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The Minimum Legal Drinking Age and Public Health

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In summer 2008, more than 100 college presidents and other higher education officials signed the Amethyst Initiative, which calls for a reexamination of the minimum legal drinking age in the United States. The current age-21 limit in the United States is higher than in Canada (18 or 19, depending on the province), Mexico (18), and most western European countries (typically 16 or 18). A central argument of the Amethyst Initiative is that the U.S. minimum legal drinking age policy results in more dangerous drinking than would occur if the legal drinking age were lower. A companion organization called Choose Responsibility—led in part by Amethyst Initiative founder John McCardell, former Middlebury College president—explicitly proposes “a series of changes that will allow 18–20 year-olds to purchase, possess and consume alcoholic beverages” (see ⟨http://www.choose responsibility.org/proposal/⟩).

Fueled in part by the high-profile national media attention garnered by the Amethyst Initiative and Choose Responsibility, activists and policymakers in several states, including Kentucky, Wisconsin, South Carolina, Missouri, South Dakota, Minnesota, and Vermont, have put forth various legislative proposals to lower their state's drinking age from 21 to 18, though no state has adopted a lower minimum legal drinking age yet.

Does the age-21 drinking limit in the United States reduce alcohol consumption by young adults and its harms, or as the signatories of the Amethyst Initiative contend, is it “not working”? Alcohol consumption and its harms are extremely common among young adults. According to results from the 2006–2007 National Health Interview Survey, adults age 18–25 report that on average they drank on 36 days in the previous year and typically consumed 5.1 drinks on the days they drank. If consumed at a single sitting, five drinks meets the clinical definition of “binge” or “heavy episodic” drinking. This consumption contributes to a substantial public health problem: five drinks for a 160-pound man with a limited time between drinks leads to a blood alcohol concentration of about 0.12 percent and results in moderate to severe impairments in coordination, concentration, reflexes, reaction time, depth perception, and peripheral vision. For comparison, the legal limit for driving in the United States is generally 0.08 percent blood alcohol content. Not surprisingly, motor vehicle accidents (the leading cause of death and injury in this age group), homicides, suicides, falls, and other accidents are all strongly associated with alcohol consumption (Bonnie and O'Connell, 2004). Because around 80 percent of deaths among young adults are due to these “external” causes (as opposed to cancer, infectious disease, or other “internal” causes), policies that change the ways in and extent to which young people consume alcohol have the potential to affect the mortality rate of this population substantially.

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In this paper, we summarize a large and compelling body of empirical evidence which shows that one of the central claims of the signatories of the Amethyst Initiative is incorrect: setting the minimum legal drinking age at 21 clearly reduces alcohol consumption and its major harms. However, this finding alone is not a sufficient justification for the current minimum legal drinking age, in part because it does not take into account the benefits of alcohol consumption. To put it another way, it is likely that restricting the alcohol consumption of people in their late 20s (or even older) would also reduce alcohol-related harms at least modestly. However, given the much lower rate at which adults in this age group experience alcohol-related harms, their utility from drinking likely outweighs the associated costs. Thus, when considering at what age to set the minimum legal drinking age, we need to determine if the reduction in alcohol-related harms justifies the reduction in consumer surplus that results from preventing people from consuming alcohol.

We begin this paper by examining the case for government intervention targeting the alcohol consumption of young adults. We develop an analytic framework to identify the parameters that are required to compare candidate ages at which to set the minimum legal drinking age. Next, we discuss the challenges inherent in estimating the effects of the minimum legal drinking age and describe what we believe are the two most compelling approaches to address these challenges: a panel fixed-effects approach and a regression discontinuity approach. We present estimates of the effect of the minimum legal drinking age on mortality from these two designs, and we also discuss what is known about the relationship between the minimum legal drinking age and other adverse outcomes such as nonfatal injury and crime. We then document the effect of the minimum legal drinking age on alcohol consumption, which lets us estimate the costs of adverse alcohol-related events on a per-drink basis. Finally we return to the analytic framework and use it to determine what the empirical evidence suggests is the correct age at which to set the minimum legal drinking age.

Economic Economic Considerations for Determining the Optimal Minimum Legal Drinking Age

Alcohol consumption by young adults results in numerous harms including deaths, injuries, commission of crime, criminal victimization, risky sexual behavior, and reduced workforce productivity. A substantial portion of these harms are either directly imposed on other individuals (as is the case with crime) or largely transferred to society as a whole through insurance markets as is the case with injuries (Phelps, 1988). In addition, there is the theoretical possibility (supported by laboratory evidence) that youths may discount future utility too heavily, underestimate the future harm of their current behavior, and/or mispredict how they will feel about their choices in the future (O'Donoghue and Rabin, 2001). If this is the case, even risks that are borne directly by the drinker are not being fully taken into account when an individual is deciding how much alcohol to consume. Given that young adults are imposing costs on others and probably not fully taking into account their own cost of alcohol consumption, there is a case for government intervention targeting their alcohol consumption. The minimum legal drinking age represents one approach to reducing drinking by young adults.[1]

Determining the optimal age at which to set the minimum legal drinking age requires estimates of the loss in consumer surplus that results from reducing peoples' alcohol consumption. It also requires estimating the benefits to the drinker and to others from reducing alcohol-related harms. Unfortunately, it is not possible to obtain credible estimates of these key parameters at every point in the age distribution. First, there are no credible estimates of the effects of drinking ages lower than 18 or higher than 21 because the minimum legal drinking age has not been set outside this range in a signififi cant portion of the United States since the 1930s, and the countries with current drinking ages outside this range look very different from the United States. In fact, as we describe in detail in the next section, even estimating the effects on adverse outcomes of a drinking age in the 18 to 21 range is challenging. Second, we lack good ways to estimate the consumer surplus loss that results from restricting drinking, a problem that has characterized the entire literature on optimal alcohol control and taxation (see Gruber, 2001, for a general discussion).

Thus, rather than try to estimate the optimal age at which to set the minimum legal drinking age, we focus on an analysis that is more feasible and useful from a policy perspective. The drinking age in the United States is currently 21, and there is no push to raise it. If it is lowered, there are many reasons to believe it will most likely be lowered to 18. First, the primary effort by activists for a lower drinking age is to lower the age to 18, either on its own or in conjunction with other alcoholcontrol initiatives such as education programs. In fact, 18 was the most commonly chosen age among the states that adopted lower minimum legal drinking ages in the 1970s. Second, 18 is the age of majority for other important activities such as voting, military service, and serving on juries, thus making it a natural focal point (though notably many states set different minimum ages for a variety of other activities such as driving, consenting to sexual activity, gambling, and purchasing handguns). Finally, many other countries have set their minimum legal drinking age at 18.

Because a change in the drinking age is likely to involve lowering it from 21 to 18, we focus on estimating the effect of lowering the drinking age by this amount on alcohol consumption, costs borne by the drinker, and costs borne by other people. Alcohol consumption can result in harms through many different channels. The effects of age-based drinking restrictions on long-term harms are very hard to estimate so we focus on the major acute harms that result from alcohol consumption including: deaths, nonfatal injuries, and crime. We pay particular attention to the effect of the drinking age on mortality because mortality is well-measured, has been the outcome focused on by much of the previous research on this topic, and is arguably the most costly of alcohol-related harms. To avoid the difficulty of trying to estimate the increase in consumer surplus that results from allowing people to drink, we estimate how much drinking is likely to increase if the drinking age is lowered from 21 to 18 and compare this to the likely increase in harms to the drinker and to other people. This allows us to characterize the harms in terms of dollars per drink. Since we are missing some of the acute harms and all of the long-term harms of alcohol consumption, the estimates we present in this paper are lower bounds of the costs associated with each drink.

Adding how much the drinker paid for the drink to the cost per drink borne by the drinker yields a lower bound on how much a person would have to value the drink for its consumption to be the result of a fully informed and rational choice. The per-drink cost borne by people other than the drinker provides a lower bound on the externality cost. If the externality cost is large or if the total cost of a drink (costs imposed on others plus costs the drinker bears privately plus the the price of the drink itself) is larger than what we believe

[1]Other possible interventions have received attention in the economics literature. For example, age-targeted drunk driving laws and graduated licensing programs set very low legal blood alcohol content limits for young adult drivers and have been shown to reduce youth drinking and related harms (for example, Carpenter, 2004a; Voas, Tippetts, and Fell, 2003). Increases in sanctions and/or enforcement of age-targeted drunk driving laws might further reduce youth alcohol consumption and its related harms (Kenkel, 1993a). Kenkel (1993b) explores the theoretical possibility of a "teen tax" that could be levied only on young adults, though there is no consensus on the effectiveness of state beer excise taxes on youth drinking and related harms (for example, Dee, 1999; Cook and Moore, 2001). Finally, public health education about the risks of alcohol use has been widely mentioned as an alternative strategy to reduce alcohol-related harms among youths, although we are not aware of economic evaluations of such policies. We focus here on the minimum legal drinking age due to recent high-profile attention garnered by the Amethyst Initiative and related organizations such as Choose Responsibility.

the value of the drink is to the person consuming it, then this would suggest that the higher drinking age is justified.

The Evaluation Problem in the Context of the Minimum Legal Drinking Age

Determining how the minimum legal drinking age affects alcohol consumption and its adverse consequences is challenging. An extensive public health literature documents the strong correlation between alcohol consumption and adverse events, but estimates from these studies are of limited value for determining whether the minimum legal drinking age should be set at 18, 21, or some other age. Their main limitation is that the correlation between alcohol consumption and adverse events is probably due in part to factors other than alcohol consumption, such as variation across individuals in their tolerance for risk. People with a high tolerance for risk may be more likely both to drink heavily and to put themselves in danger in other ways, such as driving recklessly, even when they are sober. If this is the case, then predictions based on these correlations of how much public policy might reduce the harms of alcohol consumption will be biased upwards. Moreover, estimates of the average relationship between alcohol consumption and harms in the population may not be informative about the effects of the minimum legal drinking age, which probably disproportionately reduces drinking among the most law-abiding members of the population. This suggests that direct estimates of the effect of the drinking age on alcohol consumption and alcohol-related harms are needed if we are to compare the effects of different drinking ages.

Estimating the effects of the minimum legal drinking age requires comparing the alcohol consumption patterns and adverse event rates of young adults subject to the law with a similar group of young adults not subject to it. Since all young adults under age 21 in the United States are subject to the minimum legal drinking age, difficult to find a reasonable comparison group for this population. Because of cultural differences and different legal regimes, young adults in countries where the drinking age is lower than 21 are unlikely to constitute a good comparison group.

However, researchers working on this issue have identified two plausible comparison groups for 18 to 21 year-olds subject to the minimum legal drinking age. The first is composed of young people who were born just a few years earlier in the the same state (and who thus grew up in very similar circumstances) but who faced a lower legal drinking age due to changes in state drinking age policies. In the 1970s, 39 states lowered their minimum legal drinking age to 18, 19, or 20. These drinking age reductions were followed by increases in motor vehicle fatalities, which were documented by numerous researchers at the time (for a review, see Wagenaar and Toomey, 2002). This evidence led states to reconsider their decisions and encouraged aged Congress to adopt the National Minimum Drinking Age Act of 1984, which required states to adopt a minimum drinking age of 21 or risk losing 10 percent of their federal highway funds. By 1990, every state had responded to the federal law by increasing its drinking age to 21. Thus, within the same state some youths were allowed to drink legally when they turned 18, while those born just a short time later had to wait until they turned 21. We use a fixed-effects panel approach to compare the alcohol consumption and adverse event rates of these two groups.

The second approach for identifying a credible comparison group is to consider a period when the minimum legal drinking age is 21 and compare people just under 21 who are still subject to the minimum legal drinking age with those just over 21 who can drink legally. These two groups of people are likely to be very similar, except that the slightly older group is not subject to the minimum legal drinking age. This approach is called a regression discontinuity design (Thistlewaite and Campbell, 1960; Hahn, Todd, and Van der Klaauw, 2001). In the next two sections, we describe these two research designs in detail and how we use them to estimate the effects of the minimum legal drinking age on mortality.

Panel Estimates of the Effect of the Drinking Age on Mortality

The panel approach to estimating the effects of the minimum legal drinking age focuses on the changes in the drinking age that occurred in most states in the 1970s and 1980s. We begin by presenting graphical evidence in Figure 1 on the relationship between the drinking age and the incidence of fatal motor vehicle accidents. The data underlying the series in Figure 1 come from the Fatality Analysis Reporting System for 1975–1993 for the 39 states that lowered their drinking age during the 1970s and 1980s. In figure, we present the time series of deaths due to motor vehicle accidents among: 18–20 year-olds during nighttime (solid circles); 18–20 year-olds during daytime (dotted line with hollow squares); and 25–29 year-olds during nighttime (stars). The time series in the figure are centered on the month in which a state took its largest step towards raising its drinking age back to 21. The daytime/nighttime distinction is standard in the literature (for example, Ruhm, 1996; Dee, 1999) and is useful for understanding the effects of young adult alcohol consumption because the majority (67 percent) of fatal motor vehicle accidents occurring in the evening hours (defined here as between 8:00 p.m. and 5:59 a.m.) involve alcohol, while only about a quarter of fatal motor vehicle accidents occurring in the daytime hours involve alcohol.

We also plot the percent of 18–20 year-olds that can drink legally in the 39 states that experimented with a lower minimum legal drinking age. This line does not drop instantly from 100 to 0 percent because some states increased their drinking age from 18 to 19 and then from 19 to 21 a few years later, and other states allowed people who could drink legally when the drinking age was increased to continue drinking legally.

Figure 1 reveals that, in the seven years after the increase in the drinking age, there is a substantial reduction in deaths among 18–20 year-olds due to nighttime motor vehicle accidents and much smaller reductions in deaths of 18–20 year-olds due to daytime accidents and of 25–29 year-olds due to nighttime accidents. That the largest reduction in death rates occurs for the type of accident most likely to drop in response to an increase in the drinking age is consistent with the possibility that the increase in the drinking age reduced the motor vehicle fatality rates of 18–20 year-olds. However, the graphical evidence in favor of the hypothesis that increasing the drinking age reduced deaths is not fully compelling. First, the decline in deaths due to nighttime motor vehicle accidents among 18–20 year-olds is not as abrupt as the decline in the percent of this population that can drink legally. Second, as can be seen in the figure, the number of 18–20 year-olds that die in nighttime accidents was already declining before the drinking age was raised in most states. For this reason turn to a state-level panel data approach that allows us to adjust for trends and time-invariant differences across states and estimate the effect of the minimum legal drinking on mortality rates.

To obtain an estimate of the decline in mortality attributable to the drinking age, we implement a panel regression analysis of the following form:

$$Y_{st}=\alpha MLDA_{st}+\theta_s+\mu_t+\psi_{st}+\varepsilon_{ist},$$

where (Y_{st}) is the number of motor vehicle fatalities per 100,000 person-years for one of four age groups: 15–17 year-olds, 18–20 year-olds (the group directly affected by changes in the drinking age), 21–24 year-olds, and 25–29 year-olds in state (s) in time period (t). For each age group, we separate daytime and nighttime motor vehicle fatality rates. As noted above, any effects of the minimum legal drinking age on motor vehicle fatalities should be primarily on evening accidents because they are much more likely to involve alcohol. The regressions include a dummy variable for each state (θ_s) to remove time-invariant differences between states and dummy variables for each year (μ_t) to absorb any atypical year-to-year variation.[2] In addition, the regression includes state-specific linear time trends (ψ_{st}). The inclusion of state-specific dummies in combination with the state-specific time trends mean that the regression will return estimates of how raising the drinking age changes the level of motor vehicle mortality in a typical state, while adjusting for any state-specific trends in outcomes that preceded the change in the drinking age. This approach lets us compare people born in the same state just a few years apart who became eligible to drink legally at different ages. The variable *MLDA* (an acronym derived from Minimum Legal Drinking Age) is the proportion of 18 to 20 year-olds that can legally drink beer in state *s* in time *t*, and the coefficient on this variable is our best estimate of the impact on mortality rates of lowering the drinking age from 21 to 18.[3] The regressions are weighted by the age-specific state-year population, and the standard errors clustered on state are presented in brackets below the parameter estimates (Bertrand, Duflo, and Mullainathan, 2004).

The estimates of the effect of the minimum legal drinking age on mortality for the subgroups described above are presented in Table 1 and are consistent with a large body of previous research showing that the minimum legal drinking age has economically significant effects on the motor vehicle mortality rates of young adults (for example, Dee, 1999; Lovenheim and Slemrod, 2010; Wagenaar and Toomey, 2002). Specifically, we find that going from a regime in which no 18–20 year-olds are legally allowed to drink to one in which all 18–20 year-olds are allowed to drink results in 4.74 more fatal motor vehicle accidents in the evening per 100,000 18–20 year-olds annually. Relative to the base death rate for this age and time of day, this is a 17 percent effect (4.74/28.1 = 0.17), and it is statistically significant. The associated point estimate for daytime fatalities (the majority of which do not involve alcohol) among 18–20 year-olds is much smaller, both in absolute terms and as a proportion of the daytime fatality rate, and it is not statistically significant. In addition, the changes in evening fatalities among 15–17 year-olds and 25–29 year-olds (whose behaviors should not be directly affected by the drinking age changes) are not statistically significant, though the 95 percent confidence intervals around the point estimates for these groups cannot rule out meaningfully large proportional effects relative to the low average death rates for individuals in these age groups. Overall, these patterns are consistent with a causal effect of easier alcohol access on motor vehicle fatalities among the 18–20 year-old young adults whose drinking behaviors were directly targeted by the laws. However, the rate of motor vehicle fatalities in the evening for 21–24 year-olds also changes when the minimum legal drinking age changes. While the proportional effect size for 21–24 year-olds (2.61/23.2 = 0.1125, or about 11 percent) is substantially smaller than for 18–20 year-olds (17 percent), this approach does not have sufficient statistical power to reject that the two estimates are equal. The apparent effect of the minimum legal drinking age on fatalities among 21–24 year-olds could reflect the effects of other unobserved anti-drunk driving campaigns that were correlated with drinking-age changes and targeted at young adults, or it may reflect spillovers, as members of these two groups are likely to socialize.

[2]This fixed effects panel approach was introduced to this literature by Cook and Tauchen (1982), who examined the effects of alcohol taxes on death rates from liver cirrhosis; it has now become standard in evaluations of this type. Note that this model cannot support inclusion of a full set of state-by-time fixed effects, because these would also absorb almost all of the variation in the minimum legal drinking age variable.

[3]Our parameterization of the minimum legal drinking age variable—that is, the proportion of 18–20 year-olds in the state who are legal to drink beer—is slightly different from most previous work on this topic, which often includes separate controls for age-18, age-19, and age-20 state drinking ages. This choice has no substantive effect on the results and is only done to facilitate a more natural comparison with the regression discontinuity approach we describe below.

In Table 2, we present estimates of the effects of the minimum legal drinking age on a more comprehensive set of causes of death. The mortality rates for this part of the analysis are estimated from the National Vital Statistics death certificate records. Since these records are a census of deaths and include substantial detail on the cause of death, it is possible to examine causes of death other than motor vehicle accidents. We present estimates of the effects of the minimum legal drinking age on all-cause mortality in Table 2 using the same fixed-effects specification as in Table 1. Specifically, the dependent variable in each regression in the bold row of Table 2 is the death rate of 18–20 year-olds per 100,000 person-years estimated from the death certificate records. All models in Table 2 include state fixed effects, year fixed effects, and linear state-specific time trends. To increase the precision of the estimates, the regression are weighted by the size of the relevant population in that state and time period.

The first estimate for all-cause mortality in Table 2 suggests that when all 18–20 year-olds are allowed to drink, there are 7.8 more deaths of 18–20 year-olds per 100,000 person-years (on a base of 113 deaths) than when no 18–20 year-olds are allowed to drink. This estimate is not statistically significant at conventional levels. Though the table reveals no evidence of a statistically significant increase in deaths due to internal causes (like cancer), it does reveal statistically significant increases in deaths due to motor vehicle accidents (4.15 more deaths on a base of 45.5 deaths, or a 4.15/45.5 = 0.091, or a 9.1 percent effect). This does not exactly match the estimate from Table 1 because the Vital Statistics records do not include the time of day when the accident occurred, so we are unable to split the rates based on the time of the accident as we did with the earlier data.[4] Table 2 also shows that increasing the share of young adults legal to drink leads to a statistically significant 10 percent increase in suicides (1.29/12.8 = 0.10), which is consistent with work by Birckmayer and Hemenway (1999) and Carpenter (2004b). There is no evidence of statistically significant effects on the other causes of death for 18–20 year-olds. The lack of a discernable impact on deaths directly due to alcohol is surprising, though in this period deaths due to alcohol overdoses appear to have been significantly undercounted (Hanzlick, 1988).

In the remainder of Table 2, we present estimates of the relationship between the proportion of 18–20 year-olds that can drink legally and the mortality rates of three age groups: 15–17, 21–24, and 25–29 year-olds. Since the proportion of 18–20 year-olds that can drink should not directly affect these groups (except possibly through spillovers), these groups should experience at most modest increases in mortality rates. As can be seen in the table, with the exception of 21–24 year-olds there is no evidence of statistically significant changes in the mortality rates of the three age groups surrounding 18–20 year-olds. This suggests that the changes in mortality rates of 18–20 year-olds are probably not being driven by safety initiatives that may have been implemented at the same time the drinking age was increased as these would have affected the other age groups also. Overall, the patterns in Tables 1 and 2 suggest that easing access to alcohol increases the overall death rate of 18–20 year-olds due to increases in two of the leading causes of death for this age group: motor vehicle accidents and suicides.

[4]We assign deaths in the Vital Statistics data to the state of residence of the decedent. In the Fatality Analysis Reporting System analyses we assigned deaths to the state of occurrence because of incomplete information on state of residence. We also calculated Vital Statistics panel estimates by state of occurrence, and these models returned larger effects of the minimum legal drinking age. This is consistent with the idea that different drinking ages across states created “blood borders” (Lovenheim and Slemrod, 2010).

Regression Discontinuity Estimates of the Effect of the Drinking Age on Mortality

Our other main strategy for identifying a plausible comparison group for people subject to the minimum legal drinking age is to take advantage of the fact that the drinking age “turns off” suddenly when a person turns 21. People slightly younger than 21 are subject to the drinking age law while those slightly older than 21 are not, but otherwise the two groups have very similar characteristics. If nothing other than the legal regime changes discretely at age 21, then a discrete mortality rates at age 21 can plausibly be attributed to the drinking age.

Again, we begin with the graphical approach by presenting the age profile of mortality rates for 19–22 year-olds in Figure 2. This figure is estimated using Vital Statistics mortality records from 1997–2003. The age profiles are death rates per 100,000 person-years for motor vehicle accidents (dark circles), suicides (cross hatches), and deaths due to internal causes (open squares), by month of age. A best-fit line for ages 19–20 shows a decreasing trend in motor vehicle fatalities. Similarly a best-fit line from age 21 to 22 shows a decreasing trend. However, the two trends show clear evidence of a discontinuity at age 21, when drinking alcohol becomes legal. The visual evidence of an effect of the minimum legal drinking age in the regression discontinuity setting in Figure 2 for motor vehicle accidents is notably stronger than the associated evidence from the annual time-series trends in Figure 1. There is also evidence of an increase in deaths due to suicide at age 21. In contrast, as can be seen in Figure 2, there is little evidence of a discontinuous change in deaths due to internal causes at the minimum legal drinking age of 21.

To estimate the size of the discrete jumps in the outcomes we observe in Figure 2, we estimate the following regression:

$$y=\beta_0+\beta_1 MLDA+\beta_2 Birthday+\mathrm{f}\,(age)+\varepsilon,$$

where *y* is the age-specific mortality rate. *MLDA* is a dummy variable that takes on a value of 1 for observations 21 and older, and 0 otherwise. The regressions include a quadratic polynomial in age, f(*age*), fully interacted with the *MLDA* dummy. This serves to adjust for age-related changes in outcomes and, as seen in Figure 2, is sufficiently flexible to fit the age profile of death rates. The *Birthday* variable is a dummy variable for the month in which the decedent's 21^{st} birthday falls and is intended to absorb the pronounced effect of birthday celebrations on mortality rates. We have recentered the age variable to take the value zero at age 21. As a result the parameter of interest in this model is β_1, which measures the size of the discrete increase in mortality that occurs when people turn 21 and are no longer subject to the minimum legal drinking age. The parameter β_1 has the same interpretation as the parameter α from the panel models: it is the effect of going from no one in a population being allowed to drink legally to everyone in a population being allowed to drink legally.

We present regression estimates of the paramete β_1 in Table 3. The regressions are estimated using mortality rates for the 48 months between ages 19 and 22. As with the state-year panel evidence in Table 2, we estimate the effect of the minimum legal drinking age on the overall death rate as well as deaths due to various causes. The results in Table 3 are consistent with the graphical evidence and reveal a statistically significant 8.7 percent increase in overall mortality when people turn 21 (8.06 additional deaths per 100,000 person-years from a base of 93.07 deaths corresponds to 8.06/93.07 = 0.087, or an 8.7 percent increase).[5] The increase in overall mortality at age 21 is almost entirely attributable to external causes of mortality. We estimate that deaths due to internal causes increase by just 3.3 percent at age 21

(0.66/20.07 = 0.033), and this estimate is not statistically significant. Among the various external causes of death, deaths due to suicide increase discretely by a statistically significant 20.3 percent at age 21 (2.37/11.7 = 0.203), and motor vehicle mortality rates increase by 12.2 percent (3.65/29.81 = 0.122). We find no statistically significant change in homicide deaths at age 21. Deaths coded as due to alcohol (including some non-vehicular accidents where alcohol is mentioned on the death certificate) increase by about 0.41 deaths at age 21 (a very large effect given the average death rate from alcohol overdose of just 0.99 per 100,000). Overall, the visual evidence in Figure 2 and the corresponding regression estimates in Table 3 provide persuasive evidence that the minimum legal drinking age has a significant effect on mortality from suicides, motor vehicle accidents, and alcohol overdoses at age 21.

Effects of the Drinking Age on Nonfatal Injury and Crime

In addition to premature death, alcohol use has been implicated in other adverse events such as nonfatal injury and crime.[6] Surprisingly, however, there is very little research directly linking the minimum legal drinking age to nonfatal injury. This is due, in part, to the lack of precise age-specific measures of injury rates during the 1970s and 1980s, which makes it impossible to estimate the effects of the minimum legal drinking age with precision using the panel approach. In ongoing work, however, we have used the regression discontinuity approach to estimate the effects of the minimum legal drinking age on nonfatal injury rates using administrative data on emergency department visits and inpatient hospital stays (Carpenter and Dobkin, 2010a). Although injuries have lower costs per adverse event than deaths, accidents resulting in a nonfatal injury are much more common than fatal accidents. We find that rates of emergency department visits and inpatient hospital stays increase significantly at age 21, by 408 and 77 per 100,000 person-years, respectively. These increases in nonfatal injuries are substantially larger than the increase in death rates of 8 per 100,000 person-years documented in Table 3. However, estimating the discrete increase in adverse events at age 21 in percentage terms reveals that emergency department visits are increasing by 1 percent, hospital stays by 3 percent, and deaths by 9 percent. This pattern holds even when we restrict the analysis to motor vehicle-related injuries and fatalities, which suggests that alcohol plays a disproportionate role in more serious injuries.

Another costly adverse outcome commonly linked to alcohol is crime, including nuisance, property, and violent crime: we provide a review in Carpenter and Dobkin (forthcoming). Since the pharmacological profile of alcohol includes both disinhibition and increased aggression, a causal effect of minimum legal drinking ages on crime rates is plausible. Three studies have examined the effects of drinking ages on crime. Two have used the state-year panel approach described above to test whether more permissive drinking ages increased arrests for youths age 18–20. Using data from the Uniform Crime Reports, Joksch and Jones

[5]For consistency with the panel regression evidence presented above, we estimate the regression discontinuity models of the effect of the minimum legal drinking age on mortality rates as opposed to mortality counts, though the latter are preferred as the population estimates used to create the rates reduces the precision of the estimates. This is the cause of the slight difference in the magnitude of the estimates from our previously published work (Carpenter and Dobkin, 2009).

[6]Some research has examined the relationship between the minimum legal drinking age and risky sexual behavior, though we are not aware of any that uses the regression discontinuity approach. Note that the pharmacological effects of alcohol on sociability and disinhibition could lead drinkers to engage in unplanned sexual behavior or riskier sex than they would have had in the absence of alcohol. Dee (2001) estimates panel regressions of teen childbearing for youths in the age groups affected by the changes in the minimum legal drinking age. He finds that the drinking age is related to childbearing rates among black teens, suggesting a causal effect of alcohol use on sexual activity leading to childbirth. Fertig and Watson (2009) also study state drinking-age policies and fertility outcomes in a fixed-effects framework, using data from the National Longitudinal Survey of Youths and Vital Statistics birth records. They find that exposure to more permissive drinking ages increased poor birth outcomes for young women, especially black mothers, and they find suggestive evidence that this is due to an increase in unplanned pregnancies. Finally, Carpenter (2005b) uses a similar panel approach to examine an alternative risky sexual outcome: rates of sexually transmitted infections. He finds suggestive evidence that a higher drinking age reduced gonorrhea rates for whites, but not for blacks.

(1993) show that states that raised their minimum drinking age reduced nuisance crimes, such as vandalism and disorderly conduct, significantly over the period 1980–1987; these results are confirmed and replicated in fixed-effects models estimated in Carpenter (2005a). More recently, we have applied the regression discontinuity design design to evaluate the relationship between alcohol access and crime (Carpenter and and Dobkin, 2010b). Using data encompassing the universe of arrests in California from 2000–2006, we found an 11 percent increase in arrest rates exactly at age 21. These effects were concentrated among nuisance crimes and violent crimes. Of the crimes for which we find a statistically significant effect, the two with the most substantial social costs are assault and robbery (larceny with force or threat of force) which increase by 63 and 8 arrests per 100,000 person-years, respectively.

Much of the literature on the minimum legal drinking age and the social costs of alcohol has focused on mortality. The evidence on other adverse outcomes suggests that an exclusive focus on mortality will lead one to substantially under-estimate the protective value of the minimum legal drinking age.

Effect of the Drinking Age on Alcohol Consumption

Estimating how a lower minimum legal drinking age would affect alcohol consumption is difficult. In addition to all of the challenges confronting researchers trying to estimate the effect of the drinking age on adverse event rates, there is an additional problem of data quality. While most adverse events are well-measured, alcohol consumption is not. Specifically, surveys of drinking do not generally include objective biological markers of alcohol consumption (such as blood alcohol concentration). Self-reported measures of drinking participation and intensity are subject to underreporting on the order of 40–60 percent (Rehm, 1998). An additional issue is that, despite the usual confidentiality assurances given by survey administrators, 18–20 year-olds probably underreport alcohol consumption even more than the typical survey respondent because it is illegal for them to drink.[7]

Recognizing these concerns, we nonetheless present estimates of the effect of the minimum legal drinking age on alcohol consumption from both the panel fixed-effects approach,and the regression discontinuity approach. For the fifi xed-effects approach, we focus on alcohol consumption reported by high school seniors age 18 and over who were surveyed in the Monitoring the Future study between 1976 and 1993. We use the same panel fixed-effects approach used to examine mortality rates with added controls for individual demographic characteristics such as race and gender. We examine three measures of alcohol consumption: whether the person drank at all in the past month, whether the person drank heavily in the past two weeks (defined as five or more drinks consumed at a single sitting), and the number of times the person drank in the last month. The effect of the minimum legal drinking age on these measures of alcohol consumption as estimated using a panel fixed-effects approach are presented in the first three columns of Table 4. The relevant independent variable in each of the first three columns is the proportion 18–20 year-olds legal to drink in the state. The results indicate that allowing 18–20 year-olds drink increases drinking participation by 6.1 percentage points, heavy episodic drinking by 3.4 percentage points, and instances of past month drinking by 17.4 percent (0.94/5.4 = 0.174). These results are similar to previous estimates of the effect of the minimum legal drinking age that used these same data and a similar approach (Dee, 1999; Carpenter, Kloska, O'Malley, and Johnston, 2007; Miron and Tetelbaum, 2009).

[7]In Carpenter and Dobkin (2009), we examine the possibility that there is a discrete change in the probability of underreporting alcohol consumption at age 21, and we do not find much evidence that this change is large in magnitude.

We also estimated the effect of the minimum legal drinking age on alcohol consumption using the regression discontinuity design. Since this approach required detailed information on alcohol consumption for people very close to age 21, we used the National Health Interview Survey which includes questions on drinking participation heavy episodic drinking, and the number of days in the last month on which the person consumed alcohol. We estimated the effect of the minimum legal drinking age on these measures of alcohol consumption using a version of the regression discontinuity design used earlier enriched with controls for individual demographic characteristics such as gender, race, region, and employment status. The estimates of β_1 are reported in the last three columns of Table 4. Given that the regression model includes a polynomial in age fully interacted with a dummy variable for being over 21 and that the age variable has been recentered at 21, these are estimates of the discrete change in drinking that occurs at exactly age 21. We find that the probability an individual reports having consumed 12 or more drinks in the past year increases at age 21 by about 6.1 percentage points, and the estimate is statistically significant. We find a 4.9 percentage point increase in the probability an individual reports heavy drinking (five or more drinks on a single day at least once in the previous year), and we estimate that the number of drinking days in the previous month increase by 19.6 percent (0.55/2.8 = 0.196) at age 21, though only the second of these estimates is statisically significant at the conventional level. These estimates are quite similar to the estimates from the panel approach and have also been replicated using other datasets including the California Health Interview Surveys (Carpenter and Dobkin, 2010b) and the National Surveys on Drug Use and Health (SAMHSA/OAS, 2009).

Below, we require an estimate of the number of additional drinks consumed if the drinking age were lowered from 21 to 18, in order to appropriately scale the cost estimates on a per-drink basis. In Column 3 of Table 4, with the panel design, we estimated that moving from a situation in which no 18–20 year-olds can drink legally to one in which all 18–20 year-olds can drink would increase the number of times a youth reported drinking in the past month by about 0.94 instances. In Column 6 of Table 4, using the regression discontinuity design, we estimated that the minimum legal drinking age increases the number of days the individual drank in the past 30 by about 0.55 days. Assuming instances are similar to days, the average of these two estimates implies that the minimum legal drinking age reduces alcohol consumption by about 0.745 drinking days per month. To put this on the same scale as the adverse event estimates (which are per 100,000 personyears), we calculate 0.745 × 12(months) × 100,000(persons) = 894,000 drinking days averted per 100,000 person-years. Young adults consume about 5.1 drinks on average each time they drink, so 894,000 drinking days corresponds to about 4.56 million drinks.

How Credible are the Estimates of the Effects of the Minimum Legal Drinking Age?

We have presented estimates of the effects of the minimum legal drinking age on alcohol consumption, mortality, and a variety of other adverse events from panel fixed-effects models and regression discontinuity models. Before using these estimates to compare drinking age regimes, it is important to examine how credible the evidence from each of these research designs is. The two approaches have different strengths and limitations, which can be roughly grouped into two categories: "internal validity" and "external validity." In the context of this paper, internal validity refers to how well a research design estimates the effects of the minimum legal drinking age on a particular population in a particular place and time. External validity refers to how well estimates from a research design are likely to predict the effect of the policy under consideration. External validity is a function of both the internal validity of the estimates and how similar the regime (population, policy, and environment) in which each of the research designs was estimated is to the regime in which the policy is being proposed.

We examine internal validity first, because the internal validity of an estimation strategy directly affects its external validity. The panel approach is subject to the concern that some states raised the drinking age at the same time that they implemented other policies targeting both alcohol consumption and its adverse consequences. If this were the case, estimates from the panel approach would likely overstate the true effect of the minimum legal drinking age because the estimates would reflect the benefits of both the minimum legal drinking age and the other policies.[8] By contrast, estimates from the regression discontinuity design are less likely to be biased by policy changes, because to cause bias the policies would have to go into effect at exactly age 21. Another possible problem with the panel approach is that enforcement of the higher drinking age was plausibly less stringent in states that were compelled to raise their drinking age by the 1984 federal National Minimum Drinking Age Act, which could impart downward bias to our panel estimates. Here again the regression discontinuity approach is unlikely to suffer from this bias because the age-21 drinking limit was a long-standing policy by the late 1990s, which is the period on which the regression discontinuity analysis is focused. A threat to the internal validity of both designs is that part of the increase in adverse events that occurs when people are first allowed to drink is probably due to people having to learn to drink responsibly. As a result, there may be an increase in mortality in the first few months after people are first allowed to drink whether the drinking age is set at 18, 21, or higher. As a result, computations that treat the reduction in deaths due to learning effects as saved lives would overstate the effect of the minimum legal drinking age. However, Tables 2 and 3 reveal that the panel and the regression discontinuity estimates of the impact of the minimum legal drinking age are quite similar, which would not be the case if learning effects were substantial, because learning effects would result in much more bias to the regression discontinuity estimates than to the panel estimates.

Yet another threat to the internal validity of the panel design is that there is likely slippage in the assignment of the treatment regime for young adults in a given state and year. These errors may arise due to border effects, as neighboring states sometimes had different drinking ages (as discussed in Lovenheim and Slemrod, 2010). Errors could also arise from grandfathering policies, in which some states allowed youths who could drink legally before the minimum legal drinking age was raised to continue drinking after the new drinking age was instituted, even if they were younger than the new legal age. This will result in imperfect assignment of treatment status due to the fact that exact age is not available in the datasets used in the panel analyses. These kinds of measurement errors would generally bias the estimated effects of the minimum legal drinking age downward.

Regarding external validity, the major advantage of the state-year panel approach is that it directly examines the effect of allowing 18–20 year-olds to buy and consume alcohol legally, which is the type of policy change that is being debated. Its primary disadvantage is that it examines changes in drinking ages that occurred 30 years ago, and many things have changed since then. For example, the minimum legal drinking age is probably more

[8]Miron and Tetelbaum (2009) make this type of argument by showing that there is heterogeneity in the effects of the minimum legal drinking age according to when states raised their drinking age. Specifically, they document that earlier adopters saw larger reductions in youth fatalities than late adopters and argue that factors other than the drinking age were responsible for the reductions in youth fatalities when drinking ages increased back to 21. These types of biases are not likely to affect regression discontinuity estimates of the minimum legal drinking age, which (as we show above) provided estimates very similar to the panel fixed-effects design, which in turn suggests that other unobserved policies and preferences are unlikely to account for the robust relationship between drinking ages and youth fatalities repeatedly documented in the fixed-effects approach (including in Miron and Tetelbaum, 2009). Of course, other types of heterogeneity may be important, such as variation across states in enforcement of the minimum legal drinking age. This is an important area for future research.

rigorously enforced now than it was in the 1970s. Public sentiment and legal sanctions against drunk driving have both increased greatly since the 1970s and 1980s. There have been numerous improvements in medicine and automobile safety in the last 30 years, including trauma centers and air bags. These changes would bias the results from the panel studies in opposing directions. The main issue with the external validity of estimates from the regression discontinuity approach is that the estimates are valid for people very near their 21^{st} birthday, and the proposed policy change would be to move the drinking age of 21 to 18. This is a problem for the external validity of the regression discontinuity estimates if the effects of the minimum legal drinking age on an 18 or 19 year-old are substantially different than the effects on a 21 year-old.

It is not possible to assess the effect of each of the threats to the internal and external validity on our estimates. However, we have some evidence that despite these concerns the estimates still may be of substantial use for predicting the likely effect of a policy change. A comparison of Tables 2 and 3 reveal that the two research designs give very similar estimates of the effects of the minimum legal drinking age on all-cause and cause-specific mortality.[9] An examination of Table 4 reveals that the two designs generate fairly similar estimates of the impact of the minimum legal drinking age on alcohol consumption. Most of the sources of bias described above affect the two research designs to different degrees so they should be moving the estimates from the two designs away from each other. We interpret the similarity in the estimated effects as suggesting that the various biases are either not very large or that they are at least partially canceling out.

Discussion

When considering whether it makes sense to lower the drinking age from 21 to 18 the critical issue is determining whether the increase in consumer surplus that results from allowing 18–20 year-olds to drink is large enough to justify the increase in alcohol-related harms. The most direct way to make this comparison is to estimate the change in consumer surplus and compare it to the increase in harms as measured in dollars. However, it is very challenging to credibly estimate the consumer surplus associated with the additional drinks that 18–20 year-olds would consume if the drinking age were lowered to 18. For this reason we implement an alternative approach of estimating the harm per drink to the person consuming the drink and the harm per drink imposed on other people.

The greatest immediate cost to the individual of an additional drink is that it increases their risk of dying. The estimates in Table 3 suggest that if the drinking age were lowered to 18, there would be an additional 8 deaths per 100,000 person-years for the 18–20 age group. A common estimate of the value of a statistical life is $8.72 million (Viscusi and Aldi, 2003, converted to 2009 U.S. dollars). This suggests that for every 100,000 young adults allowed to drink legally for a year, the cost in terms of increased mortality is about $70 million (8 × $8.72 million). Given that we estimate an increase of 4.56 million drinks for every 100,000 person-years, this suggests that the hidden cost of each drink due to the increased mortality risk is over $15 (70/4.56).[10] Given that each drink potentially has other adverse impacts on the individual, such as injuries, reduced productivity, and reduced health, this estimate is a lower bound.

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[9]The panel analysis finds a very low rate of death due to alcohol overdose and no evidence of an increase; the regression discontinuity design, however, finds a much higher rate of alcohol overdoses and a large increase. Given that the alcohol consumption among 18–20 year-olds has dropped rather than increased in the last 30 years, these difference are probably due to coding changes for International Classification of Diseases and for death certificates, as well as a slight difference in our own coding of the information on death certificates between Tables 2 and 3 (see notes under these tables).

The costs of the reduction in the minimum legal drinking age borne by people other than those consuming the drink come from many sources: we focus on three of the major ones. The first external cost includes the risk that an individual will be killed by a drinker in a motor vehicle accident. Our best estimate is that the typical young adult killed while driving drunk kills another person 21 percent of the time (Carpenter and Dobkin, 2009). This suggests that lowering the drinking age will kill at least an additional 0.77 people (3.65 drivers killed in motor vehicle accidents from Table 3 × 0.21) annually for every 100,000 18–20 year-olds allowed to drink. Using the value of a statistical life from above, this is a cost of $6.7 million (8.72 × 0.77 = 6.7) for every 100,000 people allowed to drink after the drinking age is lowered. This estimate is a lower bound, because it does not include the people killed where the drunk driver survives. The second external cost is due to the increased risk that a drinker will commit robbery or assault. The best available estimate suggests that lowering the drinking age will result in 63 additional arrests for assault and 8 additional arrests for robbery annually for every 100,000 newly legal drinkers (Carpenter and Dobkin, 2010b). Given that not every crime results in an arrest, these two estimates need to be rescaled by the proportion of reported assaults and robberies that are cleared by an arrest, which are 54 and 25 percent, respectively (U.S. Department of Justice, 2007). At an estimated cost of $20,500 per assault and $17,800 per robbery (Miller, Cohen, and Wiersema, 1996, converted to 2009 U.S. dollars), the crime cost imposed on others is $2,400,000 ($20,500 × 63/0.54 ≈ $2,400,000) for assaults and $656,000 ($17,800 × 8/0.25 ≈ $570,000) for robberies. A third external cost is that the drinker will injure themselves and require medical treatment. If the medical care is covered by insurance or if the costs are absorbed by the hospital, these costs are effectively borne by people other than the drinker. The 408 additional emergency department visits and 77 additional hospital stays per 100,000 person-years that would likely occur and 77 additional hospital stays per 100,000 person-years that would likely occur if the drinking age were lowered (estimated in Carpenter and Dobkin 2010a) impose a substantial cost: the average cost of an alcohol-related emergency department visit is $3,387, and the average cost of an alcohol-related inpatient hospital stay is $12,562 for a total cost per 100,000 person-years of $2.35 million [(3,387 × 408) + (12,562 × 77)].[11] Summing these externality costs gives a total cost of about $12.02 million per 100,000 person-years (that is, $6.7 million + $2.4 million + $0.57 million + $2.35 million = $12.02 million). Dividing this estimate by the change in the number of drinks yields an externality cost of $2.63 ($12.02/4.56) per drink. Given that there are numerous alcohol-related harms not included in this calculation, this is a downward-biased estimate of the cost that the drinker imposes on others.

The estimates above suggest that the total cost of a drink to the person drinking it is at least $15 plus what the person paid for the drink. It is unlikely that the average drinker values a drink this highly. This finding suggests that the drinker is not fully aware of the personal costs of their behavior and there is a role for government intervention. Moreover, with each drink there are costs imposed on others of at least $2.63, which again suggests a role for government intervention to deal with this externality. These estimates clearly suggest that

[10]There is, of course, a plausible range of estimates if one were to use different figures for the value of a statistical life, and indeed recent studies have returned lower estimates (see, for example, Ashenfelter and Greenstone, 2004). Viscusi and Aldi's (2003) study reports that most credible studies return estimates for the value of a statistical life of between 3.8 and 9 million in 2000 U.S. dollars (or 4.73 to 11.2 million in 2009 U.S. dollars), and the 8.72 million figure we report above is the median reported across 32 studies. Using 4.73 million as the value of a statistical life, for example, reduces the per-drink estimate to $8.30 ($4.73 million * 8 deaths / 4.56 million drinks). If self-reported alcohol consumption is underreported by 50 percent on average (i.e., within the range as suggested by Rehm, 1998) then we are overestimating the cost per drink by a factor of two (i.e., the correct per-drink estimate is closer to $7.65 (8.72 million * 8 deaths / 9.12 million drinks).

[11]The list charges for a hospital admission by a 21 year-old with a mention of alcohol on the medical record are $33,059, and the list charges for an emergency department visit with a mention of alcohol on the medical record are $8,912 (both measured in 2009 U.S. dollars). Given that hospitals are typically only paid 38 percent of list charges, the costs passed on to consumers are $12,562 and $3,387 for hospital admissions and emergency department visits, respectively (Reinhardt, 2006).

lowering the drinking age will lead to an increase in harms that is very likely larger than the value that people put on the additional drinking.

Our focus here has been on predicting the effects of lowering the minimum drinking age, but of course, a lower drinking age might be combined with other age, but of course, a lower drinking age might be combined with other policies like mandatory alcohol licensing (similar to driver licensing) and relevant, reality-based alcohol education, both of which are advocated by the Choose Responsibility group. Although the research summarized here convinces us that an earlier drinking age alone would increase alcohol-related harms, we do not think there is enough evidence to evaluate the effectiveness of alcohol education and alcohol licensing, either in isolation or in combination with a lower minimum drinking age. While we are certainly not opposed to experimentation with alternative policies for encouraging responsible alcohol consumption, the evidence strongly suggests that setting the minimum legal drinking age at 21 is better from a cost and benefit perspective than setting it at 18 and that any proposal to reduce the drinking age should face a very high burden of proof.

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Figure 1. Deaths due to Motor Vehicle Accidents Recentered around the Time Period in which the Minimum Legal Drinking Age Was Raised back to 21

Notes: This figure is estimated from the 39 states that lowered their drinking age to below 21 at some point in the 1970s or 1980s. A nighttime accident is one occurring between 8:00 p.m. and 5:59 a.m.; 67 percent of these accidents involved alcohol and 26 percent of daytime accidents involved alcohol. The figure is centered on the year a state took its largest step towards raising its drinking age back to 21.

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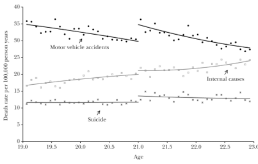

Figure 2. Age Profiles for Death Rates in the United States

Notes: The death rates are estimated by combining the National Vital Statistics records with population estimates from the U.S. Census.

Table 1

Panel Estimates of the Effect of the Minimum Legal Drinking Age on Motor Vehicle Fatalities (deaths per 100,000)

	Age 15–17		**Age 18–20**		**Age 21–24**		**Age 25–29**	
	Evening	**Day**	**Evening**	**Day**	**Evening**	**Day**	**Evening**	**Day**
Effect of proportion of 18–20 year-olds allowed to drink	1.22 [0.77]	1.07 [0.66]	4.74*** [1.33]	0.78 [1.02]	2.61*** [0.98]	0.95 [0.86]	1.51 [0.95]	0.19 [0.55]
Average mortality rate	15.4	12.9	28.1	16.5	23.2	13.8	15.6	10.9

Source: The mortality rates are estimated using data from the Fatal Accident Reporting System 1975–1993.

Notes: For the regression results presented in this table, the top number is the point estimate and its standard error is directly below in brackets. All the regressions include year fixed effects, and state-specific time trends. The regressions are weighted by the age-specific state-year population. The dependent variable in each regression is the motor vehicle fatality rate per 100,000 person years for a particular age group and time of day. A nighttime accident is one occurring between 8:00 p.m. and 5:59 a.m.; 67 percent of these accidents involve alcohol and 26 percent of daytime accidents involve alcohol. The independent variable in each regression is the proportion of 18–20 year-olds who can drink legally. The "Average mortality rate" is that from motor vehicle accidents for each particular age group and time of day.

* represent statistical significance at the 10 percent levels.

** represent statistical significance at the 5 percent levels.

*** represent statistical significance at the 1 percent levels

Table 2

Panel Estimates of the Effect of the Minimum Legal Drinking Age on Mortality Rates (deaths per 100,000)

			Deaths due to external causes				
	Deaths due to all causes	**Internal causes**	**Suicide**	**Motor vehicle accident**	**Homicide**	**Alcohol**	**Other external**
Effect of proportion of 18–20 year-olds legal to drink on mortality rates of 15–17 year-olds	2.33 [1.61]	0.65 [0.56]	0.37 [0.35]	1.35* [0.76]	0.28 [0.62]	−0.03 [0.06]	−0.29 [0.44]
Average mortality rate 15–17 year-olds	42.7	11.0	4.0	16.0	4.4	0.1	7.2
Effect of proportion of 18–20 year-olds legal to drink on mortality rates of 18–20 year-olds	**7.76 [4.92]**	**1.64* [0.97]**	**1.29*** [0.47]**	**4.15** [0.47]**	**−0.75 [2.31]**	**−0.03 [0.07]**	**1.46* [0.83]**
Average mortality rate 18–20 year-olds	**112.6**	**22.5**	**12.8**	**45.5**	**16.3**	**0.3**	**16.2**
Effect of proportion of 18–20 year-olds legal to drink on mortality rates of 21–24 year-olds	4.91 [3.02]	0.78 [1.27]	0.44 [0.55]	3.10*** [1.10]	−0.93 [1.37]	0.01 [0.08]	1.51** [0.68]
Average mortality rate 21–24 year-olds	89.2	20.1	12.0	29.4	14.2	0.4	13.0
Effect of proportion of 18–20 year-olds legal to drink on mortality rates of 25–29 year-olds	−0.85 [2.77]	−2.09 [1.86]	0.00 [0.53]	0.98 [1.04]	−0.27 [1.00]	−0.21 [0.21]	−0.74 [0.48]
Average mortality rate 25–29 year-olds	97.8	32.6	12.8	22.4	14.5	1.2	14.3

Notes: Each of the estimates presented above is from a separate regression, and its standard error is presented directly below it in brackets. The dependent variable in each regression is the mortality rate per 100,000 person years for a particular age group and cause of death. The independent variable of interest is the proportion of 18–20 year-olds that can drink legally. The regressions are weighted by the age-specific state-year population. All regressions have year fixed effects, state fixed effects, and state-specific time trends. The mortality rates are estimated from death certificate records for the 1975–1993 period. Deaths are categorized according to the primary cause of death on the death certificate.

* represent statistical significance at the 10 percent levels

** represent statistical significance at the 5 percent levels

*** represent statistical significance at the 1 percent levels

Table 3

Regression Discontinuity Estimates of the Effect of the Minimum Legal Drinking Age on Mortality Rates (deaths per 100,000)

	Deaths due to all causes	Internal causes	Deaths due to external causes				
			Suicide	Motor vehicle accident	Homicide	Alcohol	Other external
Increase at age 21	8.06*** [2.17]	0.66 [1.01]	2 37*** [0.76]	3.65*** [1.25]	−0.10 [0.58]	0.41* [0.21]	1.37* [0.77]
Mortality rate	93.07	20.07	11.70	29.81	17.60	0.99	13.40

Notes: In the table above, we present estimates of the discrete increase in mortality rates that occurs at age 21 with the associated standard error directly below in brackets. The regression estimates are from a second-order polynomial in age fully interacted with an indicator variable for being over age 21. All models also include an indicator variable for the month the 21st birthday falls in. Since the age variable has been recentered at 21, the estimate of the parameter on the indicator variable for being over 21, which we present in the table, is a measure of the discrete increase in mortality rates that occurs after people turn 21 and can drink legally. The mortality rates are estimated from death certificates and are per 100,000 person-years. The fitted values from this regression are superimposed over the means in Figure 2. The mortality rates presented below the standard errors are the rates for people just under 21. Deaths are catgorized slightly differently than for Table 2. Whereas Table 2 focused on the primary cause of death listed on the death certificate, Table 3 considers all factors mentioned on the death certificate and imposes the following precedence order: homicide, suicide, motor vehicle accident, alcohol, other external, internal.

* represent statistical significance at the 10 percent levels.

** represent statistical significance at the 5 percent levels.

*** represent statistical significance at the 1 percent levels.

Table 4

The Effect of the Minimum Legal Drinking Age on Alcohol Consumption

	Panel estimates			Regression discontinuity estimates		
	% who drank in past 30 days (1)	**% who drank heavily in past two weeks (2)**	**Times drank in past 30 days (3)**	**% with 12 or more drinks in one year (4)**	**% with any heavy drinking in last year (5)**	**Days drank in last 30 days (6)**
Effect of proportion of 18–20 year-olds that can drink legally	6.10*** [1.35]	3.41*** [1.30]	0 94*** [0.27]	6.11** [3.01]	4 92* [2.91]	0.55** [0.28]
Average	64.8	38.4	5.4	58.7	32.9	2.8

Notes: The independent variable of interest for the regression results presented in the first three columns is the proportion of 18–20 year-olds who can drink legally. These regressions are estimated using responses of high school seniors age 18 and older at the time they completed the Monitoring the Future survey. The regressions include state fixed effects, year fixed effects, state-specific time trends, and dummies for male, Hispanic, black, or other race. The regressions are estimated using a sample of 121,279 high school students from 1976–2003. The estimates in the last three columns are regression discontinuity estimates of the discrete increase in each drinking behavior that occurs after people turn 21. These are estimated using responses of 16,107 19–22 year-olds in the 1997–2005 National Health Interview Survey. These regressions include a quadratic polynomial in age interacted with a dummy for being over 21 at the time of the interview and the following covariates: indicator variables for census region, race, gender, health insurance, employment status, 21^{st} birthday, 21^{st} birthday + 1 day, and looking for work. People can report their drinking for the last week, month, or year, and 71 percent reported on their drinking in the past week or month. All the regressions include population weights. Standard errors for the panel fixed-effects analysis are clustered on state and reported in brackets below the point estimates in the first three columns. Robust standard errors for the regression discontinuity analysis are reported in brackets below the point estimates in the last three columns.

* represent statistical significance at the 10 percent levels.

** represent statistical significance at the 5 percent levels.

*** represent statistical significance at the 1 percent levels.