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Geographic variability in alcohol-related crashes in response to legalized Sunday packaged alcohol sales in New Mexico

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Abstract

On July 1, 1995 the state of New Mexico lifted its ban on Sunday packaged alcohol sales. Legislation lifting the ban included a local option allowing individual communities within the state to hold an election to reinstitute the ban on Sunday packaged alcohol sales. Previous research has shown a clear statewide increase in alcohol-related crash and crash fatality rates after the ban was lifted. The goal of this study is to measure county-level variability in changes in alcohol-related crash rates while adjusting for county socio-demographic characteristics, spatial patterns in crash rates and temporal trends in alcohol-related crash rates. Bayesian hierarchical binomial regression models were fit to the observed quarterly crash counts for all counties between July 1, 1990 and June 30, 2000. Results show marked variability in the impact of legalized Sunday packaged alcohol sales on alcohol-related crash rates. Relative risks of an alcohol-related crash for the post-repeal versus pre-repeal period vary across counties from 1.04 to 1.90. Counties with older population suffered a greater negative impact of legalized Sunday packaged alcohol sales. Counties with communities that quickly passed the local option to re-ban packaged sales on Sundays were able to mitigate most of the deleterious impact of increased alcohol availability that was observed across the state.

Keywords: Alcohol availability policy; Alcohol-related motor vehicle accidents; Geostatistical analysis

1. Introduction

On July 1, 1995, the state of New Mexico lifted its ban on Sunday packaged alcohol sales, allowing licensed outlets to sell packaged alcohol between noon and midnight on Sundays. In a previous study (McMillan and Lapham, 2006), we examined the statewide impact of lifting the Sunday packaged alcohol sales ban in New Mexico. We showed that, after adjusting for temporal and seasonal trends and holiday effects, there was a 29% statewide increase in the daily rate of alcohol-related crashes (ARC) and a 42% increase in alcohol-related crash fatalities (ARCF) on Sundays after the ban on Sunday packaged alcohol sales was lifted. These resulted in an estimated excess of 543.1 crashes and 41.6 fatalities between July 1, 1995 and June 30, 2000 over what would have been observed had the ban remained in place. These results were highly statistically significant while no other day of the week showed any significant change in alcohol-related crash or crash fatality rates.

Our analyses clearly showed a statewide, detrimental impact of legalizing Sunday packaged alcohol sales. These results, however, are largely determined by the ARC experience in population centers, such as Albuquerque, Santa Fe and Las Cruces that have the highest traffic volume. Other communities may deviate from the statewide average in their experience with legalized Sunday packaged alcohol sales. Thus, a thorough understanding of local variability in the effects of legal Sunday packaged alcohol sales is critical for two reasons. First, the Sunday Sales legislation includes a local option permitting communities to hold an election to disallow packaged alcohol sales on Sundays within their local jurisdictions. Each community is required to spend internal funds to exercise the local option and, in a relatively poor state such as New Mexico, this can be a substantial cost to the community that must be weighed against benefits from other allocations. The actual impact of lifting the Sunday sales ban in different areas of the state must be described to inform local decision-making regarding the local option.

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Second, state representatives and senators require detailed analysis of the ARC experience of their constituent communities so that legislation in the people's best interest is promoted in the state house and senate. For these reasons it is critical that the impact of legalized Sunday packaged alcohol sales is monitored at the local level.

Local variation in responses to legal Sunday packaged alcohol sales may be caused by multiple factors pertaining to the drinking and driving habits of the population, as well as the driving environment with which the drinking driver must interact. To address these issues Gruenewald et al. (1996a, 1999, 2000) and Gruenewald (1998) have advocated an ecological modeling approach to elucidating the relationship between alcohol availability and alcohol-related damage, such as driving while impaired (DWI), ARC, drunk driving fatalities and drinking related violence. Factors that interact and influence overall trends in motor vehicle crashes include the drinking patterns of the population, driving behavior of the community and geographic characteristics (e.g., urban driving environments or population density). The ecological modeling framework of Gruenwald and others thus incorporates socio-demographic features of the geographic entities under consideration (e.g., counties) into analyses linking alcohol availability and ARC rates.

In this paper, we present results of a geostatistical analysis of alcohol-related crashes occurring between July 1, 1990 and June 30, 2000 in New Mexico. Our objective is to uncover county-level variability in the impact that repealing the ban on Sunday packaged alcohol sales had on ARC rates. We also incorporate demographic and economic information from the 1990 and 2000 US censuses into the analysis to conduct an ecological analysis of the effect of legalizing Sunday packaged alcohol sales on county-level ARC rates. These results and methods can be used by local governments to decide how serious the impact of legalized Sunday sales was and if the local option to disallow Sunday packaged alcohol sales should be exercised. These results also have national significance as other state legislatures consider extending the hours and days of alcohol sales.

2. Materials and methods

2.1. Study sample

All alcohol-related motor vehicle crashes that occurred in New Mexico between July 1, 1990 and June 30, 2000, equivalent to 3652 days of observation, were included in the analysis. All crash data were extracted from the Accident Level Analysis files maintained by the University Of New Mexico Division Of Government Research. The information found in the Accident Level Analysis file is derived from Uniform Accident Reports, which police officers complete for reported crashes on public roadways that result in death, personal injury, or US$ 500 or more in property damage, according to the investigating officer's judgment. No account is kept of unreported crashes or crashes on private property. The reporting officer notes the estimated time of the crash and the cross-street, address, or mile marker where the incident occurred. Georeference coordinates for each crash are derived from the Geo-Referenced Network Database developed at the University of New Mexico, Division of Government Research. This methodology codes each crash location to universal transverse mercator (UTM) geographic coordinates, which can then be placed into the county where the crash occurred. The reporting officer also records the number of deaths occurring at the scene of the accident. Non-fatal crashes are classified as alcohol-related according to the evaluation of the reporting police officer. Fatal crashes are classified as alcohol-related if the blood alcohol concentration of any involved driver is greater than 0.0%. All information used in this analysis is available as public record. This study design was approved by the Southwestern Institutional Review Board (IRB #00003732).

County level socio-economic data were derived from the US Census Bureau 1990 and 2000 censuses. Values for the socio-economic and demographic covariates that fall on inter-census years were imputed by linear interpolation.

We chose to conduct the geostatistical analysis at the county level, as opposed to using Senate or House district geography, because these district definitions are different and not relevant to one another. Furthermore, we did not conduct city or town level analyses, or census tract analyses, due to the relatively small number of crashes, alcohol-involved or otherwise, in some rural parts of the state. The county level analysis provides the best opportunity to evaluate geographic variation in the Sunday sales effect while retaining reasonable sample sizes.

2.2. Data analysis

We assume a binomial distribution for the quarterly alcohol-related crash frequencies with parameters π_{it} and n_{it}, where π_{it} is the probability of an alcohol-related crash and n_{it} is the sum of alcohol- and non-alcohol-related crashes in the ith county during the tth quarter of observation for 33 New Mexico counties over 40 quarters between July 1, 1990 and June 30, 2000. π_{it} is modeled using logistic regression. This modeling framework is identical to proportional mortality analysis that is commonly used in cancer research (Breslow and Day, 1987) and is ideal for situations where the at-risk population (e.g., the total number of drivers per quarter) is unknown. We take a Bayesian approach to this analysis so that we can easily incorporate random effects, including spatially structured effects, into the model. Diffuse priors for each parameter in the model are used so that the posterior inferences are largely determined by the data.

We adopt a hierarchical logistic regression model of alcohol-related crash probabilities,

$$\mathrm{LOGIT}(\pi_{it}) = \mu + \alpha(\mathrm{QUARTER}_t) + \Phi(\mathrm{YEAR}_t) + \psi_i + \lambda_i + X_{it}^{\mathrm{T}}\beta, \quad (1)$$

where YEAR_t is the year of the tth quarter, $\mathrm{QUARTER}_t$ is the quarter identifier (1–4) and μ is the intercept. The α terms model statewide quarterly variability in ARC rates. The fourth quarter is the baseline and so the $\alpha(4)$ term is set to zero. The Φ terms allow for year-to-year statewide changes in the probability of an alcohol-related crash. $\Phi(1990)$ is the baseline and is set to zero for estimation purposes. Ψ_i are random intercepts that

allow for county-level variability in the ARC rate. The λ_i are random effects describing the county-level variability in the effect of the Sunday sales legislation on ARC rates. The λ_i are set to zero for each observation prior to July 1, 1995 and have mean δ after that date. The δ term is thus the statewide log relative risk of an alcohol-related crash on Sunday after the ban on Sunday packaged alcohol sales was repealed. Models with spatially and temporally correlated random effects were also fit, but were found to have no additional predictive value to the standard random intercepts analysis. Model (1) expresses the county-level (ψ terms) seasonal (α terms) and 10-year trend (Φ terms) in the probabilities of an alcohol-related crash, along with county level "jumps" in the ARC probabilities (λ terms) that occurred once the ban on Sunday packaged alcohol sales was repealed.

The X_{it}^{T} is a vector of county-level census indicators and the β are regression coefficients that expresses changes in the log odds of an alcohol-related crash with changes in county-level socio-demographic characteristics. Census indicators included in the logistic regression model are log median age of the county population, percent of the population with a high school diploma, percent of the population of Hispanic origin, log median income, log percent of the population of Native American origin, log population density, percent of the population unemployed and percent of the population that is separated or divorced. Each indicator was standardized to improve estimation of the regression coefficients. A census indicator by Sunday sales interaction term was also added to the model for each of the census indicators listed. The regression coefficients for the interaction terms measure the increase (or decrease) of the effect of the census indicator on alcohol-related crash risks once packaged alcohol is available on Sundays. We reduced the full model with all census indicators and all indicator by Sunday Sales interaction terms to achieve the best predictive model for the observed data using the method of stochastic search variable selection (SSVS) (Kuo and Mallick, 1998). Further technical details of the analysis are available from the authors on request.

2.3. Computation

Data preparation, mapping and presentation was performed using SAS software, Version 8.2. Statistical analysis was performed using WinBUGS software, Version 1.4.1.

3. Results

Fig. 1 shows the raw proportion of all crashes that involve alcohol for the period of July 1, 1990 to June 30, 2000. This figure clearly shows considerable variability in the ARC rate for New Mexico, ranging from 0.0% in De Baca county in the east-central portion of the state, to 14.2% in Valencia county, located south of Albuquerque. Western counties generally have higher ARC rates than eastern counties and northern counties appear to have somewhat higher ARC rates than the southern counties. Fig. 1 demonstrates the importance of adjusting for county-level variation in ARC rates using the random intercepts model described above.

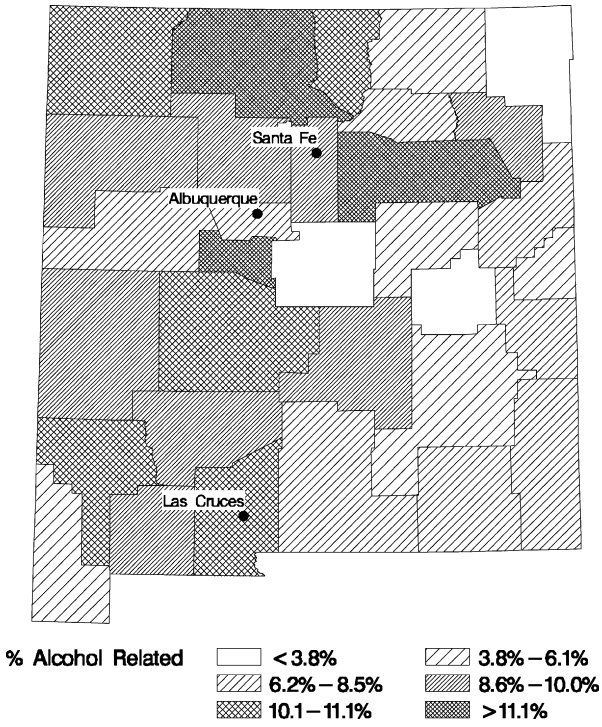

Fig. 1. Raw proportion of motor vehicle crashes involving alcohol.

Table 1 lists regression coefficients for the full model, with all census indicators and the reduced model obtained from the SSVS algorithm. The model that includes age, age by Sunday Sales interaction, separated/divorced rates and unemployment rates was found to be best supported by the data. Pearson's goodness-of-fit statistics computed by county from the best fitting model showed no gross deviations in model fit. One county, Luna county, had a p-value for the goodness-of-fit statistic of 0.02 (Pearson's statistic = 59.5, d.f. = 40), indicating possible lack of fit, although we can expect one or two counties (i.e. 5% of 33 counties) to have large Pearson's statistics just by chance alone. A time series plot of the fitted and observed probabilities showed no systematic patterning in the residuals for this county.

Table 1 shows the posterior analysis for each of the regression coefficients included in the model. The Φ terms show that, beginning in 1993, there was a statewide decrease in alcohol-related crash rates in New Mexico. This was previously observed on all days of the week (McMillan and Lapham, 2006). We suspect that this is due to 1993 legislation that reduced the legal BAC in New Mexico from 0.1 to 0.08. Even so, the δ term, which measures the jump in ARC risks that occurred once the ban on Sunday packaged alcohol sales was lifted, is statistically significant. These results show that, across the state of New Mexico, ARC rates were 1.32 times greater after the ban was lifted compared to before (95% credible interval = 1.07–1.64). The alpha terms show that there is a seasonal pattern of increased ARC rates from winter to fall, with peak ARC rates occurring in the second quarter, from April to June.

Analysis of the census indicators from the reduced model shows that the odds of an ARC increase as the proportion of the population that is unemployed or separated/divorced increases.

Table 1
Posterior analysis of the full and reduced models

	Full model			Reduced model		
	Relative risk	LCL	UCL	Relative risk	LCL	UCL
δ	1.33	1.05	1.70	1.32	1.07	1.64
α(January–March)	1.10	0.99	1.22	1.10	0.99	1.22
α(April–June)	1.27	1.15	1.41	1.27	1.14	1.40
α(July–September)	1.18	1.07	1.29	1.17	1.07	1.29
α(October–December) (baseline)	1	–	–	1	–	–
Φ(1990) (baseline)	1	–	–	1	–	–
Φ(1991)	0.99	0.81	1.20	0.97	0.81	1.17
Φ(1992)	1.00	0.81	1.23	0.98	0.82	1.18
Φ(1993)	1.17	0.92	1.47	1.14	0.94	1.38
Φ(1994)	1.11	0.85	1.45	1.07	0.88	1.30
Φ(1995)	1.01	0.72	1.40	0.97	0.77	1.23
Φ(1996)	0.78	0.52	1.17	0.78	0.58	1.05
Φ(1997)	0.61	0.39	0.95	0.62	0.46	0.85
Φ(1998)	0.61	0.38	0.98	0.64	0.46	0.88
Φ(1999)	0.50	0.30	0.84	0.53	0.38	0.74
Φ(2000)	0.44	0.25	0.79	0.48	0.33	0.71
Census indicators						
Population density	1.04	0.79	1.37	–	–	–
Age	0.92	0.73	1.17	0.88	0.73	1.05
Hispanic (%)	1.15	0.97	1.36	–	–	–
Native American (%)	1.22	1.01	1.48	–	–	–
Education	0.94	0.76	1.16	–	–	–
Income	0.86	0.59	1.27	–	–	–
Unemployed	1.02	0.79	1.32	1.26	1.07	1.48
Separated/divorced (%)	1.11	0.90	1.37	1.20	1.03	1.39
SS × population density	0.98	0.82	1.16	–	–	–
SS × age	1.23	0.97	1.56	1.13	1.01	1.27
SS × Hispanic (%)	0.96	0.85	1.08	–	–	–
SS × Native American (%)	0.97	0.82	1.13	–	–	–
SS × education	1.05	0.87	1.27	–	–	–
SS × income	1.28	0.90	1.83	–	–	–
SS × unemployed	1.32	1.02	1.72	–	–	–
SS × separated/divorced (%)	1.05	0.86	1.28	–	–	–

SS, post-repeal indicator; LCL, lower confidence limit; UCL, upper confidence limit.

The odds of an ARC increase by 26% per standard deviate of the percent population that is unemployed. Similarly, there is a 20% increase in the odds of an ARC per standard deviate in the percent of the population that is separated or divorced. In the pre-repeal period, the odds of an ARC decreased with the log median age of the county (RR = 0.88; 95% CI = 0.73–1.05). The protective effect of population age, however, was cancelled out after the ban on Sunday packaged alcohol sales was lifted, as indicated by the statistically significant age by SS coefficient. The age effect, once the ban was lifted, is equal to $\exp(\log(0.88) + \log(1.13)) = 0.99$, i.e. no effect of age on crash rates after the ban was lifted.

Fig. 2 shows a county-level map of the relative risks of an alcohol-related crash for the post-repeal versus pre-repeal periods. Relative risks were computed as $\exp(\lambda_i + \log(1.13) \times A_i)$, where A_i is the ith county's log median age on the date that Sunday packaged alcohol sales became legal and 1.13 is the posterior mean for the age × SS interaction term (Table 1). Fig. 2 shows considerable variability in the relative risks of an alcohol-related crash across New Mexico, ranging from 1.04 (McKinley county; in the western edge) to 1.90 (Sierra county; in the southwest portion). Also shown in Fig. 2 are communities that have already passed the local option to disallow packaged alcohol sales on Sundays. Three towns, Gallup, Clovis and Portales, indicated by the letter 'A' on the map, voted to disallow Sunday packaged alcohol sales in October, 1996, which was very soon after the statewide ban was lifted. The effect of passing the local option was to give these towns, which are also the largest communities in their respective counties, the lowest relative increase in alcohol-related crashes on Sundays. Other towns that passed the local option, specifically Roswell (marked 'B' in Fig. 2), San Jon (marked 'B' in Fig. 2) and Edgewood (marked 'C' in Fig. 2), did so on a later date, which had less impact on the relative risks of an alcohol-related crash on Sundays.

4. Discussion

Our previous, statewide analysis showed a considerable increase in the rates of alcohol-related crashes once the ban on Sunday packaged alcohol sales was lifted on July 1, 1995. The geostatistical analysis of changes in ARC risks when the

ban on Sunday packaged alcohol sales was repealed shows several important results that refine and expand our previous findings.

First, the overall increase in ARC rates persists when the county-level variability is adjusted for. The estimated relative risk of an alcohol-related crash of 1.32 from this analysis is similar to the estimate of 1.29 from our previous analysis that pools the statewide data. The previous estimate, along with the estimated mean excess number of alcohol-related crashes of 543.1, cannot therefore be solely attributed to the impact of increased alcohol availability on Sundays in the most populous communities of the state.

Second, despite the strong statewide change in ARC risks, considerable county-level variability in the relative risks of an alcohol-related crash is apparent. Some counties, such as Sierra county, experienced an almost two-fold increase in ARC rates, while other counties, such as McKinley, saw little or no change in ARC risks. Several counties apparently were able to offset the increased alcohol-related crash rates when large communities quickly passed the local option to reinstitute the ban on Sunday packaged alcohol sales. The results in Fig. 2 clearly show that passing the local option at the community level can have some effect on reducing the rate of alcohol-related crashes at the county level. Reinstituting the ban on Sunday packaged alcohol sales in other communities (indicated by letters 'B' and 'C' in Fig. 2) may have long term benefits for the respective surrounding counties, but ascertaining a beneficial impact would require crash data accumulated over a longer period of time. Even so, two of the communities, San Jon (Year 2000 census population 360) and Edgewood (Year 2000 census population 1893) are so small that the overall county-level impact may be minimal.

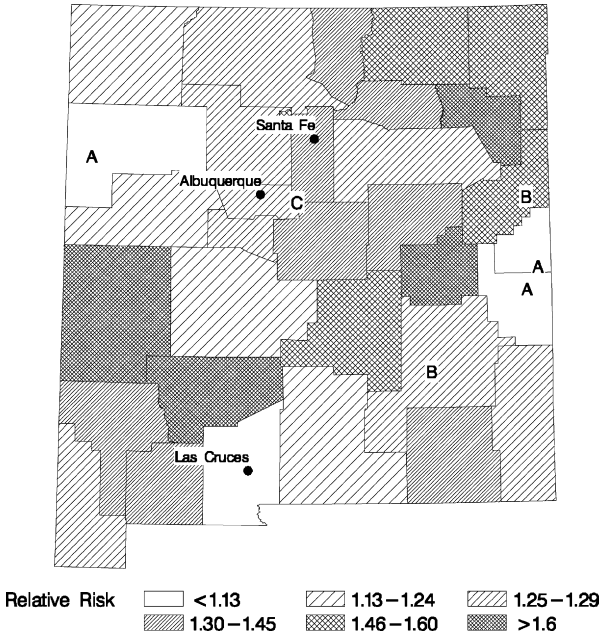

Fig. 2. Relative risk of an alcohol-related crash on Sundays, by county, after the ban on Sunday packaged alcohol sales was lifted. Letters indicate towns that have passed the local option to disallow the sale of packaged alcohol on Sundays. (A) Local option passed October, 1995; (B) local option passed March, 1996; (C) local option passed January, 2000.

Three of the counties shown in Fig. 2 are sparsely inhabited by relatively old populations (more than 25% were over the age of 65 years) and experienced very few crashes during the observation period. Because of the statistically significant age by SS effect and because the model predictions will cause those counties with small amounts of crash data to appear like the statewide average, these counties will appear to have relatively large predicted jumps in ARC rates on Sundays.

The census indicator analysis shows that the odds of an alcohol-related crash increases with unemployment rates and divorced/separated rates in the county population. An analysis of 38 states over a 12-year period, Gruenewald and Ponicki (1995) found that single vehicle nighttime crash rates from 4 a.m. to 8 a.m. increase as the median income increases. However, other indicators of economic performance, including local abundance of retail stores, do not predict single vehicle nighttime crash rates. A city level analysis of Los Angeles County (Scribner et al., 1994) found that local unemployment rates predicted alcohol-related injury crashes as well as alcohol-related property damage crash rates, findings which are consistent with the results of our study (Gruenewald et al., 1996b), however, did not find a statistically significant association between the income levels of the local population and single vehicle nighttime crash rates in four California communities. Likewise, Kelleher et al. (1996) did not find poverty indicators to be important predictors of motor vehicle fatality rates in 77 counties in Arkansas. However, rural living, which is effectively a surrogate for income, was found to be an important predictor in that and other studies (Meliker et al., 2004). To our knowledge, ours is the first study to point to the percent of the local population that is divorced or separated as an important ecological predictor of alcohol-related crash rates. These statistically significant predictors point to socio-economic instability as important predictors of ARC risks in a community. The importance of the county-level random intercepts in the model indicate that some residual variability in alcohol-related crash rates exist beyond that accounted for by the census indicator model.

The analysis also shows that counties with older populations prior to the repeal had lower rates of alcohol-related crashes. A variety of age effects on alcohol-related crash rates have been found in previous ecological studies. Gruenewald et al. (1996b) and Gruenewald and Ponicki (1995) found a quadratic relationship between age and single vehicle nighttime crash rates and Scribner et al. (1994) found that communities with older residents had lower alcohol-related property damage crashes. The average age of a county may be serving as an effective proxy for a variety of demographic influences, such as income and population size, or older populations may be more cautious and more defensive drivers. Ecological analyses such as this and the others cited do not allow one to posit a direct relationship between the alcohol use of older community members and alcohol-related crash rates. Even so, such a direct relationship cannot be discounted.

The protective effect of median age on alcohol-related crash rates, however, disappeared when the ban was lifted. Counties with older populations suffered a greater detrimental impact of the Sunday Sales legislation compared to counties with younger populations. This effect mitigates the lower ARC risks enjoyed by counties with older populations during the pre-repeal period. This "cancelling out" effect may be due to the drinking behavior and drunk-driving habits, of older individuals. Chang et al. (1996) showed that in a sample of first-time DWI offenders in New Mexico, older DWI offenders were more likely to have drunk in bars prior to their DWI arrest. Interestingly, the availability of packaged alcohol on Sundays caused an increase in the age effect on ARC rates across New Mexico, which suggests that older drinkers may have switched to off-premise alcohol consumption once it was available on Sundays. Packaged alcohol, purchased at off-premise sites, is generally cheaper than alcohol purchased by the drink in bars (Gruenewald and Ponicki, 1995). Thus, one might expect that increasing the availability of packaged alcohol on Sundays will result in a greater increase in DWI and thus alcohol-related crashes, in poorer communities where packaged alcohol is more commonly the source of alcohol intoxication. While we did not observe a statistically significant interaction between income and the availability of alcohol on Sundays, the age effect was found to change once packaged alcohol became available on Sundays. Average age of community members may, therefore, act as a proxy for income in New Mexico.

An important limitation of this, as well as any ecological analysis, is that one cannot directly associate the population characteristics of each region with drinking packaged alcohol. For example, based on our results it is not justified to argue that people who are divorced are more likely to drive drunk than married people. The results of the ecological analysis only allow one to state that communities with a larger proportion of divorced or separated residents have higher rates of alcohol-related crashes compared with communities that have relatively few divorced or separated residents. More detailed analyses of individual drinkers and their driving behavior, such as conducted by Chang et al. (1996) could help clarify these issues.

The core finding of this study is that communities passing the local option to re-ban packaged alcohol sales on Sundays experienced a substantial drop in ARC rates on Sundays. While this evidence can be used to promote the local option in other communities, these results are based primarily on 5 years of observation on three communities. A longer period of follow-up observation, particularly in the relatively large community of Roswell, may bolster the argument for passing the local option.

5. Conclusions

Our previous work has shown a significant impact of increased ARC risks when the ban on Sunday packaged alcohol sales is repealed. The current study shows that this impact varies considerably across counties in New Mexico. Furthermore, the negative impact of legalized Sunday packaged alcohol sales appear to have been mitigated in counties with large communities that quickly held an election to reinstitute a ban on Sunday packaged alcohol sales.

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