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Quasi-induced exposure method: Evaluation of not-at-fault assumption

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ABSTRACT

Crash rates are used to establish the relative safety of various variables of concern such as driver classes, vehicle types and roadway components. Appropriate exposure data for estimating crash rates is critical but crash databases do not contain information on driver or vehicle exposure. The quasi-induced exposure method, which uses not-at-fault driver/vehicle data as an exposure metric, is a technique used in order to overcome this problem. The basic assumption made here is that not-at-fault drivers represent the total population in question. This paper examines the validity of this assumption using the Kentucky crash database to define two samples of not-at-fault drivers. One sample included only not-at-fault drivers selected from the first two vehicles in a multi-vehicle crash (two or more vehicles involved) while the other included the not-at-fault drivers from multi-vehicle crashes with more than two vehicles involved and excluding the first two drivers. The assumption is that the randomness of the involvement of drivers in the second sample is more reasonable than the drivers in the first two vehicles involved in crashes. The results indicate that these two samples are similar; there is no statistical evidence demonstrating that both samples represent two different populations in the maneuvers and other variables/factors examined here; and they are representative simple random samples of the driver population with respect to the distribution of the driver age when there is no reasonable doubt about investigating officers' judgments. Thus, estimating relative crash propensities for any given driver type by using the quasi-induced exposure approach will yield reasonable estimates of exposure.

1. Introduction

Central to roadway safety is the ability to determine roadway users or roadway sections that exhibit characteristics that could be noted as less safe. Estimating crash rates is one of the most common ways to assess the relative risk of road users or road facilities. The traffic safety community can then act to improve road safety by applying the knowledge gained from such studies. The frequency of crashes for any given roadway, driver, and environmental conditions can be used in the numerator for calculating such crash rates. These frequencies can be determined with acceptable accuracy from existing databases. However, accurate estimates of a driver's exposure for the same variables are difficult or impossible to be obtained from the available data. This creates a problem not only in finding the denominator to develop crash rate calculations but also in performing statistical tests to determine the significance of the variables in question.

In order to overcome this problem, researchers traditionally used estimates like miles driven, number of licensed drivers, registered vehicles, and so forth in the denominator. Peck and Kuan (1983) suggested that annual mileage is one of the strongest predictors of crash involvement. Massie et al. (1997) revealed that men do have a consistently higher risk of crash involvement per mile driven than women for the six combinations of crash severity and light condition they examined. However, estimating exposure using annual mileage is still debatable. It has been shown that high-mileage drivers have a lower crash risk per mile driven than low-mileage drivers (Maycock, 1985). There are two main reasons for these lower rates. High-mileage drivers may accumulate their miles mostly on relatively safe highways with limited access and medians compared to the low-mileage drivers who drive fewer miles per day but with a higher percentage of these miles being driven on undivided, busy streets with two-way traffic. Another possible reason is that high-mileage drivers may possess greater driving and safety skills than low-mileage drivers due to their longer exposure and experience.

Moreover, usage of annual mileage is questionable in analyses where specific groups of drivers or environmental conditions are of interest. For example, if the relationship between light condition and driver age group is to be examined, the amount of travel done by various driver groups under different light conditions is needed to

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estimate exposure accurately. If one assumes that disaggregation of annual mileage by age groups of drivers is possible using a national database, the disaggregation of annual mileage by light condition is almost impossible. Even though some researchers have used data from Nationwide Personal Transportation Study (NPTS) in obtaining such exposure estimates, these may not be very accurate since the light condition has been estimated using the time of the trip instead of the actual light condition (Office of Highway Policy Information, 2000).

Similarly, the reliability of exposure estimates will not be improved, if the number of licensed drivers is used to estimate the exposure rates instead of miles driven. Presumably, younger drivers drive more often than older drivers. Younger drivers may comprise a larger proportion of drivers on local streets during weekend nights than on interstates during rush periods (Stamatiadis and Deacon, 1997). Likewise, the use of registered vehicle data may not allow for an accurate estimation of exposure ratios. For example, it is reasonable to assume that large trucks are more likely to use the interstate system and they are less likely to use local roads during weekdays (Stamatiadis and Deacon, 1997). Therefore, these complex situations result in changing exposure proportions in the driving/vehicle population from time period to time period, road type to road type and so on. Thus, it can be concluded that these kinds of differences are not accurately represented by traditional metrics of exposure such as vehicle miles of travel.

Recent research indicates that alternative exposure measures that use data from the crash records seem to reduce the problems mentioned earlier (Stamatiadis and Deacon, 1997). Thorpe (1967) first introduced an induced exposure analysis method to estimate driver's exposure from the crash database itself. Later, Carr (1970) developed the quasi-induced exposure method, which is used more frequently than any other induced exposure formulation. In the quasi-induced exposure method, the estimate for the drivers' exposure is derived from the distribution of not-at-fault drivers in the crash database. The key assumption is that the distribution of not-at-fault drivers closely represents the distribution of all drivers exposed to crash hazards. In other words, the distribution of the not-at-fault drivers is assumed to be a sample of the total population exposed to the particular crash hazard.

In the quasi-induced exposure method, the randomness of the not-at-fault driver sample is very important. In statistical terms, a simple random sample is a set of drivers that have been selected from the driver population in such a way that every driver had an equal opportunity to be involved in a crash without being the at-fault driver. In other words, since the driver at-fault does not intentionally select a driver to strike, it can be reasonably assumed that each driver has an equal chance to be included in the not-at-fault driver sample.

One of the criticisms of the quasi-induced exposure method however, is the determination of the not-at-fault driver. In most cases, this is identified as the driver without any contributing human factors to the crash occurrence as defined by the investigating police officer. Thus, the potential that some of the not-at-fault drivers were partly at-fault for crashes cannot be ignored because their responsibilities might not be identified by investigation officers. Moreover, it can be assumed that less capable drivers may not be able to avoid a crash due to their less effective defensive driving technique and thus, they may be also considered to be partly at-fault. If a driver of a not-at-fault sample is partially at-fault for a crash, the assumption that the particular driver's involvement in the crash is a random event is questionable. Therefore, using these partly at-fault drivers to estimate driver exposure may affect the estimation of driver exposure.

Another perceived limitation with the quasi-induced exposure method is that not all types of crashes allow for the identification of not-at-fault drivers. Almost all of the drivers involved in single vehicle crashes are considered at-fault drivers. In the cases where roadways play a role, it can be assumed that the role is common for the entire driver population. Therefore, if the drivers in question are only those in single vehicle involved crashes, the exposure for such drivers cannot be estimated using not-at-fault drivers. The double pair comparison method is an alternative method to estimate such crash rates without the need for alternative exposure measures (Hertz, 2002). The double pair comparison method is widely used in traffic safety research to estimate the effectiveness of treatments or protective devices such as air bags and seat belts. The basic concept of the double pair comparison method is the use of a *control* occupant to estimate various rates of *subject* drivers in question (Evans, 1986). The use of the quasi-induced exposure method cannot be underestimated, even though it is not possible to estimate drivers' exposure using not-at-fault drivers in single vehicle crashes. Introducing the induced exposure method, Thorpe (1967) suggested that both exposure distributions of crash involved drivers in the single vehicle and multi-vehicle drivers are the same. Thereafter, this assumption was adopted by several studies. For example, Stamatiadis and Deacon (1997) has studied single-vehicle crashes in various aspects assuming their exposure distribution is the same as that of drivers in multi-vehicle crashes and observed no unusual findings.

An issue of concern is the validation of the quasi-induced exposure method against exposure based on vehicle-miles of travel, since the latter is considered the more widely acceptable exposure metric. Efforts to validate the estimates produced by the quasi-induced exposure and compare them with other more main stream measures were undertaken in the last decade. Two such approaches compared vehicle types involved in crashes with recorded vehicle-miles of travel and utilized trip diaries to estimate vehicle-miles of travel. The first approach used the classification of vehicles in broad categories and it considered their distribution as a function of level of development, functional classification, and type of day (Stamatiadis and Deacon, 1997). Average percentages of three types of vehicles (passenger cars, trucks and combination trucks) were computed for 18 conditions representing all combinations of two levels of development (urban-rural), three functional classifications (principal and minor arterials and collectors; classification data was not available for local roads and streets), and three time periods. Because of the disaggregation, the percentages computed from classification data are considered to be reasonably representative of relative vehicle-miles of travel assuming that the classification counts were taken at representative locations. The results suggest a link between relative accident exposure and vehicle miles of travel that may justify the selected use of quasi-induced exposure analysis to obtain first-order approximations of relative travel by different classes of road users.

The second effort used a trip diary as tool for collecting data that allows for the development of exposure estimates for the various age groups of drivers (Kirk and Stamatiadis, 2001). The objective of the diary was to collect both trip and driver information. Driver information collected included the driver age, gender, and household structure. Trip information provided data for the specific trip taken such as time of day, day of the week and trip purpose. Also important in this information was the type of roadways which the individual driver selected for their designated route. Completed trip diaries were analyzed using ArcInfo, a UNIX-based Geographic Information System (GIS) that allowed for the identification of the roadway classification based on the Kentucky databases. Using the GIS, the average annual urban mileage of each driver was estimated by each roadway functional classification and extrapolated (using the number of licensed drivers in Fayette County, KY) to determine the total vehicle-miles traveled for each age group. It was then possible to disaggregate this information by both driver characteristics and environmental factors, in order to develop an