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Determinants of road traffic safety: New evidence from Australia using state-space analysis☆

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ABSTRACT

This paper examines the determinants of road traffic crash fatalities in Queensland for the period 1958–2007 using a state-space time-series model. In particular, we investigate the effects of policies that aimed to reduce drink-driving on traffic fatalities, as well as indicators of the economic environment that may affect exposure to traffic, and hence affect the number of accidents and fatalities. The results show that the introduction of a random breath testing program in 1988 was associated with a 11.3% reduction in traffic fatalities; its expansion in 1998 was associated with a 26.2% reduction in traffic fatalities; and the effect of the "Safe4life" program, which was introduced in 2004, was a 14.3% reduction in traffic fatalities. Reductions in economic activity are also associated with reductions in road fatalities: we estimate that a one percent increase in the unemployment rate is associated with a 0.2% reduction in traffic fatalities.

1. Introduction

It is well-known that drink-driving has long played a substantial role in road traffic crashes, injuries and deaths, especially among young drivers (Zador et al., 2000; Voas et al., 2006; Ramstedt, 2008). Over the past four decades, governments in Australia have implemented legislative change and enforcement measures that are designed to reduce the road toll and improve traffic safety. In relation to drink-driving in particular, the legal limit of blood alcohol concentration (BAC) for drivers was limited to 0.10 (i.e., 100 milligrams of alcohol per 100 ml of blood) in 1968, reduced to 0.08 in 1974 and then lowered again to 0.05 in 1982, resulting in a significant reduction in road traffic crashes (RTCs) involving drink-driving (The State of Queensland, 2015). Many other policies that target driving under the influence of alcohol have been implemented since the introduction of a lower BAC limit. In particular, the random breath test (RBT) program was introduced in 1988 and was expanded in 1997 to deter drink-driving. In 1991, a "zero tolerance" policy was introduced for drivers under the age of 25, who are required to have a BAC of zero when driving a motor vehicle.

The literature on this topic has shown that the effects of policies that target alcohol-impaired driving may vary by jurisdiction, especially as different jurisdictions implemented such measures at different times and in different ways. Estimates of the effects of such policies by jurisdiction are thus worthwhile, but to the best of our knowledge, the effects of these measures have not been estimated for the State of Queensland. Our contribution is to examine the effects of the policies that governments have used over the past few decades to reduce the influence of alcohol on traffic fatalities in Queensland. We do so using annual data for the period 1958–2007 and applying a state-space time-series model to control for effects of unobserved components in road traffic fatalities. Our estimates suggest that these policies –the implementation of which is typically resource-intensive –did indeed have a profound effect on road traffic fatalities in this jurisdiction. While we do not attempt to conduct a cost-benefit analysis (CBA) here, we suggest that as the next step in this program of research.

2. Literature review

There is a vast literature on the association between alcohol and road traffic fatalities. Therefore, in this section we focus on summarizing the results from meta-analyses of that literature, reviewing only those studies that are directly relevant to our objectives in this paper. Jones and Joscelyn (1978) was the first study to review the

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association between alcohol and traffic safety. One of their findings was that young male drivers are at high risk of driving under the influence of alcohol. Mayhew et al. (1986) focused on reviewing three groups of studies: the extent of drink-driving by youth, alcohol use among young drivers who were involved in road crashes, and the relative risk of crashing by young drink-drivers. They found that young drivers under the influence of alcohol were more likely to be involved in road crashes than their sober peers. They proposed two hypotheses in connection to this observation: first, that young drivers were "inexperienced" with drink-driving; and second, that after drinking young drivers systematically engaged in more risky behaviors. A meta-analysis by Erke et al. (2009) to determine the effect of driving under influence (DUI) checkpoints in reducing crash numbers across Australia, New Zealand, USA, Canada and the Netherlands indicated the Australian random breath test (RBT) to be the most effective in reducing RTCs. Overall, they found the DUI checkpoints to be effective in reducing the alcohol-related RTCs by a minimum of approximately 17%.

Mann et al. (2001) reviewed the effects of lower BAC on traffic accidents and their consequences. Their work reveals that most studies of the topic have concluded that there have been beneficial effects of lowering the BAC limits on traffic safety measures, although these effects vary in the magnitude and the duration of the effect (i.e., with some having temporary and others having lasting effects). They also argue that the benefits that most studies have shown are due to a general deterrence effect, not merely the direct consequences of lowering the BAC limit on drink-driving *per se*.

We agree with others who have written on this topic that it is difficult, if not impossible, to differentiate effects of different road safety policies that were introduced during the same period. Nevertheless, reviews by Shults et al. (2001) and Goss et al. (2008) have found that two-thirds of the studies of this kind find significant reductions in fatal crashes due to increased enforcement. The review by Zwerling and Jones (1999) also suggests that a policy of zero tolerance towards drunk driving by young drivers is a very effective way to reduce alcohol-related fatalities, and several more recent studies also corroborate this argument (Chang et al., 2012; Liang and Huang, 2008; Voas et al., 2003).

The traffic safety literature also shows that young male drivers are the most likely to be involved in RTCs and to drive under the influence of alcohol. Thus, policy interventions that lower the risks taken by this group may be expected to be the most beneficial, at the margin. The main factors that lead to the relatively higher risks to young drivers appear to include the related developmental processes that attend adolescence and young adulthood, as well as related differences in the perception of risk by different age groups. Arnett (2002), for instance, has argued that young males have higher levels of testosterone and these are also linked to risky driving behaviors. It has also been argued that young men hence may be more aggressive and tend to engage in (what they believe to be) shows of bravado, especially in the presence of young females. Thus, young male drivers appear to take more risk on the road in the presence of passengers (Preusser et al., 1998), particularly young females (Simons-Morton et al., 2005). Other explanations of the higher rate of involvement of younger people in serious crashes include an optimism bias, whereby young drivers overestimate their driving skills and hence take more risk than do other age groups (Tränkle et al., 1990). The results from previous studies (Voas et al., 2003; Carpenter, 2004; Chang et al., 2012) broadly support these views.

In Australia, most previous studies also suggest that lower BAC limits have improved traffic safety. For example, Homel (1994) and Smith (1988) found that the reduction of BAC limits from 0.08 to 0.05 was associated with a significant reduction in traffic accidents in New South Wales and Queensland, respectively. More recently Howard et al. (2014) reviewed the implications of Australian alcohol policy on public health and found evidence that RBT, lowered BAC limits and low BAC thresholds for young drivers were highly effective RTC countermeasures. Evidence from Begg et al. (2007) suggests that there are nearly 336 fatalities among young Australians each year, 31% of which are alcohol-related. Chikritzhs and Stockwell (2006) found that increased alcohol consumption and later trading hours of hotels in Perth, Western Australia, were also associated with more crashes by drinking-impaired drivers. Yakovlev and Inden (2010) have also recently found that alcohol consumption (along with air temperature and precipitation) was one of the strongest determinants of traffic fatalities in the US from 1982–2006, in the 48 contiguous states.

The possible role of the business cycle is of interest to us too. While indicators of economic activity are not always considered in quantitative studies, there is reason to believe that its consideration may be important. Leigh and Waldon (1991), for instance, hypothesized three possible effects of unemployment on fatalities. First, as aggregate unemployment increases, driving and fatalities should decrease due to lower exposure. Second, the effect of unemployment on drinking *per se* is ambiguous: some unemployed people may tend to drink more due to stress, but lower incomes may lead to less drinking, making the net effect uncertain. Third, unemployment may increase aggregate levels of stress and unhappiness, perhaps leading to poorer concentration while driving, and perhaps to more crashes and fatalities. Using US data by state the authors found evidence in support of two of these hypotheses: holding vehicle miles constant, unemployment increased road crash fatalities (the stress hypothesis), but because unemployed people drove less, there were fewer fatalities overall. Ruhm (1995) has also examined the effects of macroeconomic conditions on alcohol consumption and found them to follow business cycles (i.e., alcohol consumption increases during economic booms and decreases during busts).

Finally, in relation to the methods that have been used in this literature on the relationship between alcohol and traffic safety, we found state-space time series models to be under-represented, which may be due, at least in part, to the fact that these methods are less commonly available in widely-used statistical packages than are other time-series approaches (Comm et al., 2011). This study uses the Structural Time Series Analyser, Modeler and Predictor (STAMP), which is capable of analysing complex multivariate state space models (Mendelssohn et al., 2011). The main difference between structural time series models and the autoregressive integrated moving average (ARIMA) models, which are also widely applied in traffic safety studies, is the treatment of unobserved components such as trends, slope, cycles and seasonality. Structural time-series models aim to estimate the variance/covariance of these components while ARIMA models often remove these components using methods such as first-differencing to meet the requisite stationarity assumptions. Here, we apply a state-space method from the structural time series family to examine the effect of policy interventions that address drink-driving in the State of Queensland, Australia.

3. Data

3.1. Sources of data

The data that are used in this study were collected from several sources including the Australian Bureau of Statistics, the Australian Bureau of Meteorology, Queensland Government Statistician's Office, and Queensland Transport. Despite our considerable attempts, we simply could not however obtain information on the number of RTCs and injuries for 1990 and 1991. Fortunately, our proposed method (i.e., state-space time-series analysis) is robust to missing data (Durbin and Koopman, 2001). Data on vehicle kilo-