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State panel estimates of the effects of the minimum legal drinking age on alcohol consumption for 1950 to 2002

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Abstract

Objective—Despite strong evidence supporting the effectiveness of the Minimum Legal Drinking Age (MLDA) recent movements have attempted to evoke policy changes that will allow 18-20 year olds to buy and drink alcohol legally. The primary aim of this study was to evaluate the effects of both raising and lowering the minimum legal drinking age on per capita ethanol consumption in longer and more accurate time series panel than any previous study.

Method—Generalized least squares model specifications controlling for income, unemployment rates and population characteristics were implemented using MLDA and aggregate ethanol consumption data from US states from 1950 to 2002.

Results—Results from the full 1950-2002 period, which include both the lowering and raising of the MLDA, show that an increase in the MLDA by 3 years was associated with decreases in per capita total ethanol consumption (1.51% reduction), as well as in beer (2.31% reduction) and spirits consumption (1.86% reduction).

Conclusions—Lowering the MLDA would likely induce increased rates of drinking and subsequent alcohol-related consequences. If increased consumption is of concern, policymakers should resist movements to lower the MLDA.

INTRODUCTION

The minimum legal drinking age (MLDA) is a key policy measure used to minimize alcohol use and its corresponding problems among young people. In the United States after Prohibition ended in 1933, the MLDA corresponded with the age of majority and ranged from 16 (e.g., Ohio) to 21 (e.g., California), with most states adopting the age of 21. During the Vietnam era, many states lowered the MLDA to 18, arguing that if 18-year olds were old enough to fight in the Vietnam War, they should be old enough to legally drink. Later, pressure from the federal government through the Federal Uniform Drinking Age Act (FUDAA) led to a uniform MLDA of 21 by 1988. States would have lost federal highway funding if they did not adopt this policy. These events define a natural experiment where more than 30 states lowered the MLDA to 18 or 19 and then later raised it back to 21 with different timings.

The two most comprehensive reviews of MLDA effects both concluded that the MLDA is inversely related to alcohol consumption and traffic crashes (Carpenter and Dobkin, 2011; Wagenaar and Toomey, 2002). Wagenaar and Toomey (2002) reported that of the more

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methodologically rigorous analyses (i.e., those including a longitudinal design, comparison group(s), and probability sampling or census data) 33% reported a significant inverse relationship between the MLDA and consumption; 58% reported a significant inverse relationship between the MLDA and traffic accidents; and 35% found a significant inverse relationship between the MLDA and other alcohol-related outcomes (e.g., injury, crime). Wagenaar and Toomey identified only one study of high methodologic quality reporting a significant positive relationship between the MLDA and consumption (Hingson et al., 1983) and none reporting significant positive relationship with other outcomes.

A more recent review of the minimum legal drinking age and public health concluded that an MLDA of 21 resulted in less alcohol consumption and related harms compared to lower ages (Carpenter and Dobkin, 2011). For example, from 1975-1993, increasing the MLDA from 18 to 21 appeared to significantly reduce deaths due to nighttime motor vehicle accidents among 18-20 and 25-29 year olds, as well as deaths due to suicides among 18-20 year olds. Furthermore, both alcohol overdose and overall consumption rates appeared to be inversely related to the MLDA.

Others have not found evidence of MLDA effects (Rooney and Schwartz, 1977) or have downplayed the significance of such effects. A recent analysis using 30 years of state-level panel data by Miron and Tetelbaum found that the MLDA's effects on national traffic crashes was mostly due to states that increased their MLDA before the FUDAA was enacted (Miron and Tetelbaum, 2009) and that effects in these "early adopting states" did not persist over time. They argue that this shows that the impact of the MLDA is only minor. A contrasting view of similar results was taken in a study of beer consumption in Michigan. Wagenaar (1982) found a significant increase in draft beer sales, but not total beer consumption, immediately after the MLDA was lowered in 1972. Although this increase decayed rapidly, Wagenaar argued that because alcohol-related public health problems such as traffic injuries remained elevated, the decay is not due to the "novelty" of a lower MLDA wearing off.

Despite these mixed findings, MLDA reviews indicate that the overwhelming majority of evidence points to benefits of increasing the MLDA (Gruenewald, 2011; McCartt et al., 2010; Wagenaar and Toomey, 2002). Panel model estimates on data from the Monitoring the Future Study corroborate this evidence (Dee, 1999; Miron and Tetelbaum, 2009), and show that the prevalence of heavy episodic drinking increased by 3.4 percentage-points when 18-20 years olds were permitted to drink (Carpenter and Dobkin, 2011). Findings from a 2011 review of alcohol availability research support these findings and imply that stricter control over availability through higher minimum legal drinking ages and restricted sales can effectively reduce use and problems (Gruenewald, 2011).

The majority of extant evidence thus suggests that a *higher* MLDA protects against increased consumption among youths and its related harms. However, recent movements, like those at the University of Minnesota (Daily Editorial Board, 2012), are attempting to evoke policy changes that will allow 18-20 year olds to buy and drink alcohol legally highlighting the importance of research into the effects of *lowering* the MLDA. Furthermore, the variation in the MLDA across both time and states has created a natural experiment by which to examine the effects of both raising and lowering the MLDA.

Consequently, our aim is to assess the effects of the MLDA on alcohol consumption exploiting a longer time period, 1950 to 2002, that captures the effects of both lowering and raising the MLDA, and more accurate ethanol consumption data (Kerr et al., 2006a) than any previous study. The consumption data utilize empirically calculated mean percentage ethanol by volume (%ABV) estimates for beer, wine, and spirits sold in each state and year,

yielding more accurate conversions from beverage volume to per capita apparent ethanol consumption. Analyses of this state panel with long time-series allows the use of more conservative analytic methods involving first-differenced data series and examination of lagged relationships and differential relationships by time period. Although policymakers may be more interested in heavy drinking and health and social consequences, it has been shown repeatedly that changes in average drinking levels do affect rates of heavy use and alcohol-related outcomes, including mortality, in the United States and in many other countries (Kerr and Ye, 2011; Ledermann, 1956; Norström and Ramstedt, 2005). Therefore assessing whether the MLDA affects aggregate consumption is a crucial step in understanding MLDA effects on heavy drinking and alcohol-related consequences.

METHODS

Data sources

For the years 1970-2002, MLDA data came from the Prevention Research Center's Statewide Availability Data System (O'Malley and Wagenaar, 1991; Ponicki, 2004). MLDA data for the years 1950-1969 were more difficult to find, which may explain why no other published studies have been able to examine the effects of both the lowering and raising of MLDA over time. The online encyclopedia Wikipedia (www.wikipedia.org) contains a table of state-specific MLDA across historical eras under its "U.S. history of alcohol minimum purchase age by state" entry. Each reference cited was verified. Where the MLDA differed by beverage type or gender in a given state and year the lowest of all drinking ages was used. Beverage type included 3.2% "low-point" beer (equivalent to 4%ABV). The legal drinking age for low-point beer vs. "regular" beer did differ within some states; in these situations, the lowest age was used as the MLDA in analyses. The percentage of the population who were male and aged 15-19 and aged 20-34 were also controlled utilizing data from the US Census Bureau.

Per capita consumption data (in liters of pure ethanol) for beer, wine, and spirits specifically, and for combined total ethanol consumption, were obtained from government and industry beverage-specific sales volume data and use year- and state-specific estimates of mean ethanol content for each beverage type (described in detail in (Kerr et al., 2006b)) to convert beverage volume into ethanol volume. Consumption data for the 1950's through early 1960's are missing for Alaska, Hawaii, Mississippi and Oklahoma due to these states' either not yet being a state or being dry, yielding shorter series for those states. Two state "groups" (NH/MA and DC/MD/VA) were created with population-averaged variables because of significant cross-border alcohol purchases: New Hampshire and Massachusetts (which have had the same MLDA across time) and across the District of Columbia, Maryland and Virginia (at each timepoint, the lowest drinking age of the three was used as the MLDA in analyses for this state-group).

State-specific unemployment rates were obtained from the Bureau of Labor Statistics Current Population Survey for 1976-2002 (U.S. Bureau of the Census, 2004). For the years 1950-1975, yearly national-level unemployment rates (Office of Employment and Unemployment Statistics, 1994) were used as state-level unemployment estimates are not available for these years. Per capita disposable income for each state and year adjusted for inflation to the standard 1980-82 dollars were obtained from the Bureau of Economic Analyses (U.S. Department of Commerce and Bureau of the Census, 1982).

Statistical analyses

First-differenced panel models for 48 states/state groups were estimated using Generalized Least Squares (GLS). GLS allows different specifications of the error structure variance-

covariance matrix, enabling the modeling of differences in variances across panels (i.e., heteroskedasticity) as well as panel-specific first-order autoregressive error terms. Models were fit using STATA version 10 (Stata Corp, 2007). All models were estimated for total ethanol consumption, as well as for beer, wine, and spirits specifically.

The data were transformed by taking first differences in order to achieve stationarity and consistent estimation. We also chose to model the natural logarithm of ethanol consumption, as the transformation yields more stable estimates by reducing skewness and heteroskedasticity. Logarithmic first-differencing eliminates time-invariant effects (e.g., state), but not time-varying effects (e.g., unemployment). The resulting models regress the percent change in per capita ethanol consumption on changes in the MLDA, controlling for the unemployment rate, the log of per capita income and the percentages of the population aged 15-19 and 21-34.

Various lag specifications were examined in order to assess whether MLDA effects accumulate over time. We examined the effects of current and first- and second-year lagged MLDA as well as distributed lag MLDA variables. The choice of lag specification was informed by models which included current MLDA and separate variables for the MLDA for each of the two preceding years. These models showed that both current and preceding year MLDA predict consumption while two years' lagged MLDA does not. Furthermore, the effects of current MLDA appeared stronger than those from the past year. In presented models a declining distributed lag specification was used in which current MLDA was weighted as 2/3 and the immediately preceding year's MLDA was weighted as 1/3.

Data were analyzed across the full 1950-2002 time period as well as for 1950-1975 and 1976-2002 separately for two primary reasons. First, while national unemployment data were available for all states and years, state-level unemployment data were available only for the later half of the series. Sensitivity analyses (not shown) illustrate that controlling for national unemployment rates instead of state-level rates does not change the pattern or magnitude of MLDA effects for the later time period. Hence, state-level rates are used for all analyses that include the later period, as state-level rates are both more accurate and more representative of potential regional predictors of consumption. Second, the MLDA was lowered in many states during the early period, but raised in virtually all states during the later period so that assessing MLDA in each period separately could help to distinguish the effects of lowering the drinking age from those of raising it.

RESULTS

Table 1 displays effect estimates for the entire 1950-2002 time period and shows that increasing the MLDA by one year lowers the amount of total ethanol consumed by 0.54%. Similarly, beer and spirits consumption decreased by 0.77% and 0.62%, respectively, while wine consumption was not affected. All control variables appear to significantly affect consumption rates. A one percentage-point increase in unemployment corresponds to a 0.19% decrease in total consumption, with similar effects on beer and spirits. However, wine consumption appears to increase with unemployment rates. Consumption is also positively related to income with an elasticity of 0.091. Finally, for every one percentage-point increase in the population of males age 15-19, total consumption increases by 4.2%, and for every one percentage-point increase in the population of males age 20-34, total consumption increases by 2.2%.

Identical models were then implemented for the separate 1950-1975 and 1976-2002 time periods. Table 2 presents results for the earlier time period. Here the magnitude of the MLDA effect is noticeably lower than that for the entire period, and insignificant for total

ethanol consumption. However, increasing the MLDA by one year still appears to significantly affect beer- and wine-specific estimates, with a 0.92% decrease in beer consumption and 2.6% increase in wine consumption for every one-year increase in the MLDA. The contrasting directions of the MLDA effect on beer and wine presumably explain the lack of effect on total consumption. Control variables retain generally similar relationships to consumption for the 1950-1975 period compared to the entire 1950-2002 period. A one percentage-point increase in the national unemployment rate is related to a 0.43% decrease in total consumption, with similar effects on beer- and spirits-specific consumption. Again, wine consumption is positively related to national unemployment. Increases in income are positively related to all beverage-specific rates, with a 1% increase in income predicting increases in consumption of 0.09% (beer) to 0.23% (spirits).

Table 3 displays results for the 1976-2002 time period where effect magnitudes and directions are larger those for the entire period. Raising the MLDA by one year was found to decrease total consumption by 0.75%, beer consumption by 0.60% and spirits consumption by 1.1%, while wine is not significantly affected. Unlike the results for entire 1950-2002 and early 1950-1976 periods, increases in state-level unemployment were not found to affect total consumption. However, a one percentage-point increase in state unemployment rates does correspond to 0.18% and 0.33% decreases in beer and spirits consumption, respectively, but a 0.51% increase in wine consumption, indicating cross-beverage substitution. Income effects are also distinct for this period. Although wine and spirits consumption rates are positively related to income, beer consumption is inversely related to income during this period, such that a 1% increase in per capita income reduces beer consumption by 0.07%. Total consumption does not appear to be affected by income, again indicating that income changes result only in beverage substitution.

DISCUSSION

Our results show that increases in the minimum legal drinking age are associated with decreases in *per capita total* ethanol consumption and in beer and spirits consumption. Estimates from the full 1950-2002 period, which include both the lowering and raising of the MLDA, indicate that raising the MLDA from 18 to 21 decreased total consumption by 1.51%, beer consumption by 2.31% and spirits consumption by 1.86% across drinkers of all ages, implying substantial changes among underage drinkers. However, time-period specific results indicate that the MLDA effect observed for 1950-2002 is most likely driven by relationships during the latter half, 1976-2002, as MLDA effect estimates on total ethanol consumption were not significant during the earlier 1950-1975 period.

During the late 60's and early 70's, *per capita* consumption was rising steeply in the population in general: the large baby boom cohort was beginning to drink more heavily and at younger ages, and societal attitudes were shifting toward gender equality, subsequently increasing drinking among women. Results indicate that beer, the preferred beverage of the baby boom cohorts (Kerr, 2004), did increase in response to the MLDA reductions. This was countered by an effect in the opposite direction on wine, which is less likely to be related to youth drinking. The wine category was largely fortified wine in the early 1960's and underwent a dramatic shift with steeply declining fortified wine and rising table wine consumption during the period of MLDA reductions (Kerr, 2006b). It is possible that our results for wine during this period were spurious as they were in theoretically in the wrong direction, would not be expected to be strongly tied to youth drinking and were not replicated in the later period.

Results for the later 1976-2002 period do corroborate that the MLDA effects observed for the entire 1950-2002 period may be largely attributed to raising the MLDA. Increasing the

MLDA by three years (i.e., from 18 to 21, as was generally done) during this period significantly predicted a 2.25% decrease in per capita total consumption, a 1.8% decrease in beer consumption and a 3.36% decrease in spirits consumption. These estimates are quite substantial considering that only those under the age of 21 were impacted by the law.

These results add to the mounting evidence that increasing the MLDA decreases total ethanol consumption as well as alcohol-related harms. Although Carpenter & Dobkin (Carpenter and Dobkin, 2011) utilized individual-level data, effect estimates from both the current aggregate-level analyses and the individual-level analyses imply that the MLDA and consumption rates are inversely related. Furthermore, the current results come from what would be considered a "methodologically rigorous" study according to Waagenar and Toomey (Wagenaar and Toomey, 2002), and support their conclusion that increasing the MLDA would confer population-level benefits.

Others have proposed that alcohol policies may interact advantageously. Ponicki and colleagues (Ponicki et al., 2007) reported that raising the MLDA and raising beer taxes independently appeared to reduce fatal motor vehicle accidents in 48 US states from 1975-2001, and that increasing the MLDA appeared to reduce proportionately more accidents when taxes were high compared to when taxes are low, suggesting that alcohol policies may work synergistically. Future research may involve assessing MLDA effects combined with other policies, such as restricted alcohol outlet sales hours. Gruenewald (Gruenewald, 2011) has similarly suggested a need for quantitative theoretical models that can estimate the effects of regulatory controls across various environmental contexts.

Covariate effects: unemployment and income

Although included as covariates, results for unemployment and income effects deserve some note. Increases in the unemployment rate predicted decreased total alcohol, beer, and spirits consumption rates, but increased wine consumption rates. The significant negative relationship between unemployment and consumption persisted when including per capita income in the models, implying that reduced income does not explain the negative relationship between unemployment and total consumption. However, as Ruhm and Black (Ruhm and Black, 2002) note, income cannot capture changes in relative price or income distribution, highlighting the unemployment variable's ability to reflect other micro-level factors contributing to consumption, such as psychological influences. The association between unemployment and consumption may suggest the need for increased efforts to curb excessive drinking during times of economic prosperity (i.e., times of low unemployment).

Limitations

The inability to examine micro-level distributions in drinking patterns is one limitation of utilizing aggregate data. The effects observed here relate the MLDA to *total* alcohol sales across drinkers of *all* ages, not just among 18-20 year-olds affected by the legal changes. We have neither age-specific alcohol sales' estimates nor reliable estimates of state-specific proportions of underage drinking for 1950-2002, and therefore cannot estimate how consumption would change within the 18-20 year-old population. Furthermore, omitted variables can bias results, as changes in the drinking age may be spuriously correlated with unobserved variables. However, first-differencing and control for covariates is an attempt to preclude this issue. Finally, studies utilizing aggregate data, like the current study, are often criticized because they risk the "ecological fallacy" of assuming that those who are affected by the MLDA (i.e., 18-20 year olds) are those who curb drinking when the MLDA is 21. However, the ecological fallacy is less a threat when the association observed in aggregate data has been observed in individuals, as is the case here.

Conclusion

Our findings indicate that lowering the MLDA would likely induce increased rates of drinking and alcohol consumption among younger drinkers. Some differences in effects were noted between the 1950-75 period, during which the MLDAs were lowered, and the 1976-2002 period, during which MLDAs were raised. Other factors, such as changes in unemployment and income, were also operating on consumption rates, and were found to have differential effects during these two periods. Through increased consumption, lowering the MLDA would likely increase alcohol-related consequences among young people. Policymakers should resist movements to lower the MLDA; any speculations that legal drinking among 18-20 year olds would not increase greatly and would somehow be safer than the current situation contrast the clear evidence from this and previous studies linking lower MLDA's to increased consumption and harms.

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Table 1

Semi-logged differenced panel model estimates[a] of MLDA effects on per capita apparent consumption for alcohol, 1950-2002

Regressor	*Total Alcohol*	*Beer*	*Wine*	*Spirits*
Minimum Legal Drinking Age	−.0054 (−.0091, −.0016) **	−.0077 (−.0119, −.0034) **	.0049 (−.0039, .0137)	−.0062 (−.0121, −.0004) *
Unemployment[b]	−.0019 (−.0030, −.0009) **	−.0021 (−.0033, −.0009) **	.0053 (.0028, .0078) **	−.0033 (−.0049, −.0017) **
Income	.0914 (.0532, .1297) **	.0282 (−.0135, .0699)	.1783 (.0882, .2685) **	.2054 (.1427, .2681) **
% Population males age 15-19	4.231 (3.800, 4.666) **	2.704 (2.207, 3.202) **	4.768 (3.713, 5.823) **	6.331 (5.665, 6.998) **
% Population males age 20-34	2.229 (2.011, 2.447) **	1.997 (1.748, 2.246) **	3.326 (2.799, 3.853) **	2.485 (2.153, 2.817) **

[a] Models regress percent change in per capita consumption on changes in the MLDA, controlling for the unemployment rate, the log ofper capita income and the percentages of the population aged 15-19 and 21-34. A declining distributed lag specification was used in which current MLDA was weighted as 2/3 and the immediately preceding year's MLDA was weighted as 1/3.

[b] National-level rates used for 1950-1975, state-level rates used for 1976-2002

* $p<0.05$

** $p<0.01$

Table 2

Semi-logged differenced panel model estimates[a] of MLDA effects on per capita apparent consumption for alcohol, 1950-1975

Regressor	*Total Alcohol*	*Beer*	*Wine*	*Spirits*
Minimum Legal Drinking Age	−.0011 (−.0062, .0041)	−.0092 (−.0153, −.0030) **	.0259 (.0133, .0384) **	.0019 (−.0062, .0101)
Unemployment[b]	−.0043 (−.0057, −.0029) **	−.0051 (−.0067, −.0035) **	.0062 (.0030, .0093) **	−.0064 (−.0084, −.0044) **
Income	.1522 (.1022, .2022) **	.0877 (.0318, .1435) **	.2283 (.1251, .3315) **	.2225 (.1547, .2903) **
% Population males age 15-19	.6951 (−.4042, 1.794)	−.2771 (−1.623, 1.069)	−.0794 (−2.716, 2.557)	2.213 (.6185, 3.808) **
% Population males age 20-34	1.733 (1.413, 2.054) **	1.879 (1.478, 2.280) **	2.911 (2.159, 3.663) **	.9658 (.5055, 1.426) **

[a] Models regress percent change in per capita consumption on changes in the MLDA, controlling for the unemployment rate, the log ofper capita income and the percentages of the population aged 15-19 and 21-34. A declining distributed lag specification was used in which current MLDA was weighted as 2/3 and the immediately preceding year's MLDA was weighted as 1/3.

[b] National-level rates used for 1950-1975

* p<0.05

** p<0.01

Table 3

Semi-logged differenced panel model estimates[a] of MLDA effects on per capita apparent consumption for alcohol, 1976-2002

Regressor	*Total Alcohol*	*Beer*	*Wine*	*Spirits*
Minimum Legal Drinking Age	−.0075 (−.0120, −.0031) **	−.0060 (−.0111, −.0010) *	−.0080 (−.0182, .0021)	−.0112 (−.0183, −.0041) **
Unemployment[b]	−.0008 (−.0024, .0007)	−.0018 (−.0036, −.00004) *	.0051 (.0017, .0086) **	−.0033 (−.0057, −.0009) **
Income	.0197 (−.0380, .0774)	−.0702 (−.1359, −.0045) *	.2124 (.0763, .3484) **	.0990 (.0064, .1916) *
% Population males age 15-19	6.248 (5.534, 6.962) **	4.612 (3.827, 5.397) **	11.96 (10.29, 13.63) **	6.889 (5.723, 8.056) **
% Population males age 20-34	3.444 (3.066, 3.822) **	2.908 (2.501. 3.315) **	6.565 (5.673, 7.457) **	4.007 (3.388, 4.625) **

[a] Models regress percent change in per capita consumption on changes in the MLDA, controlling for the unemployment rate, the log of per capita income and the percentages of the population aged 15-19 and 21-34. A declining distributed lag specification was used in which current MLDA was weighted as 2/3 and the immediately preceding year's MLDA was weighted as 1/3.

[b] State-level rates used for 1976-2002

* p<0.05

** p<0.01