Tired	0.570	0.0166 [–0.0272, 0.0833] {0.986}	0.537	–0.0195 [–0.101, 0.0572] {1.00}	0.601	0.0557 [–0.0280, 0.175] {0.978}
Hopeful	0.881	0.0293 [–0.00172, 0.0728] {0.614}	0.864	0.0367 [–0.0181, 0.104] {0.979}	0.898	–0.00418 [–0.0405, 0.0388] {1.00}
Fearful	0.259	–0.0276 [–0.0687, 0.00808] {0.838}	0.207	0.000566 [–0.138, 0.106] {1.00}	0.311	–0.0516* [–0.0911, -0.00225] {0.663}
Happy	0.968	0.00793 [–0.0170, 0.0325] {0.999}	0.967	0.0128 [–0.0264, 0.0553] {1.00}	0.970	0.00486 [–0.0153, 0.0204] {1.00}
Talk less	0.432	0.0152 [–0.0346, 0.0648] {0.999}	0.454	0.00483 [–0.0615, 0.0849] {1.00}	0.413	0.0484 [–0.00216, 0.120] {0.792}
Lonely	0.334	–0.00277 [–0.0354, 0.0380] {0.999}	0.266	0.0145 [–0.0700, 0.102] {1.00}	0.404	0.00589 [–0.0197, 0.0463] {1.00}
Unfriendly	0.331	–0.00171 [–0.0388, 0.0252] {0.999}	0.330	–0.00788 [–0.0787, 0.0509] {1.00}	0.334	0.0105 [–0.0476, 0.0600] {1.00}
Enjoy life	0.954	–0.00153 [–0.0242, 0.0154] {0.999}	0.954	0.00796 [–0.0181, 0.0353] {1.00}	0.953	–0.0226** [–0.0496, -0.0122] {0.0359}
Disliked	0.336	–0.00246 [–0.0421, 0.0277] {0.999}	0.306	0.00408 [–0.0695, 0.0792] {1.00}	0.367	0.00526 [–0.0534, 0.0556] {1.00}
Difficulty in getting started	0.497	–0.0208 [–0.0909, 0.0337] {0.990}	0.467	–0.0653 [–0.186, 0.0245] {0.967}	0.527	0.0305 [–0.0122, 0.0775] {0.978}

Notes: 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-percent 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.