HHS Public Access

Author manuscript

Accid Anal Prev. Author manuscript; available in PMC 2015 December 31.

Published in final edited form as:

Accid Anal Prev. 2014 September ; 70: 33–39. doi:10.1016/j.aap.2014.02.017.

The Effect of Alcohol and Road Traffic Policies on Crash Rates in Botswana, 2004–2011: A Time-Series Analysis

Miriam Sebego, PhD[a], **Rebecca B. Naumann, MSPH**[b], **Rose A. Rudd, MSPH**[b], **Karen Voetsch, MPH**[c], **Ann M. Dellinger, PhD, MPH**[b], and **Christopher Ndlovu, MPA**[d]

Miriam Sebego: sebegom@mopipi.ub.bw

[a]University of Botswana, School of Nursing, Corner of Notwane and Mobuto Road, Private Bag UB 00712, Gaborone, Botswana; phone: 267-355-2988

[b]National Center for Injury Prevention and Control, Centers for Disease Control and Prevention; 4770 Buford Hwy, NE, MS F-62, Atlanta, Georgia, 30341 USA

[c]National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention; 4770 Buford Hwy, NE, MS K-78, Atlanta, Georgia, 30341 USA

[d]Botswana Police Service, Lekgarapana Road, Private Bag 0012, Gaborone, Botswana

Abstract

In Botswana, increased development and motorization have brought increased road traffic-related death rates. Between 1981 and 2001, the road traffic-related death rate in Botswana more than tripled. The country has taken several steps over the last several years to address the growing burden of road traffic crashes and particularly to address the burden of alcohol-related crashes. This study examines the impact of the implementation of alcohol and road safety-related policies on crash rates, including overall crash rates, fatal crash rates, and single-vehicle nighttime fatal (SVNF) crash rates, in Botswana from 2004 to 2011. The overall crash rate declined significantly in June 2009 and June 2010, such that the overall crash rate from June 2010 to December 2011 was 22% lower than the overall crash rate from January 2004 to May 2009. Additionally, there were significant declines in average fatal crash and SVNF crash rates in early 2010. Botswana's recent crash rate reductions occurred during a time when aggressive policies and other activities (e.g., education, enforcement) were implemented to reduce alcohol consumption and improve road safety. While it is unclear which of the policies or activities contributed to these declines and to what extent, these reductions are likely the result of several, combined efforts.

Keywords

road traffic; injury; alcohol; traffic fines

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

1. Introduction

More than 1.24 million people are killed on the world's roads each year with low and middle-income countries (LMICs) bearing a disproportionate burden (WHO, 2013). While 94% of road traffic-related deaths occur in LMICs, these countries represent 84% of the world's population and have just over half of the world's registered vehicles (WHO, 2013). The disproportionate road traffic injury burden of LMICs is further evident in regional death rates. The average road traffic-related death rate among the World Health Organization's (WHO) African Region is 24.1 deaths per 100,000 population, compared to 10.3 deaths per 100,000 population for countries in the WHO's European Region (WHO, 2013). Increased death rates in LMICs are driven, at least in part, by rapid motorization with a lack of concomitant road safety strategy implementation and safe road infrastructure development (Borowy, 2013; WHO, 2013). In Botswana, the situation is similar.

Botswana is a middle income country with approximately 2 million people (WHO 2013). Between 1981 and 2001, the road traffic-related death rate in Botswana more than tripled from 9.9 to 32.4 deaths per 100,000 population (Botswana Police Service, 2013). The majority of road traffic deaths (55%) are occupants of 4-wheeled cars and light trucks (WHO 2013). Over the last several years, the Government of Botswana has taken several steps to address both the overall growing burden of road traffic crashes and more specifically the problem of alcohol-related crashes, as part of a larger national effort to reduce alcohol use and abuse.

In October 2008, the Levy on Alcohol Beverages Fund Order was passed in Botswana, creating a 30% levy on alcohol products (Pitso & Obot, 2011). The purpose of the levy was to reduce alcohol consumption and related harms, including alcohol-impaired driving. Funds from the levy were designated to support programs targeting alcohol abuse and related harms. Two years later, in November 2010, the alcohol levy was further increased to 40% under the Levy on Alcohol Beverages Fund (Amendment) Order, 2010. The Amendment again called for funds raised by the levy to be used to prevent and reduce alcohol-related harms, including supporting police efforts to curb alcohol-impaired driving.

Legislation specifically aimed at improving overall road safety was also adopted during this time period. In April 2009, the Road Traffic Act of 2008 went into effect, increasing penalties and fines for several road traffic offenses, including driving without a license, speeding, alcohol-impaired driving, and failure to obey traffic signs and signals, among others. Under this new law, fines increased, nearly doubling for some offenses. For example, the fine for alcohol-impaired driving increased from 1,000–3,000 Botswana pula (bwp) (or about $115–$350 USD) or imprisonment of 1.5–2 years to 2,000–5,000 bwp (or about $250–$620 USD) or imprisonment of 2–5 years.

Findings from studies examining the effects of similar alcohol and road traffic policies on road traffic-related injuries and deaths have been mixed. Studies examining the effects of increased alcohol taxes have generally found reductions in fatal and alcohol-impaired road traffic crash rates (Chaloupka et al., 2002; Elder et al., 2010; Wagenaar et al., 2010). However, research on the effects of increased traffic offense penalties and fines has been inconsistent. Some studies indicate that certain penalties and fines may change behavior and reduce crash-related injuries and deaths, while other studies have shown no effect (Bjornskau & Elvik, 1992; Elvik & Christensen, 2007; Novoa et al., 2011; Wagenaar et al., 2007; Zambon et al., 2007). Furthermore, most of the research examining the effects of alcohol and road traffic policy implementation on crashes and injuries comes from high-income nations, and to our knowledge, there is no published research from sub-Saharan Africa on this subject. The purpose of the present study was to examine the impact of the implementation of these policies on road traffic crash rates, including overall crash rates, fatal crash rates, and single-vehicle nighttime fatal (SVNF) crash rates (a commonly used surrogate for alcohol-impaired crash rates), in Botswana from 2004 to 2011.

2. Methods

2.1 Data Sources

Road traffic crash data from January 2004 through December 2011 were obtained from Botswana's Police Service, Traffic Branch Database. The Traffic Branch Database contains data on road traffic crashes that occur on public roadways in Botswana. Crash reports are filed by police in every jurisdiction and centrally compiled at the Police Traffic Branch Headquarters in the capital, Gaborone. A crash is defined as any collision between one or more vehicles (i.e., any structure which is designed to be propelled or drawn on land) and includes single or multiple vehicle collisions of passenger vehicles (e.g., personal car, van, or light truck), motorcycles, or commercial vehicles, as well as crashes between a vehicle and a bicycle or pedestrian.

To observe whether the implementation of alcohol levies and increased traffic offense penalties and fines had an impact on different types and severities of crashes, we conducted an interrupted time series analysis of monthly crash rates for all crashes, fatal crashes, and SVNF crashes. Because it can be difficult to obtain blood alcohol concentration (BAC) readings from drivers involved in crashes in most countries, including Botswana, proxy variables for alcohol-impaired crashes are frequently used (Shults et al., 2001). Commonly used proxy variables include both fatal crashes and SVNF crashes, among others (Shults et al., 2001).

As the number of crashes was expected to increase during this time period, in part because of increased ownership and use of motor vehicles, rates were calculated using a denominator that attempted to capture this increased road use. Rates calculated as crashes per vehicle miles traveled (VMT) are frequently used in traffic safety studies. However, reliable VMT estimates are not currently available for Botswana. As a surrogate for VMT, we used fuel volume sales for the rate denominator, which has been used in numerous other international traffic studies (Novoa et al., 2011; Sukhai et al., 2011; Zambon et al., 2007).

We obtained fuel volume sales data from the Botswana Department of Energy (DoE) and from the Motor Vehicle Accident Fund (MVAF). The DoE and the MVAF data both included tabulations of fuel volume sales but each data source captured sales for different reporting intervals during different time frames. Fuel volume sales data from the DoE were available for the entire time period (i.e., January 2004 through December 2011) but volume was tabulated on an annual basis. Fuel volume sales data from the MVAF were tabulated on a monthly basis but were only available for January 2008 through December 2010. To obtain monthly estimates for the entire time period, monthly fuel volume sales were interpolated from the DoE data using the Expand procedure in SAS (v9.2, SAS Institute Inc., Cary, NC). This procedure fits cubic spline curves to the annual estimates and then generates monthly values from the spline approximations. These monthly estimates were used for the periods of January 2004 through December 2007 and for January 2011 through December 2011. MVAF fuel volume sales data were used for the period of January 2008 through December 2010.

2.2 Statistical analysis

Crash rates were calculated by dividing the number of monthly crashes by the monthly fuel volume sales. Overall crash, fatal crash, and SVNF crash rates were calculated as crashes per 10 million liters (ML) of fuel volume sales.

We used interrupted time series analyses to determine whether and when changes in crash rates occurred. To examine potential changes in crash rates, each of the three time series were first evaluated for autocorrelation using the ARIMA procedure in SAS (v9.2, SAS Institute Inc., Cary, NC). Autocorrelation was present only in the overall crash time series, so we examined this series using Box-Jenkins time series intervention analysis (Bowerman, O’Connell, & Koehler, 2005; Box & Tiao, 1975). For the fatal and SVNF crash time series, Poisson regression was used.

The Box-Jenkins intervention analysis was conducted as part of an exploratory approach to deduce from the data whether and when reductions in overall crash rates occurred (Helfenstein, 1990). A two-stage process was used to conduct the time series intervention analysis. We first determined a Box-Jenkins model describing the monthly crash rates from January 2004 through October 2008 (i.e., the months preceding policy implementation). Using the sample autocorrelation function and the sample partial autocorrelation function, we identified this stationary portion of the time series as a nonseasonal autoregressive model of order 1 (AR(1)). Because of heterogeneity of variance in the series, we modeled the natural log of the rates instead of the rates. A constant term was included in the model since the mean of the series was nonzero. Overall fit of the model and model diagnostics were assessed by examining the model standard error, Ljung-Box statistic, autocorrelation plots of the residuals, and by conducting outlier analysis. Calendar effects (i.e., variation in rates from differing numbers of higher crash days in a month, such as Fridays, Saturday, and holidays) were not included in the model due their limited impact in an irregular series over a long span of time (US Bureau of the Census, 1965).

During the second stage of the process, we identified potential months of marked decreases in the overall crash rates that occurred after October 2008, and performed Box-Jenkins intervention analyses with each potential month of change in successive models. We identified potential months of change by examining plots of the series by month, as well as a plot of the series of monthly differences (Helfenstein, 1990). Each potential month was included as a step function in the model, with a dummy variable coded as 0 for all months preceding the potential rate decrease and coded as 1 for the month of decrease and for all months following the decrease. Decreases in the log-transformed crash rates appeared to occur between April and June 2009, with rates continuing to decrease 12 months later. To model the prolonged decrease in rates, we included two step functions in the model: one indicating an April/May/June 2009 time frame as the initiation of the rate decrease, and another step function indicating a continuing decrease during the April/May/June 2010 time frame (Helfenstein, 1991). The onset of the rate decreases was investigated as either abrupt with a permanent effect or as gradual with a permanent effect. Models of all possible combinations of 2009 and 2010 step functions and onset types were analyzed with the best model identified as that with the smallest residual variance and smallest Akaike information criterion (AIC) (Helfenstein, 1990). We assessed changes in crash rates by examining the coefficients and tests of significance of the step functions from the final model. Model diagnostics were performed, as in the first stage of analysis described above. A two-sided p-value <0.05 was considered statistically significant.

A similar two-stage approach was used for the analysis of the fatal and SVNF crash time series. We developed Poisson regression models characterizing the first 58 months of each series (the months preceding any policy implementation). Variables representing seasonal trend (month of year as a categorical variable, coded as 1 through 12), secular trend (month as a continuous variable, coded 1 through 58), and the number of Fridays and Saturdays in each month were entered into the models and evaluated for inclusion in the final models. Other variables considered but ultimately excluded from the analysis included gross domestic product (GDP) and geographic area of the crash (urban versus rural location). We excluded GDP due to its correlation with fuel sales, while location of the crash was omitted due to large measurement error in the variable. Deviance and Pearson chi-square statistics and residual plots were used to evaluate model goodness of fit. In the second stage of the analysis, we identified potential months of rate reductions by examining plots of monthly series, and for SVNF crashes, plots of rates by quarter. Based on these plots, step function dummy variables were created for each month between November 2009 and May 2010 and were entered into the models one at a time to test for abrupt changes in the average rate of the series. An interaction term of the dummy variable with the secular trend variable was included in the fatal crash model to test for change in the magnitude and direction of the trend of the series. For the SVNF crash model, a quadratic term was entered into the model to better capture the secular trend. Variables were considered significant to the models at $p<0.05$. All analyses were carried out using SAS, version 9.2 (SAS Institute Inc., Cary, NC).

3. Results

Between January 2004 and December 2011, a total of 149,614 crashes occurred on public roads in Botswana (Table 1). The total number of crashes ranged from a high of 20,414 crashes in 2008 to a low of 17,037 in 2006. Annual crash rates were highest in 2004 and 2008 (244 and 243 crashes per 10 ML fuel sales, respectively) and lowest in 2011 (184 crashes per 10ML fuel sales). The number of fatal crashes ranged from a high of 407 in 2004 to a low of 322 in 2006, and fatal crash rates ranged from a high of 5.5 in 2004 to a low of 3.5 in 2010. Similarly, the number of SVNF crashes ranged from a high 150 in 2004 to a low of 115 in 2006 and rates ranged from 2.0 in 2004 to 1.4 in 2010.

Monthly overall crash, fatal crash, and SVNF crash rates showed considerable variation (Figures 1–3). Overall crash rates ranged from a high of 290 crashes per 10ML fuel sales in February 2009 to a low of 158 crashes per 10 ML fuel sales in January 2011 (Figure 1). Fatal crash rates ranged from a high of 6.9 crashes per 10ML fuel sales in March 2008 to a low of 2.1 crashes per 10ML fuel sales in February 2011 (Figure 2), and SVNF crash rates ranged from a high of 3.2 crashes per 10ML fuel sales in May 2004 to a low of 0.6 crashes per 10ML fuel sales in May 2007 (Figure 3).

For overall crash rates, results of the Box-Jenkins intervention analyses indicated two significant abrupt and permanent decreases in the time series, in June 2009 and June 2010 (Table 2; Figure 1). The model estimates indicated that the crash rate from June 2009 to May 2010 was 11.5% lower than the rate from January 2004 to May 2009 ($p<0.001$). Similarly, the rate from June 2010 to December 2011 was 12.0% lower than the rate from June 2009 to May 2010 ($p=0.001$). Cumulatively, the average overall crash rate from June 2010 to December 2011 was 22.1% lower than the average overall rate from January 2004 to May 2009. These declines are reflected in the average monthly overall crash rates of the time intervals: from January 2004 to May 2009, the average monthly overall crash rate was 238.3 crashes per 10ML fuel sales; from June 2009 to May 2010, the average rate was 212.0 crashes per 10ML fuel sales; and from June 2010 to December 2011, the average rate was 186.0 crashes per 10ML fuel sales.

Analysis of fatal crash rates indicated that the trend of the series decreased slightly from January 2004 to January 2010, when a small but abrupt decline in the expected rate of the series was observed. Interpretation of the model estimates indicate that the rate was 18.7% lower than expected at this time ($p=0.019$) (Table 2; Figure 2). However, a positive interaction term of trend with the step function dummy variable was significant in the model, indicating that the abrupt decline decayed quickly, with the trend of the series increasing back to previous rates by January 2011 (monthly percent change=0.9%, $p=.025$). The average fatal crash rate from January 2004 to December 2009 was 4.58 crashes per 10ML fuel sales, while the average rate from January 2010 to December 2011 was 3.61 crashes per 10ML fuel sales. The second lowest rate (2.2 crashes per 10ML fuel sales) of the entire time series was seen in October 2008, the month the first alcohol levy was enacted.

Analysis of SVNF crash rates revealed patterns similar to that of fatal crash rates (Table 2; Figure 3). A quadratic trend term significant in the model indicated that the trend of the series decreased slightly from January 2004 to January 2008, after which time a slight increase in the trend is observed. An abrupt decline in the series was observed in March 2010. Interpretation of model coefficients imply that the rate from March 2010 to December 2011 was 31.1% lower than expected ($p=0.016$). The average SVNF crash rate from January 2004 to February 2010 was 1.65 crashes per 10ML fuel sales, while the average rate from March 2010 to December 2011 was 1.38 crashes per 10ML fuel sales. The increasing trend in the second half of the series indicates a diminishing effect of the decline observed in March 2010.

4. Discussion

The present study examined changes in three types of road traffic crash rates (overall crash rates, fatal crash rates, and SVNF crash rates) during a time period in Botswana in which there were three important alcohol and road safety-related policies implemented. Findings from this study indicate that there were significant declines in the rate of overall crashes in Botswana beginning in 2009 and continuing through 2011, as well as a significant decline in average fatal crash and SVNF crash rates in early 2010. Since research has shown the effects of interventions might not specifically align with the time of intervention implementation (e.g., media and other awareness-raising activities might affect behavior before the intervention is actually introduced), the analysis approach used in this study took into account these possibilities by seeking to identify ‘change points’ and examining these points in relation to intervention implementation (Chang et al., 2004, Helfenstein, 1990; Helfenstein, 1991).

Our results indicate that the average overall crash rate declined by nearly 12% after June 2009. The decline began seven months after the first alcohol levy and two months after the implementation of increased road traffic penalties and fines under the Road Traffic Act. Moreover, the average overall crash rate declined by another 12% after June 2010. This second decline began five months before the implementation of the second alcohol levy increase. It should also be noted that following the implementation of all three policies, overall crash rates were at their lowest levels for the entire time period examined. Additionally, in examining fatal and SVNF crash rates, we found decreases in the average rates in January 2010 and March 2010, respectively, which then gradually attenuated. The fatal crash rate and SVNF crash rate decreases occurred fourteen and sixteen months, respectively, after the implementation of the first alcohol levy; nine and eleven months, respectively, after the traffic offense penalty and fine increases under the Road Traffic Act; and ten and eight months, respectively, before the implementation of the second alcohol levy.

These findings suggest that the policies might have impacted overall crash rates; however, we were unable to determine to what extent each policy might have contributed to the observed decreases. While Chaloupka et al. (1997) found that alcohol price increases can lead to decreases in all crashes, particularly among young drivers, few other studies have examined alcohol price increases or road traffic offense penalty and fine increases on rates of overall crashes. Most studies examine the effects of these policies on crash outcomes that are more likely to have involved alcohol (e.g., fatal crash rates, SVNF crash rates) (Elder et al., 2010; Wagenaar et al., 2010).

Several studies have examined the impact of alcohol and road traffic policies, and particularly alcohol tax policies, on more severe and specific crash outcomes, including fatal crashes and alcohol-impaired crashes (Chaloupka et al., 2002; Elder et al., 2010; Wagenaar et al., 2010; Xu et al, 2011). These studies have consistently documented the inverse relationship between alcohol price increases and crash-related fatalities, including alcohol-related fatalities and single-vehicle nighttime fatalities. Given these findings, it was somewhat unexpected that we did not see fatal and SVNF crash rate reductions more closely associated with the implementation of these policies. While we did observe a particularly low fatal crash rate in October 2008, when the first alcohol levy went into effect, it was not until several months later that significant rate reductions occurred. Additionally, the observed reductions in fatal and SVNF crash rates did not closely coincide with the implementation of the Road Traffic Act penalty and fine increases, as the reductions occurred several months later. Research examining the effectiveness of increasing fines or penalties on crash rates has produced inconsistent results. Some studies suggest that increased penalties for road traffic offenses can lead to increases in certain road user behaviors (e.g., belt use) and reductions in the crash-related injuries and fatalities (Nichols et al., 2010; Novoa et al., 2011; Zambon et al., 2007). However, other studies have found that increased penalties and fines are not necessarily associated with road user behavior changes (e.g., speeding, alcohol-impaired driving) (Bjornskau & Elvik, 1992; Elvik & Christensen, 2007; Lawpoolsri et al., 2007; Wagenaar et al., 2007).

In general, the timing of the decreases and the attenuation of fatal and SVNF crash rate decreases observed in our study in relation to the implementation of the alcohol and road safety policies is difficult to explain. However, one possible explanation is that rate reductions were related to several collective efforts to improve road safety that accumulated during this time period. In addition to the implementation of the three policies described above, several other alcohol and road safety-related efforts were carried out during this time period which were difficult to capture by intensity or by specific time points. For example, funds from the levies were used to conduct community outreach and education on alcohol abuse and alcohol-related harms. Additional resources from a Traffic Fines Fund were used to support enforcement and road safety education programs. The Police Service also received new equipment for use in conducting sobriety checkpoints and saturation patrols and increased enforcement efforts of not only impaired driving but also speeding and non-compliance with road traffic lights and other road traffic regulations. Finally, several controls and changes to the operating hours of bars, nightclubs, liquor outlets, and festivals were implemented during this time period. The attenuation of the fatal and SVNF crash rate decreases might be the result of a later decline in certain road safety-related efforts, or may be from decreased public attention over time. Without sustained efforts, improvements in road safety can lessen (Williams et al., 2004).

This study was subject to at least three limitations. First, the reliability of surrogate measures for alcohol-impaired crashes (e.g., SVNF crashes) in Botswana has not, to our knowledge, been investigated. Second, our ability to analyze changes in crash rates by driver characteristics (e.g., gender, age) was limited due to a lack of information about road use by driver type. The policies we examined might have impacted certain road user groups (e.g., young adult males) more than others. However, without the ability to account for specific groups' changing density on the roads over time, we cannot determine whether changing crash numbers in various demographic groups might be attributed to changing road use or some other factor. Third, the surrogate measure that we used to capture road use (i.e., fuel sales) is only an approximate measure for VMT. Additionally, since monthly fuel sales were interpolated for five years, crash rates may be overestimated or underestimated for some months. To examine the quality of our interpolated data, we compared three years of interpolated fuel sales estimates to the actual monthly fuel sales data and found that a few months (e.g., June, December) frequently had five to ten percent greater monthly fuel sales reported than was predicted, while the month of January often had sales five to ten percent lower than predicted. The December and January sales patterns correspond to payroll cycles in Botswana, when employees are paid earlier in December than is usual, but then have a longer span of time until their next payday in January. It is unclear whether the fuel sales corresponded with increased or decreased driving during these months, or if the driving occurred in a consecutive month. While overestimation or underestimation of rates for certain months would affect the predictive power of the monthly rates, it most likely has little impact on the mean of the series or changes in the mean of the series, as the over- and under-estimates will offset each other.

Over the last several years, a majority of middle-income countries have continued to see increases in road traffic-related death rates (WHO, 2013); however, Botswana has documented impressive reductions. Botswana's recent crash rate reductions have occurred during a time when aggressive policies (i.e., levies, increases in traffic offense penalties and fines) and other activities (e.g., education, enforcement) were implemented to reduce alcohol consumption and improve road safety. While it is unclear which of the policies or activities contributed to these declines and to what extent, these reductions are likely the result of several, combined efforts. Further evaluation of the reach and effects of educational and enforcement activities could provide a better understanding of the contributions of these efforts. As Botswana continues to work toward reducing traffic-related injury and death rates, sustaining a multi-faceted approach to road safety will be needed for continued improvements (Peden et al., 2004).

Acknowledgments

We would like to thank the Botswana Police Service, specifically the Traffic Branch, for their valuable input, guidance, and support; the Motor Vehicle Accident Fund and the Department of Energy for assistance in obtaining national fuel data; Andrew Kestler for his work in establishing the injury-related partnerships and research collaborations that helped make this study possible; and the Road Traffic Safety Reference Group and the University of Botswana's Working Group on Injury and Trauma for their guidance and encouragement.

References

Bjornskau T, Elvik R. Can road traffic law enforcement permanently reduce the number of accidents? Accid Anal Prev. 1992; 24(5):507–520. [PubMed: 1520433]

Borowy I. Road traffic injuries: social change and development. Med Hist. 2013; 57(1):108–138. [PubMed: 23393405]

Botswana Police Service, Traffic Branch. National Traffic Database. Gaborone, Botswana: 2013.

Bowerman, BL.; O'Connell, RT.; Koehler, AB. Forecasting, time series, and regression. 4. Thomson Brooks/Cole; Belmont, California: 2005.

Box GEP, Tiao GC. Intervention analysis with applications to economic and environmental problems. J Am Statist Assoc. 1975; 70:70–79.

Chaloupka FJ, Grossman M, Saffer H. The effects of price on alcohol consumption and alcohol-related problems. Alcohol Res Health. 2002; 26(1):22–34. [PubMed: 12154648]

Chalopuka FJ, Laixuthai A. Do youths substitute alcohol and marijuana? Some econometric evidence. Eastern Economic Journal. 1997; 23:253–276.

Chang HL, Yeh CC. The life cycle of the policy for preventing road accidents: an empirical example of the policy for reducing drunk driving crashes in Taipei. Accid Anal Prev. 2004; 36(5):809–18. [PubMed: 15203358]

Elder RW, Lawrence B, Ferguson A, Naimi TS, Brewer RD, Chattopadhyay SK, Toomey TL, Fielding JE. the Task Force on Community Preventive Services. The effectiveness of tax policy interventions for reducing excessive alcohol consumption and related harms. Am J Prev Med. 2010; 38(2):217–229. [PubMed: 20117579]

Elvik R, Christensen P. The deterrent effect of increasing fixed penalties for traffic offences: the Norwegian experience. J Safe Res. 2007; 38:689–695.

Helfenstein U. When did a reduced speed limit show an effect? Exploratory identification of an intervention time. Accid Anal Prev. 1990; 22(2):79–87. [PubMed: 2322372]

Helfenstein U. The use of transfer function models, intervention analysis and related time series methods in epidemiology. Int J Epidemiol. 1991; 20(3):808–815. [PubMed: 1955267]

Lawpoolsri S, Li J, Braver ER. Do speeding tickets reduce the likelihood of receiving subsequent speeding tickets? A longitudinal study of speeding violators in Maryland. Traffic Inj Prev. 2007; 8:26–34. [PubMed: 17366333]

Nichols, JL.; Tippetts, AS.; Fell, JC.; Auld-Owend, A.; Wiliszowski, CH.; Haseltine, PW.; Eichelberger, A. Strategies to increase seat belt use: an analysis of levels of fines and the type of law. National Highway Traffic Safety Administration; Washington, DC: 2010.

Novoa AM, Perez K, Santamarina-Rubio E, Borrell C. Effect on road traffic injuries of criminalizing road traffic offences: a time series study. Bull World Health Organ. 2011; 89:422–431. [PubMed: 21673858]

Peden, M.; Scurfield, R.; Sleet, D.; Mohan, D.; Hyder, AA.; Jarawan, E.; Mathers, C. World report on road traffic injury prevention. World Health Organization; Geneva, Switzerland: 2004.

Pitso JM, Obot IS. Botswana alcohol policy and the presidential levy controversy. Addiction. 2011; 106:898–905. [PubMed: 21477246]

Shults RA, Elder RW, Sleet DA, Nichols JL, Alao MO, Carande-Kulis VG, Zaza S, Sosin DM, Thompson RS. the Task Force on Community Preventive Services. Reviews of evidence regarding interventions to reduce alcohol-impaired driving. Am J Prev Med. 2001; 21(4S):66–88. [PubMed: 11691562]

Sukhai A, Jones AP, Love BS, Haynes R. Temporal variations in road traffic fatalities in South Africa. Accid Anal Prev. 2011; 43:421–428. [PubMed: 21094340]

U.S. Bureau of the Census. Estimating trading-day variation in monthly economic time series. Technical paper No. 12. U.S. Government Printing Office; Washington, DC: 1965.

Wagenaar AC, Maldonado-Molina MM, Erickson DJ, Ma L, Tobler AL, Komro KA. General deterrence effects of U.S. statutory DUI fine and jail penalties: long-term follow-up in 32 states. Accid Anal Prev. 2007; 39(5):982–994. [PubMed: 17854574]

Wagenaar AC, Tobler AL, Komro KA. Effects of alcohol tax and price policies on morbidity and mortality: a systematic review. Am J Public Health. 2010; 100(11):2270–2278. [PubMed: 20864710]

Williams AF, Wells JK. The role of enforcement programs in increasing seat belt use. J Safe Res. 2004; 35(2):175–180.

World Health Organization. Global status report on road safety 2013: supporting a decade of action. World Health Organization; Geneva, Switzerland: 2013.

Xu X, Chaloupka FJ. The effects of prices on alcohol use and its consequences. Alcohol Res Health. 2011; 34(2):236–245. [PubMed: 22330223]

Zambon F, Fedeli U, Visentin C, Marchesan M, Avossa F, Brocco S, Spolaore P. Evidence-based policy on road safety: the effect of the demerit points system on seat belt use and health outcomes. J Epidemiol Comm H. 2007; 61:877–881.

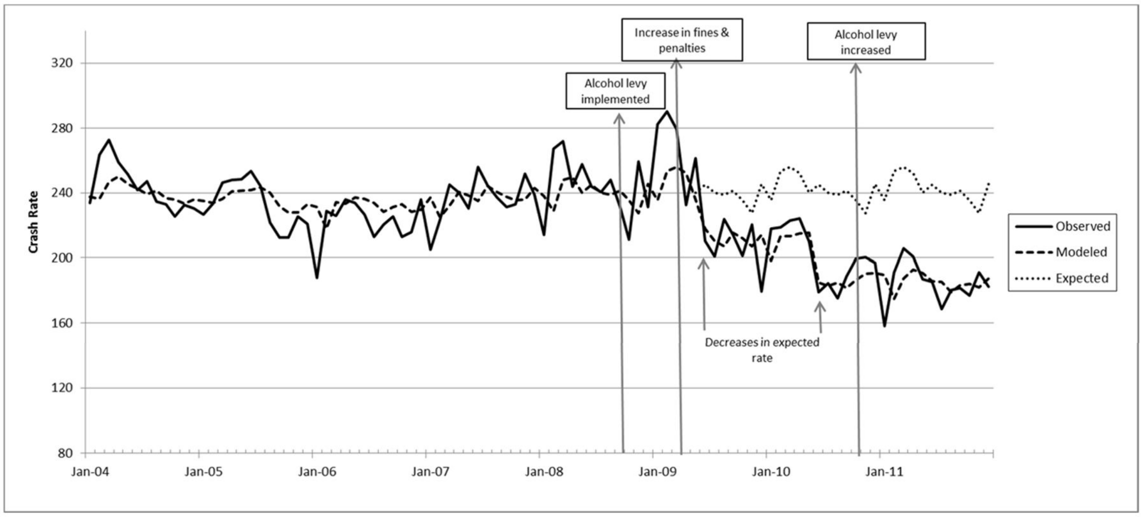

Figure 1.
Crash rates per 10 million liters of fuel sales by month, Botswana, 2004–2011

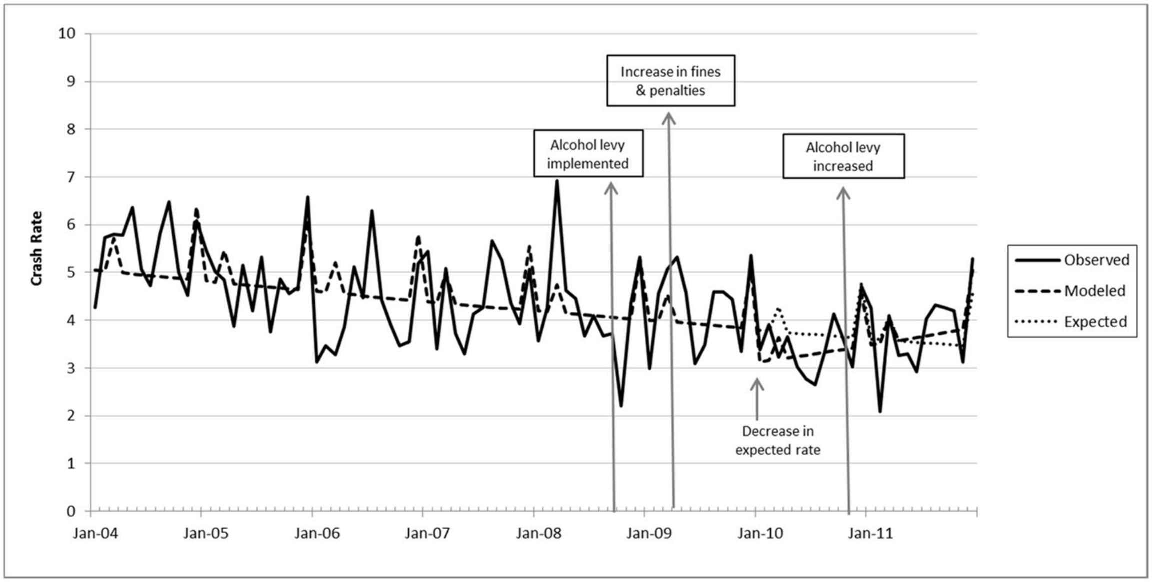

Figure 2.

Fatal crash rates per 10 million liters of fuel sales by month, Botswana, 2004–2011

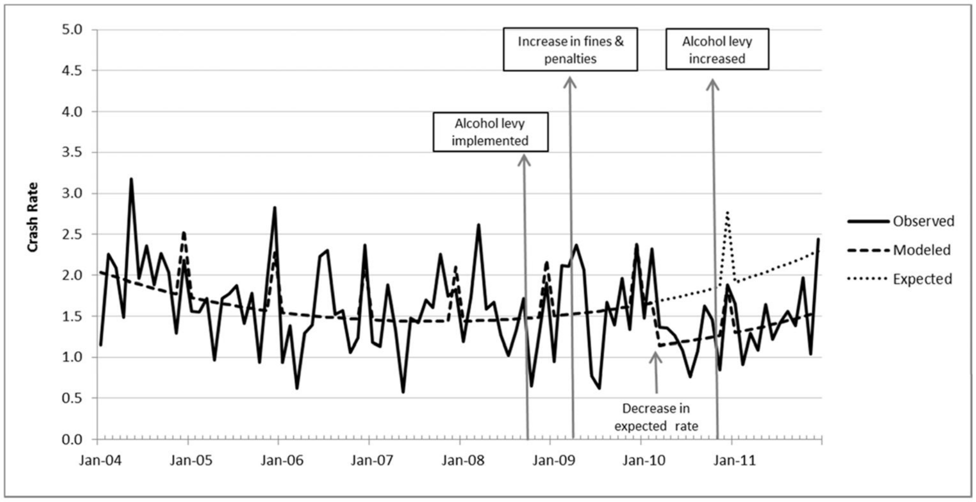

Figure 3.

Single-vehicle nighttime fatal crash rates per 10 million liters of fuel sales by month, Botswana, 2004–2011

Table 1

Annual counts and rates of all crashes, fatal crashes, and single-vehicle nighttime fatal crashes, Botswana, 2004–2011

	All crashes		Fatal crashes		Single-vehicle nighttime fatal crashes	
Year	Count	Rate [a]	Count	Rate [a]	Count	Rate [a]
2004	18,132	244	407	5.5	150	2.0
2005	17,522	233	366	4.9	126	1.7
2006	17,037	222	322	4.2	115	1.5
2007	19,485	237	369	4.5	125	1.5
2008	20,414	243	355	4.3	125	1.5
2009	20,000	230	372	4.5	142	1.7
2010	18,995	201	327	3.5	129	1.4
2011	18,029	184	369	3.8	144	1.5

[a]Number of crashes per 10 million liters (ML) of fuel sales

Table 2

Results of Box-Jenkins interrupted time series analysis and Poisson regression analyses examining overall crash, fatal crash, and single vehicle nighttime fatal (SVNF) crash rates, Botswana, 2004–2011

	Rate ratio	(RR CI)	Monthly median rate (IQR), before step function/ dummy variable	Monthly median rate (IQR), after step function/dummy variable
Overall crash rate, AR(1) [a]			238.3 (22.1)	216.2 [b] (16.1), 185.2 [c] (18.2)
Step function, June 2009	0.89	(0.83, 0.95)		
Step function, June 2010	0.88	(0.82, 0.95)		
Fatal crash rate, Poisson regression [d]			4.55 (1.41)	3.52 (1.09)
Dummy variable, January 2010	0.81	(0.68, 0.97)		
SVNF crash rate, Poisson regression [e]			1.64 (0.75)	1.36 (0.54)
Dummy variable, March 2010	0.69	(0.51, 0.93)		

RR= rate ratio; CI=confidence interval; IQR = interquartile range; AR(1) = first order autoregressive model; SVNF = single-vehicle nighttime fatal

[a] Mean of model (natural log scale) = 5.47 ($p<0.001$), AR(1) parameter = 0.37 ($p<0.001$)

[b] Median rate after first step function (June 2009)

[c] Median rate after second step function (June 2010)

[d] Model includes predictors for the months of March and December, secular trend and interaction term of secular trend with intervention dummy variable. Calculation of rate ratio for dummy variable adjusts for predictors.

[e] Model includes predictors for the month of December as well as a linear and quadratic term for secular trend. Calculation of rate ratio for dummy variable adjusts for predictors.