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Determinants of motor vehicle crash fatalities using Bayesian model selection methods

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ABSTRACT

Motor vehicle crashes continue to result in large numbers of fatalities each year and represent the leading cause of death for young persons. In 2006, for example, there were over 42,700 fatalities associated with these crashes. Understanding the causes of these crashes and methods to reduce them continues to be of great interest to economists, public health officials, and policy makers. We present in this paper statistical models using a rich set of panel data covering the period 1980 to 2007 by state and the District of Columbia. Our choice of variables is based on an extensive literature highlighting the importance of policy, safety, demographic, and economic determinants of fatality rates.

The estimation techniques used in this paper takes cognizance that standard econometric inference focuses on parameter uncertainty. Models are estimated conditional on the assumption that the model to be estimated and reported is the "true" model. Tests are then made on a multitude of alternative models, each sequentially assumed to be the "true" model. Model uncertainty is manifested in this procedure, but it is often ignored in practice. Recent Bayesian statistical methods speak directly to the issue of both model choice and variable selection. This paper utilizes three Bayesian techniques: Extreme Bounds Analysis, Bayesian Model Averaging, and Stochastic Search Variable Selection to address model and parameter uncertainty in models estimating the determinants of motor vehicle crash fatalities.

1. Introduction

The determinants of fatalities due to motor vehicle crashes continue to be of major interest to public health officials, economists, statisticians, policy makers, among others. Fatalities hit a high point in 1972 with 54,589 deaths. Between that year and 2007, deaths due to crashes were generally above forty thousand per year. More recently the numbers have diminished significantly. Between 2007 and 2010, deaths have fallen from 41,059 to 32,885.[1] This precipitous drop in deaths lately may be due to things other than the prior trend. For example, some of this decline may be due to economic events, i.e., the Great Recession as well as a change in tastes among the public. That is, there seems to be a preference, especially among the youth, to move from the suburbs to the cities where there is a greater reliance on public transportation and walking. Furthermore, while the baby boomers had a strong desire to obtain powerful cars while in their teens, the current population of youths may be more inclined to desire powerful cell phones and electronic equipment. Regardless of these changes in preferences, there remains a significant number of crash related fatalities in the U.S. which scientist attempt to explain.

Many factors thought to contribute to motor vehicle crashes and crash fatalities have been examined over the last two decades. These include, motor vehicle speed, speed variance, alcohol, speed limits, vehicle miles traveled, measures of income and wealth, unemployment rates, advances in technology, the age of the motor vehicle fleet, population characteristics, insurance effects, seat belts and seat belt legislation, the deregulatory climate of the 1980's, among others. In general we can classify these factors into three categories: those associated with vehicles such as technology and design characteristics; those associated with roadways such as speed limits; and those associated with drivers themselves such as alcohol consumption and seat belt usage. Most recently, there has been an interest in the effects of cell phone usage on motor vehicle crashes and fatalities along with the effects of other socioeconomic and technology factors such as the age of the fleet, education, and suicidal propensities.

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[1] See the National Highway Traffic Safety Administration (NHTSA), Fatality Analysis Reporting System (FARS) for data on crash fatalities.

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We provide a background for our research in Section 2. Our data is described in Sections 3 and 4 lays out the general Bayesian framework underlying all the procedures we use in this analysis; it then introduces Extreme Bounds Analysis (EBA), and finally uses EBA on models of motor vehicle fatality rates. Section 5 discusses and implements Stochastic Search Variable Selection (SSVS) developed by George and McCulloch (1993) as another way of exploring models. Section 6 explores the problem further using Bayesian Model Averaging (BMA) as discussed by Raftery, Madigan, and Hoeting (1997). Section 7 highlights agreement among EBA, SSVS, and BMA methods as applied to the motor vehicle crash fatality rate models. Section 8 provides a summary of our findings and some concluding comments and policy recommendations.

2. Background

Most of the factors considered to be important determinants of crash fatalities have been investigated using econometric models based on classical methods. These models have attempted to examine whether various factors had significant statistical effects on crash fatalities and to provide a measure of their marginal effects. Many of these determinants are reviewed in Loeb, Talley, and Zlatoper (1994). The models have often followed the classic approach suggested by Peltzman (1975). His model is of particular interest given that he was concerned with the potential offsetting behavior of drivers as they adjusted their driving behavior in the face of various imposed regulations by the state. For example, one can recognize that drivers (as well as other members of society) have a given risk tolerance. If seat belts were required by law, risk imposed on the driver might be reduced, all else equal. However, drivers might then increase other risk behaviors, such as driving faster, which might not only affect their vehicle, but impose additional risks on, e.g., pedestrians. In any case, many factors have been evaluated by econometric models and not all of them have provided consistent results which might be expected from economic theory, public heath experiences and various statistical studies viewing the same determinants. Differences between studies may be due to different models, different estimation techniques, data differences, and changes which occur over time. As suggested above, the examined factors effecting safety are numerous. Some of the more significant ones (although not all of them) are reviewed below.

Motor vehicle inspection has been imposed in different degrees by many states over the last several decades. The catalyst for these regulations stems from the Highway Safety Act of 1966 which set standards for inspection and used the threat of withholding federal highway funds for noncompliance. In 1976, Congress relaxed its position regarding the imposition of state inspections. Numerous studies were conducted over time on the effectiveness of inspection on safety resulting in varying conclusions. Crain (1980), for example did not find strong statistical results suggesting the effectiveness of inspection. Garbacz and Kelly (1987) also did not find reason to support vehicle inspection. These results were countered by other investigators including, Loeb (1985, 1988, 1990), Loeb and Gilad (1984), among others.[2] The reason for such different results may be due to model uncertainty and different time regimes under investigation. To address some of this, Loeb often made use of specification error analysis to minimize the likelihood of model misspecification. In more recent work using Bayesian methods, Blattenberger, Fowles, Loeb, and Clarke (2012) found the effects of inspection to be fragile. However, the efficacy of inspection may also have changed over time as the age of the fleet, and hence the technologies available, changed. Keeler (1994) finds some evidence for this where inspection is found efficacious using data for the period 1970 but not so using data for 1980.

Speed and later speed variance were considered major factors contributing to crash related injuries and deaths. Speed adds to utility by diminishing travel time and, at least for some, provides thrills. Yet, it is argued that speed comes at a price of increasing the probability of crashes and deaths. This has been found to be the case in papers, e.g., by Peltzman (1975), Forester et al. (1984), Zlatoper (1984), Sommers (1985), and Loeb (1987, 1988), among others. However, Lave (1985) has argued that it is primarily speed variance as opposed to vehicle speed itself which is the speed related factor contributing to fatalities. Levy and Asch (1989) and Snyder (1989) found some evidence for this as well, while Fowles and Loeb (1989) using Bayesian methods found support for both speed and speed variance.

Speed limits have also been investigated as contributors to crashes especially after the Arab Oil Embargo in 1973. Statistical results varied among studies depending on model specifications and data used. Contributing effects have been found by Forester et al. (1984), Loeb (1991), among others. However, speed limits have been found also to reduce measures of crash fatalities by Garbacz and Kelly (1987), and Loeb (1990). More variable results are found, for example, in Keeler (1994), Blattenberger et al. (2012), and Fowles, Loeb, and Clarke (2010).

The effect of alcohol use has almost uniformly been found to have significant effects on motor vehicle crashes in recent research. This result is found both using classical as well as Bayesian methods as seen in Loeb, Clarke, and Anderson (2009), Fowles et al. (2010), Blattenberger et al. (2012) among others.[3] The effect of the minimum legal drinking age has also been investigated with varying results. For example, Sommers (1985) found a negative relationship between the minimum legal drinking age and fatality rates, while more recently, Blattenberger et al. (2012) and Fowles et al. (2010) find fragile results regarding the effect of the Minimum Legal Drinking Age on crash related fatalities.[4]

Related to alcohol consumption itself has been an analysis of the use of varying blood alcohol thresholds to determine if a driver is operating a vehicle under the influence. Recently, some evidence has been found by Loeb et al. (2009) indicating more severe limits on blood alcohol concentration (BAC) to designate driving while impaired reduced vehicle fatalities.

An interesting observation was found by Fowles and Loeb (1992) when examining the effects of alcohol on motor vehicle related crashes. They found evidence that altitude intensifies the adverse effect of alcohol on highway safety. This may be due to the fact that at higher altitudes, oxygen intake is less than at lower altitudes and may adversely impact on reaction time.[5]

Seat belts (and airbags) have been shown to have life-saving and injury reducing attributes. Researchers have estimated that seat belts have the potential to reduce fatalities by 40 percent or more.[6] Seat belt laws, both primary and secondary, have been imposed so as to induce the driving public to wear belts. New York was the first state to impose a seat belt law and currently 32 states and the District of Columbia have primary seat belt laws and 17 states have secondary laws. The laws vary further from state to state by who must wear a belt (front seat versus all seats) and the fine structures imposed for violating the law. Numerous studies have been conducted regarding the efficacy

[2] See Loeb et al. (1994) for a more complete review of the literature.

[3] See Loeb et al. (1994) for a review of earlier work including those resulting in opposite or insignificant results.

[4] See Loeb et al. (1994) for additional reviews.

[5] See Newman (1949) and Mazess, Picon-Reategui, Thomas, and Little (1968).

[6] See Partyka (1988) and Evans (1991).