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Newer cars: Much safer

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Abstract

Secondary safety refers to mitigation of injury given that a crash occurs, as distinct from prevention of crashes. Evidence is presented that secondary safety of new cars has been improving substantially in recent years.

(a) Single-car crashes, South Australia. The later the year of the car, the smaller is the probability of the driver being killed.

(b) Car-car collisions, South Australia. Comparison of the severities of injury to the two drivers in the one collision is useful because speed of the impact is the same for the two drivers. The basic question is, which driver is killed? It is shown that it is much more likely to be the driver of the older car.

(c) Car-car collisions, New South Wales. The finding was replicated with NSW data. In this case, the sample size was sufficient to include the mass ratio of the cars as a covariate.

In each analysis, allowance was made for some covariates.

Our interpretation of these results is that recent cars genuinely have appreciably better secondary safety than older ones. Possible reasons are discussed.

Our results are from a time period starting several years ago and cars are about a decade old on average. Thus we cannot be sure an improvement is continuing in new cars now: the data is not yet available. The results are nevertheless relevant to the current and future road safety situation. As older cars are scrapped, the proportion of crashes that result in car occupant death will continue to fall for at least one decade into the future.

1. Introduction

Anderson and Hutchinson (2010) compared the severities of injury to the two drivers in the one collision, and found that it is usually the driver of the older car who is killed, rather than the driver of the newer car. This within-crash method of research is useful because speed of the impact is the same for the two drivers: thus, even though it is unknown, its effect cancels out. Newstead and colleagues (e.g., Newstead et al., 2004, 2008) have for some time been reporting that the crashworthiness of cars in Australia has been improving over recent decades, but we thought it desirable to check their findings. Specifically, the methods they use could potentially suffer from bias, such as excessive under-reporting of damage-only crashes of older, less valuable, vehicles.

Newstead et al. (2008) have measured the safety of vehicles by examining the rate of serious and fatal crashes per tow-away crash. They define crashworthiness in this way to allow them to measure the relative safety of individual vehicle models, market segments, and vehicle vintages. They use more than ten years of data from each of Victoria, New South Wales, Western Australia, Queensland, South Australia. Newstead et al. (2008) found that the average crashworthiness of vehicles in each particular age cohort improves with year of manufacture, implying that drivers of newer cars are less likely to be killed or admitted to hospital after a crash. The average crashworthiness value for all vehicles in their sample was 3.8 per cent, the best average crashworthiness was for vehicles manufactured in 2003 at 2.2 per cent and the worst for vehicles manufactured in 1969 at 6.4 per cent. Similar trends were observed when the vehicle fleet was divided into market groups --- small cars, four wheel drives, and so on.

Our study (Anderson and Hutchinson, 2010) used South Australian data. We have subsequently analysed two further datasets.

- We have used the same method, comparison of the severities of injury to the two drivers in the one collision, with data from New South Wales.
- We have examined whether the advantage of being in a newer car can be detected in single-car crashes, using data from South Australia.

The present paper gives an overview of findings from all three datasets. As the more straightforward form of data is that concerning single-car crashes, this will be dealt with in the Methods and Results sections before the car-car data. Section 2 will summarise the methods, and note the different advantages of car-car and single-car crash data. Sections 3-5 will respectively give the results from the S.A. single-car study, the S.A. car-car study, and the NSW car-car study. Section 6 is discussion.

2. Methods

2.1 Datasets

The datasets used are those routinely assembled by the police and passed to the relevant government department.

In South Australia, the severity of injury of each casualty is coded as one of the following (from most to least severe): fatal, admitted to hospital, treated at hospital, treated by doctor, none. In New South Wales, the severity of injury is coded as fatal, non-fatal injury, or none.

We have supplemented the datasets with vehicle details from the proprietary database of R L Polk. The vehicles' VINs (Vehicle Identification Numbers) were used to access the vehicle details. Mass of car and year of car, not specific safety features, are studied in the present paper.

2.2 Single-car crashes

In the single-car crash study, the crashes of interest were those in which a single car struck a fixed object or rolled over, with the driver being injured. Cars were restricted to 1990 and later, in order for the results to reflect what has been happening in recent years, and the time period for the crashes was 2007-2009. Vehicles that are used similarly to cars or that are usually variant body styles of them --- station wagons, SUV's, utilities, panel vans, and taxis --- will be described as falling within a broad definition of "car", but outside a narrow definition that includes sedans (and hatchbacks) only.

A logistic regression was carried out with the binary distinction being fatal versus nonfatal injury. The independent variables of most interest were car mass and car year. Covariates were speed limit, crash location classified as within versus outside the Adelaide metro area, time of day, driver sex, driver age, whether or not the vehicle was within a narrow definition of car (as distinct from a station wagon, SUV, etc.), and whether or not the vehicle overturned in the crash. Results were also obtained with the levels of injury severity scored as 2, 3, 5, 9 for the categories treated by doctor, treated at hospital, admitted to hospital, and fatal; for these results, see Hutchinson and Anderson (2011).

It is well-known that crashes involving only minor injury are under-reported. We should note, as a limitation of this study, that if this under-reporting varies with mass of car or year of car, the apparent effects of these variables will be distorted. It is difficult to judge how serious a distortion there might be. There have been some findings that the reporting of damage-only crashes is affected by the vehicle value (e.g., Milic, 1972; Loukissas and Schultz, 1985), but we do not know of any evidence about the current magnitude of the variation within the population of reasonably common car masses and years.

2.3 Car-car crashes

Anderson and Hutchinson (2010) considered collisions between two cars, and compared the survival of the two drivers in the one collision. Cars were restricted to 1990 and later, and the time period for the crashes was 1991-2008. The question at issue is, given that one driver survived and the other was killed, is the difference in outcome associated with the difference between the years of manufacture of the cars? The method of comparison may simply be by cross-tabulation, or by using logistic regression to allow for other characteristics of the drivers and their cars. The strategy of matching two casualties and comparing their survival or their injury severities is not a new one: for example, Campbell and Kihlberg (1965) compared front seat occupants wearing a lap belt with those not wearing a belt. We are using routine crash data, and the fact that the two drivers are in the one crash matches for the speed of the crash, which is not recorded in routine data. Analyses from other countries quite similar to ours include those of Crandall et al. (2001), Martin et al. (2003), and Martin and Lenguerrand (2008).

The relevant equation is the logit model $\ln(p_2/p_1) = \beta_1.x_1 + \beta_2.x_2 + \beta_3.x_3$, where probabilities p_1 and p_2 refer respectively to the drivers of car 1 and car 2 being killed, conditional on exactly one of them being killed (and thus $p_1 + p_2 = 1$). The β's are coefficients to be estimated, and x_1 is the independent variable of chief interest, the difference between the two cars in the years they were built. (The difference is positive if car 2 is the more recent. If there tends to be less serious injury in more recent cars, β_1 will be negative.) The other variables x_2 and x_3 are respectively the difference between the two drivers in their ages, and the difference between the cars in whether or not they fell within a narrow definition of "car", i.e., were sedans or hatchbacks. (The difference x_2 is positive if driver 2 is older. If the probability of death is higher for older drivers, β_2 will be positive. The difference x_3 is +1 if car 2 is outside the narrow definition and car 1 is within, and -1 if the reverse is the case. If vehicles that are outside the narrow definition of car tend to be the heavier, β_3 will be negative.) It may readily be seen that no constant needs to be in the equation, as when the differences x_1, x_2, and x_3 are all 0, the two cars are equivalent, and so p_1 and p_2 must both be 0.5. Unfortunately, attempting to include in the equation the mass ratio of the cars was unsuccessful: there were appreciably fewer cases, due to one of other of the car masses being unknown, and a substantial increase in the standard errors of the estimates of the coefficients.

Similar methods were used for the NSW dataset (Anderson and Hutchinson, 2011). In this case, the time period for crashes was 1999-2008, and the difference x_3 was the difference between the cars in the logarithms of their masses.

2.4 Overview of the two strategies

The more straightforward form of data is that concerning single-car crashes. In principle, different years of car may be compared in respect of injury severity, and regression analysis may be used to make allowance for such other variables as driver age. However, datasets commonly lack estimates of crash speeds. Consequently, an effect that apparently reflects secondary safety could instead reflect crash speed. Similarly, absence of an effect could be due to the cancelling out of effects of secondary safety and crash speed --- for example, some group of cars (big, small, new, or old) could have better secondary safety but also higher crash speed. Crash speed itself can be dissected into travelling speed and pre-impact loss of speed. Allowance can be made in the regression for some variables that are presumably related to crash speed, notably speed limit and driver age, and appeal may be made to common practice in this field of accepting the absence of speed information, but nevertheless the possibility remains that distortion of the results could be occurring.

Comparison of injury severities of two drivers in the one crash means that the effect of speed will be expected to roughly cancel out.

- The effects of other variables that act similarly on both drivers similarly cancel out. (For example, the effectiveness of medical treatment might be more similar in the case of two casualties in the one crash than in the case of two randomly-selected casualties. And in the case of judging severity of nonfatal injury, the criteria might be more similar in the case of two casualties in the one crash than in the case of two randomly-selected casualties.)
- The mass ratio of the vehicles involved, however, will affect the injury severities in opposite directions. If mass ratio is known, it can be allowed for in the regression. If it is not known and is not associated with car year, it adds to the fog through which we are trying to perceive a possible effect of car year. (In Anderson and Hutchinson, 2010, though, we found a positive correlation between driver injury severities. That is, the effect of the between-crash variation in crash speed outweighs the effect of the within-crash difference in car masses.) If it is not known and is associated with car year (e.g., the average mass of new cars may be increasing over the years), then an apparent effect of car year could really be due to changing mass.
- This strategy of analysis cannot, of course, lead to the cancelling out of things that are different for the two drivers. It is conceivable that the seat belt wearing rate might be different in older and newer cars, or that driver frailty might tend to be different.

3. Results: Single-car crashes, South Australia

3.1 Simple aggregated comparison

For car year grouped as 1990-1993, 1994-1997, 1998-2001, 2002-2005, and 2006-2009, the respective proportions of fatalities were 2.3 per cent, 3.1 per cent, 2.7 per cent, 1.6 per cent, and 0.4 per cent. These figures suggest an improvement in secondary safety over the years.

3.2 Logistic regression

As described in section 2.2, the dependent variable was the binary distinction, fatal versus nonfatal injury. The independent variables of most interest were car mass and car year, and there were some covariates also. The estimated coefficient of car year was -0.06 per year, statistically significant at the 5 per cent level. The estimated coefficient of car mass was -0.04 per 100 kg of mass, not statistically significant at the 5 per cent level.

Coefficients like these are easy to interpret. That the coefficient of car year is -0.06 per year means that if a car is one year later than another, death is approximately 6 per cent less likely. (That is, the probability of death is 94 per cent of what it is in the earlier car.)

4. Results: Car-car collisions, South Australia

4.1 Simple cross-tabulation

The driver of the older car is much more likely to die than the driver of the newer car. The exact proportions naturally depend upon what the set of crashes is, and two examples are shown in part (A) of Table 1. (In principle, cross-tabulation shows whether the driver of the newer car was killed and whether the driver of the older car was killed, two possibilities × two possibilities = four combinations. Each row of Table 1 is an abbreviated version of such a 2 × 2 table, with the number of nonfatal crashes omitted.)

4.2 Logistic regression

Multiple logistic regression was carried out as described in section 2.3. There were 49 relevant crashes: the 47 in Table 1 (first line of results of part A) for which one driver died and the other did not, plus 2 crashes for which the cars were of the same year.

As might be expected from such a clear difference in the aggregated numbers (10 versus 37), the effect of car year remained when making allowance for covariates. The coefficients β_1, β_2, and β_3 were estimated to be -0.33 (per car year), 0.065 (per year of driver age), and -1.52. All are of the expected sign. All are statistically significant ($p < .05$), the respective standard errors being estimated as 0.11, 0.023, and 0.68. It might even be thought that β_1 = -0.33 (per year) is too large an effect to be credible: if the cars differ by 10 years, for example, the ratio of p_1 to p_2 would be 27.

5. Results: Car-car collisions, New South Wales

5.1 Simple cross-tabulation

Again the driver of the older car was found to be more likely to die than the driver of the newer car: two examples are shown in part (B) of Table 1.

5.2 Logistic regression

The analysis of the NSW data took account of the masses of the cars (via calculation of x_3), and so these needed to be known, and this reduced the number of crashes in the analysis.

Table 1: Numbers of collisions in which one or both drivers were killed

Description of set of collisions	Number of collisions: Driver of newer car (only) killed	Driver of older car (only) killed	Both drivers killed
(A) South Australia. *The collisions involve exactly two cars and no other units, the time period is 1991-2008, and the cars are of build years 1990-2008.*			
All crashes, cars include car derivatives and SUVs also	10	37	8
All crashes, cars restricted to sedans and hatchbacks only, both drivers aged under 65	3	9	4
(B) New South Wales. *The collisions involve exactly two cars and no other units, the time period is 1999-2008, and the cars are of build years 1990-2008.*			
All crashes, cars include car derivatives and SUVs also	54	96	11
Head-on crashes, cars restricted to sedans and hatchbacks only	13	31	5

First, multiple logistic regression (see section 2.3) was carried out for vehicles including car derivatives, 4WD sports utility vehicles, and passenger vans, as well as sedans and hatchbacks. There were 111 relevant crashes. The effects β_1, β_2, and β_3 were estimated to be -0.09 (per car year), 0.03 (per year of driver age), and -2.9. All are statistically significant ($p < .05$), and all are of the expected sign.

Second, the regression was restricted to sedans and hatchbacks only. There were 58 relevant crashes. The effects β_1, β_2, and β_3 were estimated to be -0.14 (per car year), 0.06 (per year of driver age), and -2.1. The first two are statistically significant ($p < .05$), and all are of the expected sign.

6. Discussion

6.1 Overview of results

In the case of single-car collisions, the estimated coefficient of car year was -0.06 per year. This implies that comparing two cars that differ in age by 10 years, for example, the probability of death in the newer car is 55 per cent of that in the older car.

In the case of car-car collisions, the estimated coefficients of car year in the regressions reported in sections 4.2 and 5.2 were -0.33, -0.09, and -0.14. These respectively imply that if the cars differ by 10 years, for example, the ratio of p_1 to p_2 would be 27, 2.5, and 4. Substantial differences are also evident in the simple cross-tabulations summarised in Table 1.

Even if the 27 is considered too large to be credible, the other estimates of the effect of age difference are still very substantial, and we think it fair to describe newer cars as being much safer than older cars.

Logistic regression is complicated computationally. The model is simple, though --- too simple to be realistic for road crash data. It may be that in an appreciable number of crashes, something unusual happens, something that is not included in the model, that is. The possibility of this reduces our confidence in statistical testing: even if it does not bias the estimates of the effects, it may mean the standard errors are estimated inappropriately.

6.2 Possible reasons for improved safety

Our conclusion is that three datasets show appreciably better secondary safety of recent cars as compared with older cars. This adds to other evidence from Australia (e.g., Newstead et al., 2004, 2008) and elsewhere (e.g., Crandall et al., 2001; Martin et al., 2003; Martin and Lenguerrand, 2008; Ryb et al., 2009).

We earlier noted four possible types of reason for better secondary safety of newer cars (Anderson and Hutchinson, 2010).

A. As time goes on, specific safety features (e.g., superior restraint systems) are included in more and more cars.

B. There may be improved resistance to intrusion into the occupant compartment.

C. Sophisticated management of the crushing process during impact may be beneficial.

D. More recent cars may tend to have a greater mass.

At present, we have no evidence about the relative importance of these possibilities, other than that the NSW data suggests that increasing car mass is not the only factor.

But could the results be due to something else? It might be said that results from single-car crashes can be dismissed because speed is a possible confounder, and that the estimated sizes of the effect in car-car collisions are too large to be plausible. A devil’s advocate might even say that once occupants are wearing seat belts and the integrity of the occupant compartment is maintained, not much else can be done. We have discussed a variety of possibilities in Anderson and Hutchinson (2010), and at present we consider it likely that at least one of reasons (A) - (C) is operative.

6.3 Implications

These results are from a time period starting several years ago and cars are about a decade old on average. Consequently, we cannot be sure an improvement is continuing in cars coming on to the market now: the data is not yet available. The results are nevertheless relevant to the current and future road safety situation. As older cars are scrapped, the proportion of crashes that result in car occupant death will continue to fall for at least one decade into the future.

The work described above indicates that new cars are much safer than older cars in respect of occupant protection. The way in which this improvement will go on to affect crashes depends on several factors.

- The age distribution of cars in the fleet, and turnover rates;
- The effect of vehicle age on crash risk;
- The pattern of vehicle use amongst the driver population, in particular, the association between young drivers and old cars.

Anderson et al. (2009) examined some of these issues in relation to the ages of vehicles in South Australia and the implications of those ages for vehicle safety. The median age of vehicles in Australia is about 8 years, and so the majority of vehicles on the road have not benefited from improvements that have occurred in design, for example, over the past 10 years or so. The median age in some states is somewhat greater, the oldest fleets being 12-18 months behind the newest fleets. Further, the age distribution of vehicles that crash shows an over-representation of older vehicles. This is partly, but not wholly, related to the fact that young drivers crash relatively old vehicles (around 15 years old), presumably because they tend to drive relatively old vehicles. This emphasises the delay incurred between the sale of vehicles with better safety features and benefits to those most at risk.

This paper has highlighted the fact that new cars are very much safer than old cars. Thus turnover of the fleet will be expected to improve the average safety of vehicles in the future. However, it should be noted that this improvement is likely to be uneven: young drivers who crash tend to do so in older, less crashworthy vehicles (Keall and Newstead, 2010; Anderson et al., 2009) and so improvements to the fleet will benefit young drivers, who are at increased risk of crashing, last of all. Therefore, attention needs to be given to examining if and how vehicle turnover might be accelerated, and to the barriers that exist to younger at-risk drivers driving newer (hence safer) vehicles. In particular, families may be able to adjust their driving so that the youngest drivers maximise the proportion of their driving that is in the newest, safest, vehicle in the household.

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