The Effects of Vehicle Redesign on the Risk of Driver Death

CHARLES M. FARMER and ADRIAN K. LUND

Insurance Institute for Highway Safety, Arlington, Virginia

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Objectives: This study updates a 2006 report that estimated the historical effects of vehicle design changes on driver fatality rates in the United States, separate from the effects of environmental and driver behavior changes during the same period. In addition to extending the period covered by 8 years, this study estimated the effect of design changes by model year and vehicle type.

Methods: Driver death rates for consecutive model years of vehicle models without design changes were used to estimate the vehicle aging effect and the death rates that would have been expected if the entire fleet had remained unchanged from the 1985 calendar year. These calendar year estimates are taken to be the combined effect of road environment and motorist behavioral changes, with the difference between them and the actual calendar year driver fatality rates reflecting the effect of changes in vehicle design and distribution of vehicle types. The effects of vehicle design changes by model year were estimated for cars, SUVs, and pickups by computing driver death rates for model years 1984–2009 during each of their first 3 full calendar years of exposure and comparing with the expected rates if there had been no design changes.

Results: As reported in the 2006 study, had there been no changes in the vehicle fleet, driver death risk would have declined during calendar years 1985–1993 and then slowly increased from 1993 to 2004. The updated results indicate that the gradual increase would have continued through 2006, after which driver fatality rates again would have declined through 2012. Overall, it is estimated that there were 7,700 fewer driver deaths in 2012 than there would have been had vehicle designs not changed. Cars were the first vehicle type whose design safety generally exceeded that of the 1984 model year (starting in model year 1996), followed by SUVs (1998 models) and pickups (2002 models). By the 2009 model year, car driver fatality risk had declined 51% from its high in 1994, pickup driver fatality risk had declined 61% from its high in 1988, and SUV risk had declined 79% from its high in 1988. The risk of driver death in 2009 model passenger vehicles was 8% lower than that in 2008 models and about half that in 1984 models.

Conclusions: Changes in vehicles, whether from government regulations and consumer testing that led to advanced safety designs or from other factors such as consumer demand for different sizes and types of vehicles, have been key contributors to the decline in U.S. motor vehicle occupant crash death rates since the mid-1990s. Since the early 1990s, environmental and behavioral risk factors have not shown similar improvement, until the recession of 2007, even though there are many empirically proven countermeasures that have been inadequately applied.

Keywords: FARS, crashworthiness, vehicle design, safety

Introduction

Occupant protection in passenger vehicles has improved greatly over the past 50 years (Lund 2011; Mogodin et al. 2011; Paine et al. 2009; Walz 2003; Youn et al. 2011). Some of this has been due to government regulation. For example, frontal airbags have been required for all new passenger vehicles in the United States since model year 1998. Other improvements in occupant protection were influenced by the publication of comparative safety test information. Automakers often have made vehicle structural improvements in order to perform better in crash test evaluations. Finally, some improvements have come in response to consumer demand. Consumers have shown a preference for vehicles with enhanced safety features (Kaul et al. 2010).

The crash avoidance potential of passenger vehicles has also improved over time (Highway Loss Data Institute [HLDI] 2014). Safety features such as improved vehicle lighting, electronic stability control, and automated crash warning and intervention systems have been shown to reduce the likelihood of crashing as well as the severity of collisions that still occur (HLDI 2012; Sivinski 2011).

The NHTSA has been publishing estimates of the effectiveness of various vehicle safety enhancements since its creation in 1966. Kahane (2004) used these published estimates to compute the number of lives saved by safety enhancements. He estimated that by the end of 2002, 12,000 lives had been saved in the United States by frontal airbags, 14,000 lives had been saved by side door beams, 53,000 lives had been saved by energy-absorbing steering columns, and 168,000 lives had been saved by safety belts.
Farmer and Lund (2006) addressed the more general question of what would have happened if vehicle designs had not changed at all. By comparing driver death rates per registered vehicle for consecutive model years of vehicle models without design changes, they were able to predict the death rates that would have been expected if the entire fleet had remained unchanged. They estimated that improvements to the U.S. vehicle fleet between 1985 and 2004 lowered the driver death rate by 20%.

Glassbrenner (2012) developed statistical models for estimating the effects of vehicle safety improvements on both crashworthiness and crash frequency, while controlling for human and environmental factors. She concluded that safety improvements made to U.S. vehicles between model years 2000 and 2008 lowered the likelihood of a crash by one sixth and were responsible for 2,000 fewer deaths in calendar year 2008.

Newstead et al. (2010) estimated the risk of driver death or serious injury in an Australian crash for each of 45 model years. The risk estimates declined by 67% from model year 1964 to model year 2008, from 6.9 to 2.3 per 100 crash-involved drivers. The greatest gains in crashworthiness occurred over model years 1970–1979, when many Australian safety regulations took effect.

The present study had 2 main objectives. One objective was to update the results of Farmer and Lund (2006) to calendar year 2012 to see whether there had been any changes in the trends. The second objective was to use U.S. data to derive estimates of relative safety for each successive vehicle model year and to compare these with the Australian data of Newstead et al. (2010).

Method

Driver death rates per million vehicle registrations in the United States were computed using the 1985–2012 files of the Fatality Analysis Reporting System (FARS) and the National Vehicle Population Profile (NVPP). FARS is a database maintained by the NHTSA that contains a census of all motor vehicle crashes occurring on public roadways and resulting in death within 30 days. NVPP is a database maintained by R.L. Polk and Company that compiles national vehicle registration counts by make, model, body style, and model year during each calendar year. Most vehicles do not have a full year of on-road exposure during the year when they are first sold, so vehicle registration counts are a poor measure of exposure when the calendar year precedes or is equal to the model year. Thus, driver death rates were computed only when the calendar year was later than the model year.

Following the methods of Farmer and Lund (2006), driver death rates in the same calendar year for up to 3 consecutive model years with identical designs were compared in order to estimate the effects of single-year vehicle age differences. For any vehicle model, model years were deemed identical in design if there were no differences in the platform (including size and weight) or the availability of airbags and electronic stability control. Only 3 model years were considered and only single-year effects estimated in order to maximize the number of vehicle models used in the estimates. The registration counts for each model year had different distributions of vehicle types and sizes, such as an increasing proportion of small SUVs (4% of model year 1993, 5% of model year 1994, 6% of model year 1995). Driver death rates vary by vehicle type and size, so the overall rates for each model year were standardized as a weighted average of these rates. The common weights were the proportion of registrations of each type and size class for the 3 model years combined.

For example, when a group of vehicle models was identified that had essentially the same structure and equipment for model years 1993–1995, the driver death rates for model years 1993 and 1994 in calendar year 1995 provided an estimate of the relative risk for 2-year-old versus 1-year-old vehicles. The driver death rates for model years 1994 and 1995 in calendar year 1996 provided another estimate of the same relative risk. In the same way, the driver death rates for model years 1993 and 1994 in calendar year 2000 provided an estimate of the relative risk for 7-year-old versus 6-year-old vehicles. Varying the model years and calendar years yielded multiple estimates of each relative risk, which were averaged to produce the final estimates.

Longer-term age effects were estimated by multiplying the single-year age difference final estimates. For example, the relative risk for 3-year-old versus 1-year-old vehicles was estimated as the relative risk for 3-year-old versus 2-year-old vehicles times the relative risk for 2-year-old versus 1-year-old vehicles. Approximate 95% confidence limits were calculated using the formulae

\[
(m_1 m_2) \exp \left(-2 \sqrt{2 \left(s_1^2/(n_1 m_1^2) + s_2^2/(n_2 m_2^2)\right)}\right),
\]

and

\[
(m_1 m_2) \exp \left(+2 \sqrt{2 \left(s_1^2/(n_1 m_1^2) + s_2^2/(n_2 m_2^2)\right)}\right),
\]

where \(m_1\), \(s_1\), and \(n_1\) are the mean, standard deviation, and number of rate ratios used to estimate the age 1 to 2 comparison, and \(m_2\), \(s_2\), and \(n_2\) are the mean, standard deviation, and number of rate ratios used to estimate the age 2 to 3 comparison (see Appendix, online supplement).

Next, driver death rates for each model year in consecutive calendar years were corrected for the vehicle age difference, thus providing estimates of the effect of calendar year. For example, if a 2-year-old vehicle was expected to have a driver death rate 3% higher than a 1-year-old vehicle, then the relative risk for a 1986 model in calendar years 1988 versus 1987 was divided by 1.03. Any remaining difference in the 1988 and 1987 calendar year death rates was assumed to be due to factors common to all vehicles. For example, changes in weather and traffic conditions would have had similar effects on all vehicles (at least within the same region), so these were considered as part of the calendar year effect. Similarly, trends in driver behavior, such as the general increases in seat belt use, were considered as part of the calendar year effect. Again, multiple relative risk estimates were produced by varying the model years and then averaged to produce the final estimates.

Finally, the effects of vehicle design changes were estimated by computing driver death rates for consecutive model years during each of their first 3 full calendar years and then correcting for the difference in calendar years. This assumed that the changes in risk due to the progression of calendar years were the same for all model years. For example, if driver death
rates in calendar year 2008 were expected to be 5% lower than in calendar year 2007, then the relative risk of a 2007 model in calendar year 2008 versus a 2006 model in calendar year 2007 was divided by 0.95. Both vehicle groups were 1 year old, and the rates were adjusted for calendar year differences, so any remaining effect was classified as due to vehicle design changes from model year 2006 to model year 2007. Multiple relative risk estimates were produced by varying the vehicle ages and then averaged to produce the final estimates.

It should be noted that the terms vehicle age effect, calendar year effect, and vehicle design effect used here, though seemingly simple, summarize relatively broad sets of variables that can affect vehicle safety. For example, the vehicle age effect includes the effects of physical deterioration as well as any changes in how and by whom the vehicle is used. The calendar year effect includes changes affecting the general population, such as changes in speed limits, licensing laws, road design, or traffic law enforcement, to the extent that these affect the riskiness of the driving environment or driver behavior. Finally, the vehicle design effect includes model year changes affecting the performance, crash avoidance potential, and crashworthiness of a particular vehicle model. Some of these design changes, such as size and weight increases or driver airbags, directly affect the risk of driver death. Others, such as seat belt reminder systems, indirectly affect risk by changing driver behavior.

Table 1. Mean estimates of relative risk of driver death by vehicle type and age

| Vehicle age comparison | Number of estimates | Cars/ minivans | Pickups | SUVs | All passenger vehicles |
|------------------------|---------------------|----------------|---------|------|-----------------------|
| 2 versus 1             | 37                  | 0.977          | 1.083   | 1.076| 1.005                 |
| 3 versus 2             | 35                  | 1.025          | 1.094   | 1.113| 1.047                 |
| 4 versus 3             | 33                  | 1.031          | 1.033   | 1.115| 1.038                 |
| 5 versus 4             | 31                  | 1.011          | 1.080   | 1.083| 1.029                 |
| 6 versus 5             | 29                  | 0.988          | 0.986   | 1.052| 1.003                 |
| 7 versus 6             | 27                  | 1.025          | 0.985   | 1.112| 1.022                 |

Comparisons of vehicle ages more than 1 year apart were accomplished by multiplying the successive 1-year relative risks. For example, the estimated relative risk for 4-year-old versus 1-year-old vehicles was \((1.005 \times 1.047 \times 1.038) = 1.09\). Driver death risk generally increased from vehicle ages 2 through 7 (Figure 1). The dashed lines in Figure 1 represent estimated 95% confidence limits.

The estimates of Figure 1 were based on a wide range of vehicle model years. It was implicitly assumed that the vehicle age effect was the same for each model year. In other words, it was assumed that the relative risk for 4-year-old versus 1-year-old vehicles was the same in the 1990s and the 2000s. As a check on this assumption the relative risk estimates of Figure 1 were recomputed after splitting the data into 2 halves: model years 1992–2001 and model years 2002–2011. Although there was some slight variability, all of the relative risk estimates computed using the half samples fell within the confidence bounds of Figure 1. For example, the relative risk for 4-year-old versus 1-year-old vehicles was 1.08 for the first half of the data and 1.11 for the second half.

Driver death rates for model years prior to 1978 were unavailable, so it was possible to derive calendar year effects beginning in 1985 using vehicles ages 1 through 7. There were 6 estimates of each calendar year effect, one for each of the model years common to both calendar years. For example, the age-adjusted estimated relative risks for 1986 versus 1985 were 0.96, 1.01, 0.97, 0.88, 0.88, and 0.91, averaging to 0.94. Comparisons of each calendar year to 1985 were accomplished by multiplying the successive 1-year relative risks, and the results are shown in Figure 2. If not for changes in the designs and type/size distributions of vehicles in the fleet, driver death risk would have generally declined from 1985 to 1993, slowly increased from 1993 to 2006, and then again declined from 2006 to 2012.

Fig. 2. Relative risk of driver death by calendar year if vehicle designs did not change (with 95% confidence limits).
The calendar year effects of Figure 2 were assumed to be the same for vehicles of all ages. Thus, they could be used to predict death rates for the overall vehicle fleet. The driver death rate per million registered passenger vehicles in 1985 was 177. Figure 3 compares the actual driver death rates for calendar years 1985–2012 with what would have been expected if the vehicle fleet had not changed (i.e., the relative risks of Figure 2 multiplied by 177). The actual rates were higher than expected for calendar years 1990–1997 and subsequently lower than expected. This implies that, with regard to designs for safety, the overall vehicle fleet did not improve over that of calendar year 1985 until calendar year 1998. However, the 2012 death rate was much lower than would have been expected with a 1985 fleet (65 versus 98). This equates to approximately 7,700 fewer driver deaths in 2012 than would have been expected if the safety of the vehicle fleet had not improved.

These data can be reconfigured to provide estimated relative risks for each model year relative to the previous model year. Table 2 lists the driver death rates for each of model years 1984–2009 during their first full calendar year. For example, the rate for model year 1984 in calendar year 1985 was 141.24. The rate for model year 1985 in 1986 was 138.86. The ratio of these 2 rates is 0.98. The vehicle age was the same (1 year old), and the ratio of rates for these two calendar years was expected to be 0.94 (see Figure 2). Therefore, the estimated relative risk for these 2 model years, adjusted for age and calendar year, is 0.98/0.94 = 1.05.

Similarly, tables were constructed for the adjusted relative risk in the second and third calendar years. For example, the adjusted relative risk for model years 1985 and 1984 during their second full calendar year is 1.01/0.98 = 1.03, and the adjusted relative risk during their third full calendar year is 1.01/0.98 = 1.04. The mean of the 3 relative risk estimates for model year 1985 versus 1984 is 1.04. Similar mean estimates were computed for the other model year pairs. The relative risk estimate for each model year relative to 1984 was computed as the product of relative risk estimates for each of the earlier model years. These are plotted in Figure 4. According to Figure 4, the 1985–1995 model fleets were less safe than the 1984 model fleet, with peak risk occurring for 1988 models. It was not until the 1998 model year that the vehicle fleet provided as much driver protection as the 1984 fleet. Nevertheless, there was steady improvement in safety for the 1994–2009 model fleets. The risk of driver death in 2009 model passenger vehicles was 8% lower than that in 2008 models and about half that in 1984 models. This is similar to the conclusions of Figure 2 but based on comparisons of individual model years rather than the overall vehicle fleet. According to Figure 2, the 2010 calendar year fleet (including model years up through 2009) had a driver death risk 42% lower than that of the 1985 calendar year fleet (including model years up through 1984).

The driver death rate over calendar years 2010–2012 for the 2009 model fleet was 38.3 per million registrations per year. If the 2009 model fleet had the same design as the 2008 fleet, then its expected driver death rate would have been 39.6. Based on approximately 9 million vehicle registrations per year, there were about 12 fewer driver deaths in these vehicles per year than would have been expected without the changes in vehicle designs. Similarly, the 2009 model fleet experienced about 82 fewer driver deaths per year compared with the 1999 designs and 95 fewer driver deaths per year compared with the 1989 designs.

Relative risks by model year were computed separately for cars/minivans, pickups, and SUVs (see Figures A1–A3, online supplement). The 1985–1994 model car/minivan fleets were progressively less safe and remained less safe than 1984 models until 1997. Nevertheless, car safety has improved each model year since risk peaked for 1994 models. The risk of driver death in 2009 model cars and minivans was about two thirds that in 1984 models and 51% less than the peak risk in 1994.

The 1985–1988 model pickup fleets were progressively less safe, and it was not until 2002 that pickup driver fatality risk fell below the risk for 1984 pickups. However, pickup safety has been improving since risk peaked in model year 1988. The risk of driver death in 2009 model pickup was about three fifths that in 1984 models and 61% lower than the peak in 1988.

There was no clear pattern in SUV safety during model years 1985–1994, although risk was generally higher than for 1984 models. However, SUV safety has improved rapidly since model year 1995, with fatality risk dropping below the risk for 1984 models in 1998 and later models. As with pickups, driver fatality risk peaked for 1988 models. The risk of driver death in 2009 model SUVs was about one quarter that in 1984 models and 79% less than the peak risk in 1988.

Variability of the single-year relative risk estimates was very high for early model SUVs. For example, the adjusted relative risks for model year 1987 versus 1986 were 0.75 during the first full calendar year, 1.02 during the second calendar year, and 1.45 during the third calendar year. Thus, the confidence intervals for comparing later model SUVs to the 1984 models were much wider than those for cars and pickups. As a result, although the estimated decline in risk for SUVs between model years 1984 and 2009 was statistically significant ($P = .006$), it...
Table 2. Driver death rates per million registered vehicles during 1st full year

| Calendar year | Model year | Driver death rate | Relative risk to previous | Expected relative risk for calendar year | Relative risk adjusted for calendar year |
|---------------|------------|-------------------|---------------------------|----------------------------------------|----------------------------------------|
| 1985          | 1984       | 141.24            |                          |                                        |                                        |
| 1986          | 1985       | 138.86            | 0.98                      | 0.94                                   | 1.05                                   |
| 1987          | 1986       | 143.33            | 1.03                      | 0.98                                   | 1.05                                   |
| 1988          | 1987       | 144.68            | 1.01                      | 0.98                                   | 1.03                                   |
| 1989          | 1988       | 147.64            | 1.02                      | 0.94                                   | 1.08                                   |
| 1990          | 1989       | 130.28            | 0.88                      | 0.92                                   | 0.96                                   |
| 1991          | 1990       | 114.68            | 0.88                      | 0.89                                   | 0.99                                   |
| 1992          | 1991       | 109.79            | 0.96                      | 0.93                                   | 1.03                                   |
| 1993          | 1992       | 101.98            | 0.93                      | 0.98                                   | 0.95                                   |
| 1994          | 1993       | 106.41            | 1.04                      | 1.01                                   | 1.03                                   |
| 1995          | 1994       | 104.50            | 0.98                      | 1.03                                   | 0.95                                   |
| 1996          | 1995       | 105.53            | 1.01                      | 1.01                                   | 1.00                                   |
| 1997          | 1996       | 89.14             | 0.84                      | 0.99                                   | 0.86                                   |
| 1998          | 1997       | 84.59             | 0.95                      | 1.00                                   | 0.95                                   |
| 1999          | 1998       | 87.36             | 1.03                      | 1.03                                   | 1.00                                   |
| 2000          | 1999       | 80.30             | 0.92                      | 0.99                                   | 0.93                                   |
| 2001          | 2000       | 81.51             | 1.02                      | 1.04                                   | 0.98                                   |
| 2002          | 2001       | 84.35             | 1.03                      | 1.02                                   | 1.01                                   |
| 2003          | 2002       | 79.64             | 0.94                      | 1.02                                   | 0.93                                   |
| 2004          | 2003       | 70.69             | 0.89                      | 1.00                                   | 0.89                                   |
| 2005          | 2004       | 71.58             | 1.01                      | 1.02                                   | 0.99                                   |
| 2006          | 2005       | 67.94             | 0.95                      | 1.00                                   | 0.95                                   |
| 2007          | 2006       | 63.85             | 0.94                      | 0.97                                   | 0.97                                   |
| 2008          | 2007       | 54.52             | 0.85                      | 0.93                                   | 0.92                                   |
| 2009          | 2008       | 46.11             | 0.85                      | 0.92                                   | 0.92                                   |
| 2010          | 2009       | 38.77             | 0.84                      | 0.95                                   | 0.88                                   |

was not significantly greater than the decline for cars ($P = .121$) and pickups ($P = .166$).

Discussion

Farmer and Lund (2006) concluded that, if not for improvements in vehicle design, the historical decline in driver fatality rates in the United States would have ended in calendar year 1993. In other words, the nonvehicle factors affecting highway safety, such as driver behavior and the roadway environment, were no longer improving. For example, the steep decline in alcohol-impaired driving during the 1980s tapered off in the early 1990s (NHTSA 2014). In addition, the relaxation of the 55 mph national maximum speed limit in 1987, and its repeal in 1995 led to higher speed limits in most states (NHTSA 1998).

More recent data show that the decline in relative risk by calendar year began again in 2007 and has continued at least through 2012 (Figure 2). One factor behind this more recent decline may have been the economic recession of 2007–2009. Motor vehicle crash fatalities tend to decline during economic downturns, possibly due to a drop in discretionary travel (Longthorne et al. 2010). The steepest declines in relative risk occurred in 2008 and 2009. Other factors could be improvements in road designs or driver behavior. For example, seat belt use in the United States has continued to increase, from 81% in 2006 to 86% in 2012 (Pickrell and Ye 2012). However, driver and road design changes occur relatively slowly and are unlikely to explain the precipitous decline that occurred from 2006 to 2009.

This finding supports Evans’s (2014) concern that the United States has not emphasized strongly enough ways to improve driver behavior and reduce the hazards of roads. Clearly, these efforts have not kept pace with other factors that increased driver fatality risk every year after 1993 until the economic recession of 2007. The United States could benefit from a renewal of the kind of behavioral and traffic engineering efforts that powered the successive improvements in road safety during the late 1980s. It has been observed elsewhere that there are several examples of known nonvehicle safety countermeasures that could be applied, given the political will to do so (Insurance Institute for Highway Safety [IIHS] 2011).

However, Evans’s (2014) suggestion that U.S. efforts on vehicle safety design have been harmful (amounting to an “orgy of toxic misinformation,” p. 1351) is not supported. While the decline in driver fatality rates in the 1980s was almost exclusively due to environmental and behavioral factors (including large increases in seat belt use), the more recent decline has been dominated by vehicle design improvements. Again, it should be stressed that safety-related vehicle design as defined here includes more than crashworthiness features such as airbags and structural improvements. For example, changes in vehicle mass, often due to consumer demand, are considered an integral part of the vehicle design process. The downsizing of vehicles during the late 1980s and early 1990s and the high rollover rates of early SUVs were not beneficial to drivers, but the relative risk of driver death by model year has been dropping steadily since the 1996 model year. Between model years 1984 and 2009 the risk of driver death declined by an estimated 42% in cars, 44% in pickups, and 75% in SUVs.

These large benefits for vehicle design changes are consistent with estimates from other authors. Glassbrenner (2012) estimated that between model years 2000 and 2008 the likelihood of a car being involved in a frontal crash declined approximately 22% and the likelihood of occupant death given a frontal crash declined 4%. Thus, the likelihood of a car occupant dying in a frontal crash (i.e., the product of the involve-
ment and conditional fatality likelihoods) declined approximately 25%. Similarly, the likelihood of a light truck occupant dying in a frontal crash declined approximately 24%. The likelihood of occupant death in near-side crashes declined 31% in cars and 28% in light trucks.

From 1993 to 2006, this analysis shows that the historical improvement in driver fatality risk was accounted for entirely by vehicle design changes that were large enough to offset the gradually worsening traffic environment. It is estimated that in 2012 there would have been 7,700 additional driver deaths absent the improvements in vehicle design. In short, although the United States could have benefited from more aggressive application of known traffic safety countermeasures, the improvements in vehicles have significantly increased the safety of motor vehicle travel.

It was not possible to isolate what aspects of vehicle changes have been most influential, but it is noteworthy that the average weight of vehicles in the fleet increased from 2,998 pounds in 1993 to 3,383 pounds in 2004 (Farmer and Lund 2006). Regulation and consumer information testing also have been effective at reducing the risk of deaths in crashes. Kahane (2004) summarized the estimated effectiveness of vehicle enhancements regulated by the NHTSA. For example, in the 1990s, the NHTSA began requiring frontal airbags, which are estimated to reduce driver fatalities by 29%. In addition, in the 1980s and 1990s, many of the regulatory safety standards first put in place for cars were extended to pickups and SUVs. Technological advances that were evaluated after the Kahane (2004) study include advanced frontal airbags, side airbags, and rollover curtain airbags (Greenwell 2013; Kahane 2014). Side airbags designed to protect only the torso reduce fatality risk by 26% for car drivers and by 30% for SUV drivers, whereas those that protect the head reduce a car driver’s risk of death in driver-side crashes by 37% and an SUV driver’s risk by 52% (McCarrt and Kyrchenko 2007).

The NHTSA’s New Car Assessment Program (NCAP) began with 1979 model cars and 1983 model light trucks. The IIHS instituted a consumer information program based on an offset frontal impact crash test in 1995. The NHTSA instituted a side impact NCAP test in 1997, and the IIHS instituted a side impact test in 2004. Roof strength evaluations were added to the IIHS battery of crashworthiness evaluations in 2009. Vehicle designs with better ratings in consumer information tests are also associated with lower fatality risk (Brumbelow and Teoh 2009; Harless and Hoffer 2007; Newstead et al. 2003; Teoh and Lund 2011). Models in U.S. NCAP tests with low composite injury scores were associated with a 20–25% lower risk of fatality in front crashes than those with high injury scores (Kahane et al. 1994). In head-on crashes of IIHS-rated vehicles, the estimated odds of driver fatality was approximately 46% lower for the good-rated vehicle than for the vehicle rated poor (IIHS 2006).

Moreover, improvements of vehicle crashworthiness have accelerated since the mid-1990s. A study by the HLDI (2013) showed that the number of years for the proportion of vehicles rated good in IIHS evaluations to reach 50% has shortened with each new evaluation. This took 14 years for the IIHS’s front crashworthiness evaluations begun in 1995, 9 years for its side evaluations begun in 2004, and 4 years for roof strength evaluations begun in 2009. This rapid improvement is enabled by shorter design cycles at all automakers (Winters et al. 2004).

Similar improvements in vehicle design safety have been observed in other developed countries. For example, except for the 1970s, Newstead et al. (2010) reported a pretty steady decline in serious injury risk by model year in Australia. They estimated on average a 2.8% decrease in serious injury risk per model year over the model years 1970–1979, a 1.8% decrease per model year over model years 1980–1989, a 2.1% decrease per model year over model years 1990–1999, and a 1.8% decrease per model year over model years 2000–2008. The steepest declines, approximately 2.4% per model year over model years 1982–2008, were for the market groups termed 4-wheel drive medium and people mover.

The trends in the United States, though not as steady as those in Australia, were more dramatic. For the U.S. data reported here, there was on average a 3.4% increase in fatality risk per model year over the model years 1984–1989, a 2.0% decrease per model year over model years 1990–1999, and a 4.4% decrease per model year over model years 2000–2009. It is not clear why there was an initial increase in fatality risk for 1984–1989 models, but Farmer and Lund (2006) noted that vehicles were getting smaller, probably as a result of automakers coming into compliance with corporate average fuel economy standards. For example, while small and midsize cars were growing in popularity during the 1980s, large and very large cars were shrinking; until 1990, the most popular cars were small and mini (see Figure A4, online supplement).

Trends for pickups and SUVs show similar results, with small vehicles accounting for the most registrations in the late 1980s and early 1990s. The effect of smaller vehicle size and weight on fatality rates is well documented (Kahane, 1997, 2003, 2012).

The decline for SUVs was approximately 2.9% per model year over model years 1984–2009. Some early models of SUVs were relatively unstable, and significant improvements came slowly. Even as late as 2001, 61% of all SUV occupant deaths in the United States occurred in SUVs that rolled over (NHTSA 2003). More recent models have a lower center of gravity, which has improved their stability. The static stability factor, a measure that increases as center of gravity height decreases, fluctuated between 1.06 and 1.10 for 1975–1998 SUVs but rose steadily to an average of 1.17 for model year 2003 (Walz 2005). Finally, a substantial percentage of SUVs had begun to adopt electronic stability control, which greatly reduces the risk of rollover crashes (IIHS 2010), by the 2009 model year. Therefore, whereas driver death rates in cars and SUVs were about equal as late as 1999, in 2012 the SUV rate was less than half that in cars (IIHS 2014).

There were a few limitations to the present analysis. Primarily, the analysis was limited by availability of data. The latest available fatality data were for calendar year 2012 and, because the methodology required 3 years of exposure for each model year, the latest model year risk estimate was for 2009. Therefore, the effects of newer crash avoidance technologies likely are minor. Electronic stability control, although not required for all passenger vehicles until model year 2012, was on 69% of new cars and 84% of new light trucks sold in 2009 (Sivinski 2011). However, other crash avoidance technologies, such as forward collision avoidance and lane departure warning, were rare in model year 2009. In addition, some of the estimates in the present study are imprecise, again due to limited data. For example, the design and vehicle age effect estimates for
early pickups and SUVs were based on relatively little data and should be treated with caution.

In conclusion, many safety-related improvements in vehicle design may have been driven by government regulation, the publication of comparative safety test information, and consumer demand for different sizes and types of vehicles. Although these influences have been present since the 1960s, they have been particularly strong since the 1990s. This growth in influence and the increased pace of vehicle redesign has been accompanied by a steep decline in the risk of driver death. At the same time, it is remarkable that the pace of improvement in driver and environmental risk factors observed in the 1980s and early 1990s has been largely missing in recent years, at least prior to the economic recession in 2007, despite the availability of proven countermeasures.

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**Supplemental Materials**

Supplemental data for this article can be accessed on publisher’s website.

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