AN ANALYSIS OF TRAFFIC DEATHS BY VEHICLE TYPE AND MODEL

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ABSTRACT

This study compares the risk of death in traffic accidents, depending on type of vehicle and vehicle model. Here, risk is driver deaths per year per million vehicle sales, for model years 1995–1999. Two risks are evaluated: the risk to the driver of the vehicle model in question in all types of crashes and the risk to the drivers of other vehicles involved in crashes with the model in question. The sum of those risks is the combined risk. Our main results are that sport utility vehicles (SUVs) are not necessarily safer for their drivers than cars; on average they are as risky as the average midsize or large car, and no safer than many of the most popular compact and subcompact models. Minivans and import luxury cars have the safest records. If combined risk is considered, most cars are safer than the average SUV, while pickup trucks are much less safe than all other types. Characteristics of the drivers of certain vehicle types probably have a strong effect on safety. For example, sports cars as driven are extremely risky for their drivers, who tend to be young males, and minivans are extremely safe for their drivers, very few of whom are young males. However, there is no evidence that driver age and sex distributions increase the risk of the average SUV compared to the risk of the average midsize car or a safe smaller car model.

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INTRODUCTION

In this study we explore some aspects of the role of vehicle type and model in traffic fatalities. This is part of a larger program to determine whether smaller/lighter vehicles are less safe than larger/heavier ones, motivated by recent disagreements about the interpretation of traffic fatality data (Nash 2001; NRC 2001; Ross and Wenzel 2001). The focus of most statistical analyses of this issue has been on averages, especially the average weight of cars and light trucks. In our opinion, the issue is too complex for such broad averaging. The risks depend on the vehicle type (for example, car class, van, SUV, or pickup truck) and model, as well as who drives the vehicle, and where, when, and how much it is driven. In this paper we ask what we can learn by going beyond average weight to examine relative safety by vehicle type and of individual vehicle models. For example, the category "passenger cars" encompasses a wide range of very different vehicles that appeal to highly diverse drivers; thus it should be no surprise that luxury imports have a completely different safety record than sports cars. This is a preliminary study about what can be learned by separately examining the safety of different vehicle types and vehicle models.

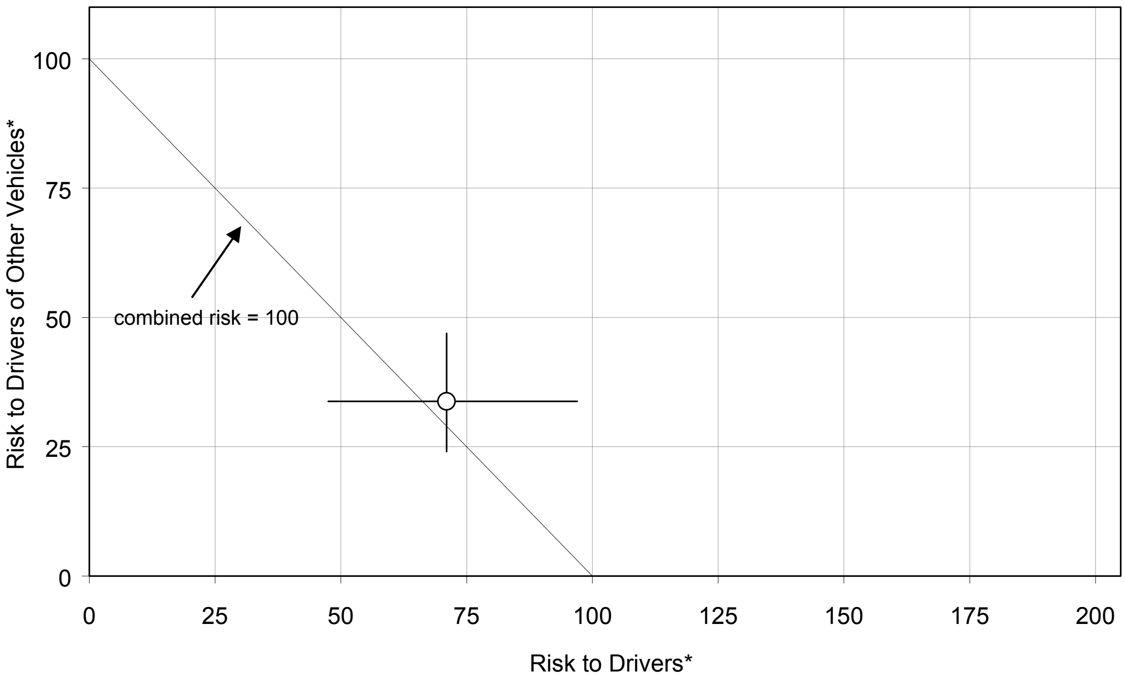
Our analysis is based on "driver death rates," a concept of risk developed by the Insurance Institute for Highway Safety (IIHS 2000) and defined in detail below. Our analysis uses the same data source as the IIHS study, the number of deaths in the annual census of traffic fatalities, the Fatality Analysis Reporting System (FARS), published by the National Highway Traffic Safety Administration (NHTSA). Our analysis differs from the IIHS analysis in important ways, however. First, we focus on the risk not only to occupants of vehicles of type A, but to occupants of other vehicles that crash with type-A vehicles. In our individual decisions as buyers of vehicles, as well as citizens in decisions about public policy, we need information on how dangerous vehicles are, to both their occupants and others. A shortcoming of many safety analyses has been that only risks to drivers or occupants of a given kind of vehicle are evaluated and risks imposed on others are ignored. Second, we limit our analysis to recent vehicle models with good statistics, i.e., enough sales and fatalities in each analysis year to give confidence that our calculated risks reflect the true risk of the vehicle model and not a statistical aberration. By studying risks associated with late 1995–1999 model years, we focus on recent safety designs and constraint technologies that have undergone a great deal of improvement. Third, we aggregate individual car models into vehicle classes differently than IIHS. The details of this grouping or classification are somewhat arbitrary and affect some conclusions. In particular, we believe that IIHS's finding that the safety of each type of vehicle decreases as vehicle weight decreases is sensitive to how the vehicles are grouped for the analysis.[1] We try to avoid applications, such as weight analysis, which are subject to that sensitivity.

Our analytical approach is shown in Figure 1, using the example of midsize cars. The figure shows risk, defined as driver deaths per year per million vehicles sold. The horizontal axis is "risk to drivers" of midsize cars. The vertical axis is "risk to drivers of other vehicles" that crash with midsize cars. The other vehicle may be of any model year or type (including motorcycles and heavy-duty trucks and buses). Both risks are calculated from the number of deaths in the years 1995 to 1999; the subject midsize cars are relatively recent, of model years 1995 to 1999. The risk to drivers includes driver fatalities from all types of collisions,

1. In addition, we use vehicle sales, rather than registered vehicles, as the denominator in our estimate of driver risk, simply because sales by vehicle type and model are readily available, whereas registrations are not. Annual miles driven probably is an even better measure of the "exposure" of vehicles to fatal crashes; however, these data also are not readily available by vehicle model. It is not clear how accounting for the number of registered vehicles and their annual usage would affect our sales-based estimates of the risk of cars relative to SUVs, minivans, and pickups (this issue is discussed further in the appendix).

whether with another vehicle, a fixed object, or a pedestrian or pedal-cyclist, as well as non-collisions (vehicle rollovers). The risk to drivers of other vehicles is based on the fatalities only when the subject vehicle collides with another vehicle. We only consider deaths of vehicle drivers in this report.

Figure 1. Two Measures of Risk for Drivers of Model Years 1995–99 Midsize Cars. "Risk" is driver deaths per year per million vehicles. Solid lines represent the range in each risk for the most popular models. These are not statistical error bars.



* The "risk to drivers" is for drivers of vehicle type shown, for all crashes in models of that type.
The "risk to drivers of other vehicles" is for drivers of the other vehicle in crashes with the vehicles of the type shown.

The point in Figure 1 shows the two average risks, while the lines through the point represent the ranges in each risk based on the most popular models.[2] Thus the average risk for drivers in recent midsize cars is 71 deaths per year per million such cars. This is found as the ratio of 2,137 driver deaths in popular 1995–99 midsize cars (from NHTSA's FARS database for 1995–99) to 30.1 million sales-times-years on the road for the crash years and model years in question. (Our method is explained in detail in the appendix and includes and a list of car models studied.) The horizontal line shows the range of the risk in midsize cars based on the most popular models, from 47 deaths per year per million cars for the lowest risk model (Camry) to 97 for the highest risk (Lumina). (We present risks for only the most popular individual models because of uncertainties associated with limited statistics, as discussed further below.)

The average "risk to drivers of other vehicles," defined as the risk to drivers of other vehicles that collided with 1995–99 midsize cars, is 34 deaths per year per million midsize cars, as shown in Figure 1 on the vertical axis. Note that this definition of risk to others is restricted in that it involves only the drivers of struck vehicles. The vertical bar in Figure 1 shows the range for the most popular midsize cars in risk to others; it is 24 to 47.

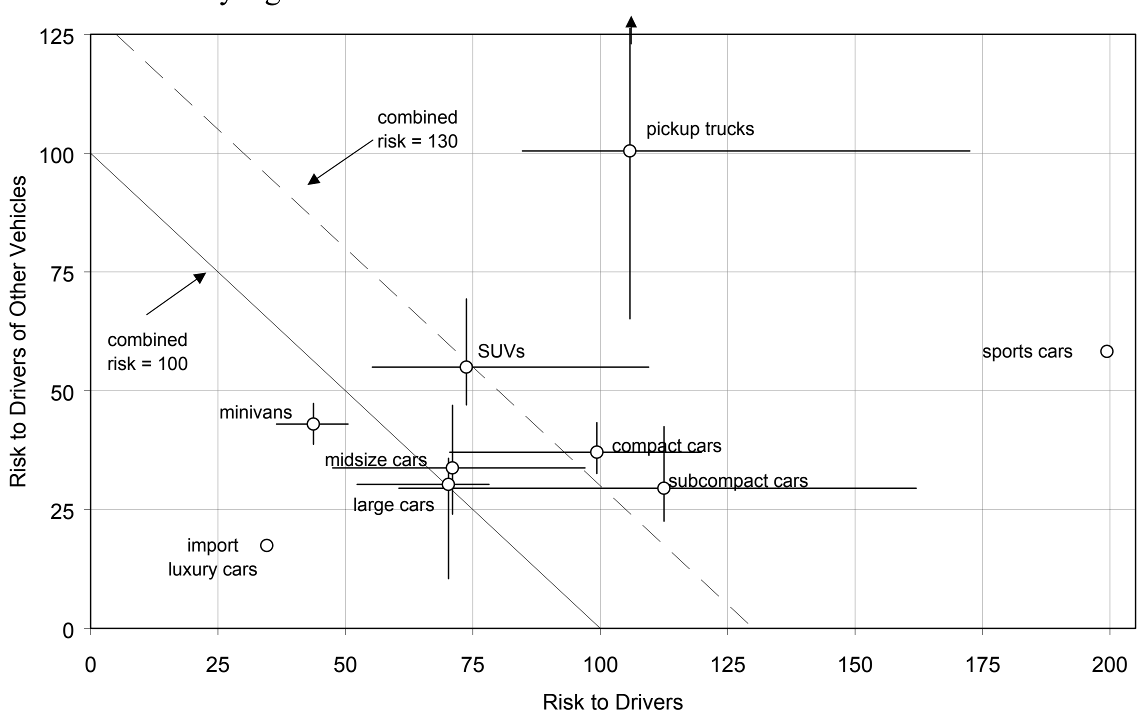
2. The average risks by vehicle type are estimated using popular models of each vehicle type, while the risks of individual models are restricted only to the most popular models with consistent sales in each year.

We define "combined risk" as the sum of the "risk to drivers" plus the "risk to drivers of other vehicles." This combined risk is a step closer to societal risk. (Total societal risk would also include occupants other than drivers, others outside of vehicles, and injuries as well as fatalities, which is beyond the scope of this particular analysis.) A sample line for combined risk of 100 driver deaths per year per million midsize cars is the diagonal line in Figure 1.[3]

ANALYSIS

Figure 2 shows the average risk to drivers and the risk to drivers of other vehicles for minivans, SUVs, pickup trucks, and six classes of cars (the same as in Figure 1). It shows as well the minimum and maximum risks for the most popular models of each vehicle type. (Criteria for selecting the vehicles of each type are discussed in the appendix.) These ranges are due to differences among vehicle models of the same general type as well as differences among their drivers. Sample lines for combined risks of 100 and 130 driver deaths per year per million vehicles are shown. Thus the combined risk of the average SUV (129) is 30% higher than that for the average large car (100) and 25% higher than that for the average midsize car (105). Differences in either measure of risk that are less than 10% between the major vehicle types are not statistically significant. We discuss these results below.

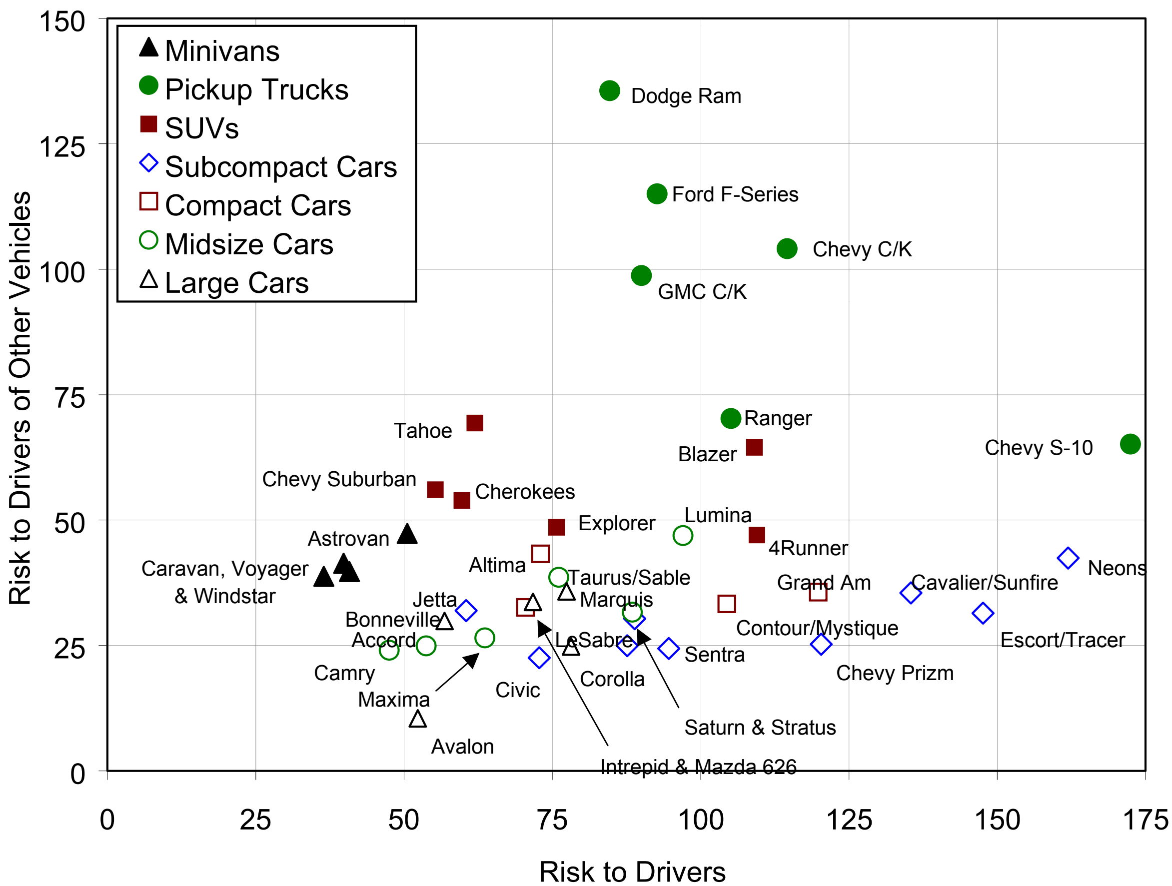
Figure 2. Two Measures of Risk to Drivers by Vehicle Type for Popular Cars and Light Trucks from 1995–99. (See the appendix for definitions.) Solid lines represent the range in risk for the most popular models within each vehicle type. They are not statistical error bars. Differences in either measure of risk that are less than 10% between the major vehicle types are not statistically significant.



3. Our estimated combined risk is somewhat overstated as it includes the same deaths in risk to drivers and risk to other drivers for crashes where the two vehicles are in the same category. This overcounts the combined risk by 3% for the most numerous vehicle type, pickup trucks. This overcount is negligible for individual models.

Figure 3 shows the two risks for the most popular vehicle models (defined in the appendix). Keep in mind that driver behavior may strongly influence risk for particular models. One should not give differences between *individual models* smaller than roughly 20% any consideration; they are typically within the statistical uncertainty of the risk estimates for a given vehicle model. The risk to drivers of the most popular subcompact cars ranges by nearly a factor of three for individual models; similarly, the risk from the most popular pickups to other drivers ranges by a factor of two among individual models.

Figure 3. Two Measures of Risk for Drivers by Vehicle Type and Model for the Most Popular Cars and Light Trucks from 1995–99. (See the appendix for definitions.)



It is extremely difficult to determine the inherent safety of a vehicle type or model because of the difficulty in separating the contribution of driver characteristics and behavior from the contribution of vehicle design. (We use "behavior" to refer to vehicle condition, when and where the vehicle is driven, and the care taken by the driver in ongoing vehicle operation, including the use of seat belts.) For example, some car models may attract relatively aggressive drivers, who increase the fatalities in the model, independent of its design. Due to the limitations of statistical analysis, one can only study some general behavioral characteristics of crashes that may correlate with risk.

In that connection we have studied driver age and sex (see the appendix). The proportion of driver fatalities in a vehicle that are young males may be a good surrogate for driver aggressiveness. Sports models *are* characterized by high risk and, except for the Corvette, a high fraction of the driver fatalities in sports cars are young males. (This justifies our treatment of sports cars as a separate class.) However, the fraction of young male drivers does not explain the lowest risk cars; in fact, some of the safest subcompacts have a high fraction of young male drivers. At the other extreme of driver age, elderly drivers dominate certain large cars but there is no clear pattern suggesting that those cars have especially high risk as a result. An analysis to determine the expected contribution of these two driver groups to the risk to drivers shows that if we corrected for the effect of these driver groups, the midsize car would be less risky relative to the SUV than shown in Figure 2 (see the appendix). In summary, we have found no evidence that driver age and sex overstates the risk in the average SUV or understates the risk in the average midsize car or particular smaller car models.

We have also studied the differences in risk of corporate “twins” like the Ford Taurus and Mercury Sable, which might indicate a role by driver behavior; the risk differences within twins are essentially consistent with simple statistical variability (see the appendix, Figure A2). In summary, although we cannot rule out driver behavior as the explanation of the high risk of some SUVs or the low risk of some cars, we have found no evidence for it.[4] More study is needed, but our tentative conclusion is that, while the driver behavior variables we study here are an important determinant of risk, they are not responsible for the most important result of this study—that SUVs and pickup trucks are more dangerous than most cars. In the following, the risk or "safety" of types of cars and light trucks are “as driven” by their drivers; that is, referring to their record on the road without adjustment for behavioral variables. All risks are for the drivers only, and not for any other occupants of the vehicle.

CONCLUSIONS

1. *Midsize and Large Cars.* The safest midsize and large cars (Avalon, Camry, and Accord) are as safe as the safest SUV (Suburban); average midsize and large cars are just as safe as the average SUV. However, SUVs impose a greater risk on drivers of other vehicles than do all types of cars. The combined risk of the average SUV (129) is about 30% higher than that for the average large car (100) and 25% higher than that for the average midsize car (105), while the safest SUV (Suburban, 111) has at least a 40% higher combined risk than the three safest midsize and large cars (Avalon, 63; Camry, 72; and Accord, 79).

2. *Subcompact and Compact Cars*. The safest subcompact (Civic and Jetta) and compact (626 and Altima) car models are as safe to their drivers as the *average* SUV (see Figures 2 and 3, and Table A5 in the appendix). When one considers the combined risk, including those killed in the other vehicle in two-vehicle crashes, then the safest subcompact and compact models are actually *safer* than the average SUV. Moreover, the combined risk for the *average* subcompact or compact car (147 and 136, respectively) is only slightly higher than that for the *average* SUV (129).

   A critical aspect of the dispute regarding whether light or small cars are relatively dangerous for their occupants is the very large range in the risk to drivers of subcompact cars (see Figure 2). At one end are the low-risk Jetta and Civic models, as just mentioned, but at roughly twice their risk are the Cavalier, Escort, and Neon models (and their twins). Those three very popular models are responsible for increasing the average risk to drivers of subcompact cars. Does the safety record of those three models prove that light cars are unsafe? We present evidence that there is no such simple rule. Might it instead

4. One study found that a lower percentage of drivers involved in fatal rollover crashes (54%) wear their seatbelts than drivers involved in other fatal crashes (70%) and that these percentages are identical for car and SUV drivers (Malliaris and Digges 1999). Therefore, some of the higher risk in SUVs relative to cars is due to the tendency of SUVs to rollover and the danger of these types of crashes to unbelted drivers.

suggest that relatively inexpensive cars tend to be unsafe? Perhaps. In any event, the argument that the low weight of cars with high fuel economy has resulted in many excess deaths is unfounded; that by paying careful attention to safety in vehicle design, smaller cars can be, and indeed have been, made as safe as larger ones.

3. *Minivans*. Of all major vehicle types, minivans have the lowest risk and the lowest combined risk. This is probably due in part to the fact that minivans tend to be driven with special care, often being used for transporting a family's children. Relatively few minivan drivers are found to be young males (see appendix, Table A3). But the relatively low risk in minivans is probably not all due to driver behavior. The popular minivans are built on car rather than pickup truck platforms, which may reduce the risk to their drivers and certainly reduces the risk to other drivers (Gabler and Hollowell 1998; Hollowell and Gabler 1996; Joksch 1998, 2000). An example of this is that the car-based body of the Grand Cherokee has about 20% lower risk to its drivers than the truck-based Cherokee, a suggestive though statistically marginal result.

4. *Pickup Trucks*. Pickup trucks, as driven, are riskier than any other major type of vehicle. The risk to drivers of the *average* pickup is higher than that for minivans, SUVs, and large and midsize cars, although it is not significantly different from that for the *average* compact and subcompact car. The combined risk is much higher than that for other vehicle types. This high risk is partly due to pickup trucks being driven more in rural areas. It is well established that risk is high in rural driving due to factors such as higher speeds, more miles traveled, and poor road design and conditions.

   Light trucks, especially pickups and to a lesser extent SUVs, are responsible for the deaths of many people in other vehicles, as shown by the vertical scale in Figures 2 and 3. This result supports earlier findings by Joksch (2000, pp. 9–10), who examined the outcomes of two-vehicle crashes reported by the police. He found that there are twice as many deaths in car-to-pickup crashes as in car-to-car crashes and 1.8 as many deaths in SUV-to-car crashes as in car-to-car crashes. The pattern in car-to-truck crashes is that people die in the truck somewhat less often than in car-to-car crashes, while people die in the car much more often. Nevertheless, trucks are not safer than cars: SUV and pickup users are at unusually high risk of death in one-vehicle crashes, such that drivers of average SUVs face the same risk as drivers of average midsize and large cars while drivers of average pickups face the same risk as drivers of average compact and subcompact cars. A substantial part of the risks light trucks impose on other drivers is associated with the design of trucks (Gabler and Hollowell 1998; Hollowell and Gabler 1996; Joksch 1998, 2000).

5. *Import Luxury and Sports Cars.* Import luxury cars have the lowest combined risk, while sports cars have the highest combined risk, of all vehicle types studied. The relatively high fraction of young males driving sports cars suggests that much, but not all, of their high risk is associated with aggressive driving.

APPENDIX

The Data

The data used in our analyses are primarily from the Fatality Analysis Reporting System produced annually by the National Highway Traffic Safety Administration. It includes a record for every fatal highway crash, with information on about 340 variables for each. Annual sales data by model come from data reported by vehicle manufacturers (Ward's 2000, pp. 16–23).

Definition of Risk

For crashes during 1995–99 of model years 1995–99 cars and light trucks, the risk to drivers for each model is the number of drivers killed in that model, summed over the years, divided by million vehicles sold times their years in use. To explain this calculation, consider the illustration in Table A1. For illustrative purposes, sales of recent vehicles of the model are set at 100,000, or 0.10 million, each year. Our analysis shows that the average vehicle in its first calendar year is on the road about 70% of that year. (In other words, the average model year 1999 vehicle starts, roughly, to be driven in April 1999.) After its first year, vehicle use is taken to be the same each year, as discussed below. For example, model year 1995 vehicles were on the road 4.7 years during calendar years 1995 through 1999. Therefore, for model year 1995 the sales times road years is 0.47 million. For the illustration, the deaths of drivers of the vehicle model are assumed to follow the pattern shown in the bottom line (which corresponds to an exactly constant risk).

Table A1. Illustration of the Calculation of Risk of a Vehicle Model. (See text.)

MODEL YEAR	1995	1996	1997	1998	1999	TOTAL
Sales (million)	0.10	0.10	0.10	0.10	0.10	
Sales $*$ years	0.47	0.37	0.27	0.17	0.07	1.35
Deaths in 1995–99	47	37	27	17	7	135

In this illustration, the risk is then 135 / 1.35 = 100 deaths per year per million vehicles. At this level of sales and risk, the purely statistical error is about ±9% (standard error) or ±17% (95% confidence interval). (The risk is proportional to the number of deaths, 135, and the corresponding standard deviation is the square root of 135, which, compared to 135, is 9%.)

This approach assumes that the number of vehicles in use of a given model/model year does not vary significantly during the first five years of vehicle age. This assumption is sufficiently accurate. Recent model year car and truck registrations show survival rates of 97% for cars but only 94% for SUVs, minivans, and pickup trucks in their fifth year (Wards 2000, pp. 44–5). Using registrations rather than sales, therefore, would tend to decrease our estimate of the risk in cars relative to that in SUVs, vans, and pickup trucks. On the other hand, new SUVs, minivans, and pickups tend to be driven 7% to 14% more miles per year than new cars.[5] Using annual miles traveled rather than sales would tend to *increase* our estimate of the risk in cars relative to that in SUVs, vans, and pickups. It is not clear how accounting for both the number of registered vehicles, and their annual usage, would affect our sales-based estimates of the risk of cars relative to SUVs, minivans, and pickups. Finally we observe no trends in driver deaths for the first five years for a fixed model year. There

5. Based on analysis of the 1995 National Personal Transportation Survey (Davis and Truett 2000). These findings are confirmed by our analysis of odometer readings from one- to five-year old vehicles in emissions inspection program data from Arizona and California in 2000.

also appears to be no trend in the first five yeas of vehicle age in the fatality risk relative to involvement in minor crashes (Joksch 2000, Figure A.1-5.). Therefore, vehicle sales appears to be a reasonable proxy for vehicle exposure to a fatal crash for the relatively young vehicles studied here.

Classification and Selection of Models

As seen in Figures 2 and 3, there is a wide range in risk by vehicle model within certain vehicle types. We selected for analysis vehicle models with the highest sales between 1995 and 1999 for estimation of the risks by vehicle class in Figures 2 and 3. To show the range in risk of particular car models in the figures, we exclude models with inconsistent sales over the five-year period (sales phasing out in 1998 and no sales in 1999, or no sales in 1995 and few in 1996).

The car models we selected for the separate analyses are shown in Table A2.[6] The car classifications are from the annual *Consumer Guide for Automobiles.* (See the specifications table at the back of the 1999 edition.) We chose this rather than the slightly different classification that the U.S. Environmental Protection Agency (EPA) and Department of Energy (DOE) use in their annual *Fuel Economy Guide.* EPA's car classes are based on interior volume, with station wagons treated separately. The consumer guide classes are somewhat closer to public perceptions, depending more on price and weight; the Consumer Guide puts luxury and sports car models in separate classes.

Table A2. Popular Car Models Considered. The most popular models (shown in Figure 3) are italicized. The other popular models that are included in calculating the average risks in Figure 2 are not italicized.

SUBCOMPACT	COMPACT	MIDSIZE	LARGE
Honda Civic/Del Sol	*Pontiac Grand Am*	*Toyota Camry*	*Pontiac Bonneville*
Ford Escort/Merc Tracer	*Ford Contour/*	*Honda Accord*	*Dodge Intrepid*
Chevy Cavalier/	*Mercury Mystique*	*Ford Taurus/*	*Mercury Marquis*
Pontiac Sunfire	*Nissan Altima*	*Mercury Sable*	*Buick LeSabre*
Saturn SC/SL/SW	*Mazda 626*	*Chevy Lumina*	*Toyota Avalon*
Toyota Corolla	Olds Achieva/Alero	*Nissan Maxima*	Chrysler Concorde
Chevy Prizm	Mitsubishi Galant	*Dodge Stratus*	Oldsmobile 88
Dodge & Plymouth Neons		Pontiac Grand Prix	
Nissan Sentra		Buick Century	LARGE U.S. LUXURY
VW Jetta		Buick Regal	Lincoln Town Car
VW Golf, New Beetle		Olds Cutlass	Cadillac DeVille
Chevy Metro		Plymouth Breeze	Oldsmobile Aurora
Mazda Protegé		Chrysler Cirrus	Buick Park Avenue
Hyundai Accent, Elantra		VW Passat	Chrysler LHS
Acura Integra		Chevy Malibu	Cadillac Seville
Kia Sephia		Olds Intrigue	Lincoln Continental
Mitsubishi Mirage			

6. The group of cars of curb weight under 2,500 lbs. is not included because the sales of particular models in later years are extremely low and would bias our results. The cars in this group tend to have a high risk to their drivers (169 deaths per million sold), at least on U.S. roads shared with large vehicles.

"Popular" models are used to determine the averages for each type, but only the "most popular" models are used to determine the ranges of particular models. The most popular models all have high sales (at least 70,000 per year weighted-average) and roughly constant sales volumes between 1995 and 1999. The popular models accounted for 83% of all cars, 69% of all minivans, 91% of all pickup trucks, and 63% of all SUVs sold between 1995 and 1999, while the most popular models accounted for 58% of all cars, 61% of all minivans, 77% of all pickup trucks, and 55% of all SUVs sold.

In Table A3 the selected light truck models are shown for the three body types. In Table A4 the selected cars for the two special groups of cars, luxury imports and sports, are shown. The latter two groups of cars do not have high sales but are of interest because of their very low and high risks, respectively; all models shown are used to calculate average risks.

Table A3. Popular Light Truck Models Considered. The most popular models are italicized. The other popular models that are included in calculating the average risks are not italicized.

MINIVAN	PICKUP TRUCK	SUV
Dodge Caravan	*Ford F-series*	*Ford Explorer*
Ford Windstar	*Chevrolet C/K-series*	*Jeep Cherokee*
Plymouth Voyager	*Dodge Ram*	*Chevrolet Blazer*
Chevrolet Astro Van	*Ford Ranger*	*Chevrolet Tahoe*
Ford Aerostar	*Chevrolet S-10*	*Chevrolet Suburban*
Chevrolet Venture	*GMC C/K-series*	*Toyota 4-Runner*
	Toyota Tacoma	Ford Expedition
	Dodge Dakota	Dodge Durango
	Nissan Pickup, Frontier	

Table A4. Two Special Groups of Cars Considered.

IMPORT LUXURY	SPORTS
BMW 3 & 5 series	Chevy Camaro/Pontiac Firebird
Lexus ES 300 & LS400	Ford Mustang
Mercedes C & E	Mitsubishi Eclipse
Acura TL	Nissan 200SX
Infiniti 130	Chevy Corvette

Results for Individual Models

Figure 2 lists the most popular models by their combined risk, and shows the risk to drivers and the risk to drivers of other vehicles. The ten safest models include three minivans and midsize cars, and two large and subcompact cars. Six of the ten safest models are foreign cars, three are domestic minivans, and one is a domestic large car. Note that the differences in the risks of models whose confidence intervals do not overlap are statistically significant; for example, the combined risk of the Toyota Avalon (63 + 16 = 79) is statistically lower than that of the Honda Civic (95 – 9 = 86). Also note that the *average* risk to drivers and combined risk of popular foreign luxury cars (35 and 52, respectively, from Figure 2) is lower than that of all of the most popular models shown in Table A4. Similarly, the *average* risk to drivers and combined risk of popular sports cars (199 and 258, respectively, from Figure 2) is higher than that of all of the most popular models.

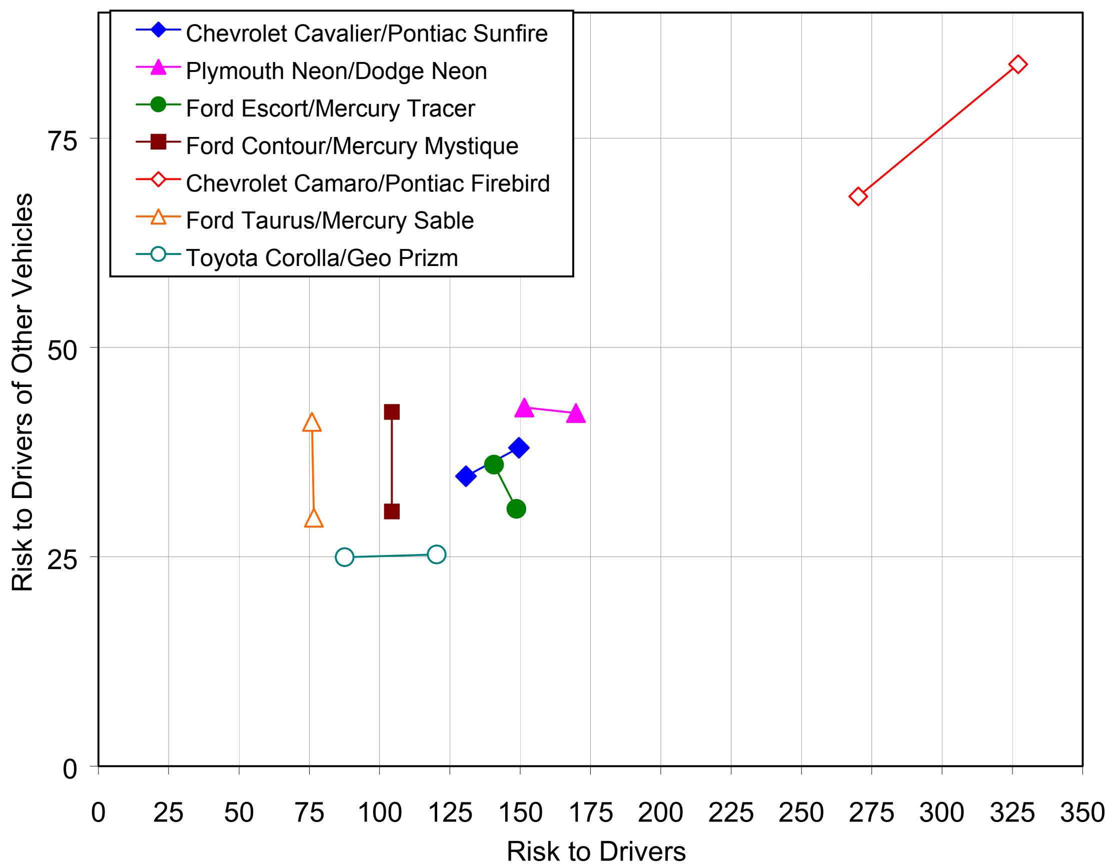
Table A5. Three Types of Risk and the Fraction of Fatalities in Two Risky Driver Groups for the Most Popular Cars and Light Trucks Sold Between 1995 and 1999. All are risks "as driven." Models are sorted by ascending combined risk. Risk is driver deaths per year, per million vehicles sold. Combined risk is the sum of risk to drivers and risk to drivers of other vehicles. 95% confidence interval shown for each type of risk.

		Risk and 95% Confidence Interval:			Fraction of Driver Fatalities That Are:	
Make and Model	Type	Combined	To Drivers	To Other Drivers	Young Males	Elderly
Toyota Avalon	Large car	63 ± 16	52 ± 14	10 ± 6	16%	24%
Toyota Camry	Midsize car	72 ± 7	47 ± 6	24 ± 4	16%	23%
Plymouth Voyager	Minivan	75 ± 11	36 ± 8	39 ± 8	5%	24%
Honda Accord	Midsize car	79 ± 8	54 ± 6	25 ± 4	20%	14%
Ford Windstar	Minivan	80 ± 10	41 ± 7	40 ± 7	5%	23%
Dodge Caravan	Minivan	81 ± 9	40 ± 6	41 ± 6	8%	22%
Pontiac Bonneville	Large car	87 ± 18	57 ± 15	30 ± 11	14%	28%
Nissan Maxima	Midsize car	90 ± 14	64 ± 12	27 ± 8	19%	17%
VW Jetta	Subcompact car	92 ± 18	60 ± 14	32 ± 10	31%	6%
Honda Civic/del Sol	Subcompact car	95 ± 9	73 ± 8	23 ± 5	30%	8%
Chevrolet Astro Van	Minivan	98 ± 16	51 ± 11	47 ± 11	10%	6%
Buick LeSabre	Large car	103 ± 14	78 ± 13	25 ± 7	1%	76%
Mazda 626	Compact car	103 ± 19	70 ± 15	33 ± 10	20%	4%
Dodge Intrepid	Large car	105 ± 15	72 ± 12	34 ± 8	8%	26%
Chevrolet Suburban	SUV	111 ± 18	55 ± 13	56 ± 13	6%	16%
Toyota Corolla	Subcompact car	113 ± 12	88 ± 11	25 ± 6	16%	17%
Mercury Marquis	Large car	113 ± 18	77 ± 15	36 ± 10	2%	66%
Jeep Cherokee/Grand Cherokee	SUV	114 ± 9	60 ± 7	54 ± 6	15%	8%
Ford Taurus/Mercury Sable	Midsize car	115 ± 8	76 ± 7	39 ± 5	10%	29%
Nissan Altima	Compact car	116 ± 15	73 ± 12	43 ± 9	14%	12%
Nissan Sentra	Subcompact car	119 ± 17	95 ± 15	24 ± 8	21%	8%
Saturn SC/SL/SW	Subcompact car	119 ± 11	89 ± 10	30 ± 6	16%	17%
Dodge Stratus	Midsize car	120 ± 19	88 ± 17	32 ± 10	17%	17%
Ford Explorer	SUV	124 ± 9	76 ± 7	49 ± 6	13%	8%
Chevrolet Tahoe	SUV	131 ± 18	62 ± 13	69 ± 13	12%	5%
Ford Countour/Mercury Mystique	Compact car	138 ± 13	104 ± 12	33 ± 7	20%	19%
Chevrolet Lumina	Midsize car	144 ± 14	97 ± 11	47 ± 8	12%	32%
Chevrolet Prizm	Subcompact car	146 ± 24	120 ± 22	25 ± 10	16%	13%
Pontiac Grand Am	Compact car	155 ± 14	120 ± 12	36 ± 7	24%	7%
Toyota 4Runner	SUV	157 ± 21	109 ± 18	47 ± 12	14%	3%
Chevrolet Cavalier/Pontiac Sunfire	Subcompact car	171 ± 12	135 ± 11	35 ± 5	24%	10%
Chevrolet Blazer	SUV	174 ± 15	109 ± 12	65 ± 9	17%	9%
Ford Ranger	Pickup	175 ± 13	105 ± 10	70 ± 8	29%	11%
Ford Escort/Mercury Tracer	Subcompact car	179 ± 12	148 ± 11	31 ± 5	16%	18%
GMC C/K-series	Pickup	189 ± 18	90 ± 12	99 ± 13	24%	10%
Dodge/Plymouth Neon	Subcompact car	204 ± 16	162 ± 14	42 ± 7	24%	11%
Ford F-series	Pickup	208 ± 9	93 ± 6	115 ± 7	19%	10%
Chevrolet C/K-series	Pickup	219 ± 11	115 ± 8	104 ± 8	23%	9%
Dodge Ram	Pickup	220 ± 14	85 ± 8	136 ± 11	21%	10%
Chevrolet S-10	Pickup	238 ± 18	172 ± 16	65 ± 10	34%	14%

Corporate Twins

Some models manufactured under different nameplates are virtually the same vehicle. We combined these "corporate twins" in our analysis by model. For the most part, these twins have similar risk. Figure A1 shows the matched results of six corporate twins among the most popular cars of the major types, plus the Camaro/Firebird twin. These data are consistent with the hypothesis that the differences in risk between the two members of each twin are mainly or entirely statistical, and that differences in behavior play only a minor role. The difference in only two of the fourteen pairs is statistically significant: the Taurus/Sable risk to other drivers and the Corolla/Prizm risk to their drivers. The differences between individual twins within a pair give a sense of the minimum uncertainty of all fatality risk estimates by model. A difference larger than 20% in the risks to the driver of different models suggests that other factors, such as behavior, are contributing to the relative risk.

Figure A1. Comparison of the Risks of "Twins," Essentially Similar Cars with Different Names.

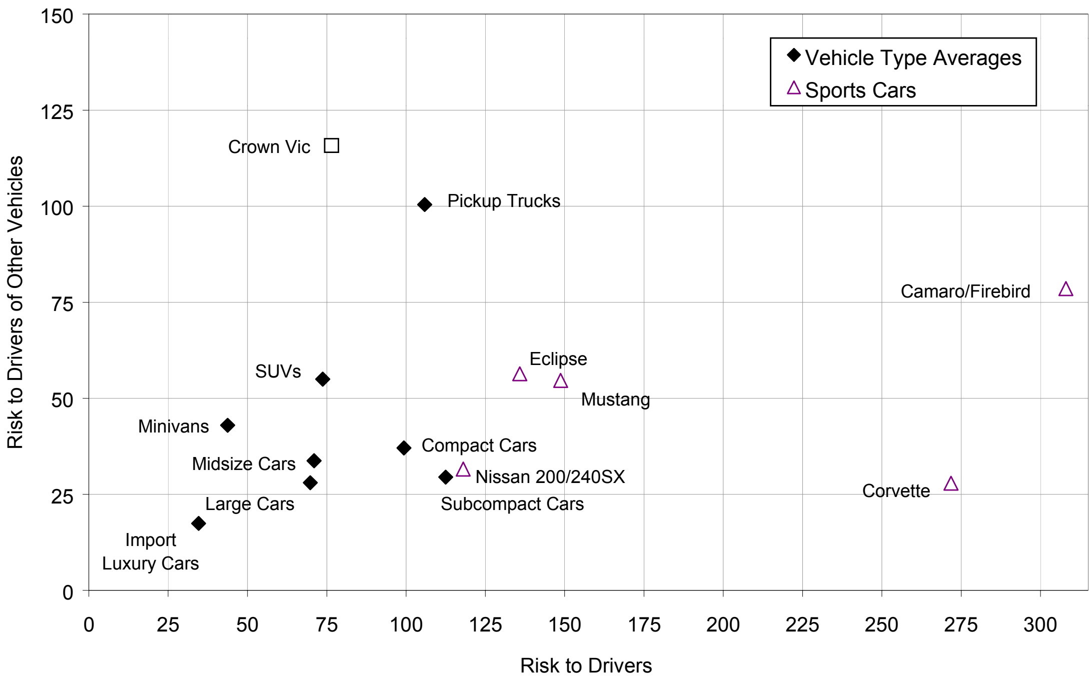


Driver Behavior

Before taking a risk rating seriously as an indication of a model's inherent safety, one must judge the extent to which driver characteristics affect the estimated risk in the vehicle. We cannot resolve this issue here but will try to shed some light on it.

Some evidence in the data for the importance of driver behavior is found in the risk characteristics of sport cars and of a car model, the Ford Crown Victoria, often used by the police (see Figure A2). All of the sports car models have high or very high risk for their drivers and some have high risk for the drivers of other vehicles. The Crown Vic has a very high risk for other drivers, if not for its drivers. Some 60% of the fatalities related to this model occurred with cars specifically manufactured for police use (based on the vehicle identification number). Since we do not know what fraction of total Crown Vic sales were actually sold to police departments, however, we cannot separately estimate the risk from Crown Vics used in police activities.[7]

Figure A2. The Risk of Some Sports Cars and Other Special Cars Relative to Other Vehicles.



The Chevy Corvette is an interesting case. Its high risk to its drivers suggests dangerous driving, not a surprise; however, it has the lowest fraction of young male fatalities of the sports car models, 22%. In contrast, its risk to other drivers is as low as for the average subcompact and large car, suggesting that its low-slung design and mostly plastic body makes it particularly safe for drivers of other cars.

Another indicator of the effect of behavior on risk is the impact of drivers belonging to high-risk groups. Analysts have emphasized the strong role of driver age and sex in traffic fatalities. Kahane (1997, p. 6) finds that male drivers under 26 are several times more likely to suffer a fatal crash than men aged 35 to 55. He finds similarly that elderly drivers are disadvantaged.

The average roles of what are probably the two most important high-risk groups are shown by vehicle type in Table A6 (similar data for the most popular vehicle models are shown in Table A5, above). Table A6 indicates that the fraction of young male driver fatalities (of all driver fatalities) is lowest in minivans and highest in sports cars. And the fraction of elderly driver fatalities is lowest in sports cars and highest in large cars. Neither of these high-risk groups account for a large portion of driver fatalities in SUVs; apparently, elderly drivers had not been swept up by the fad for SUVs in the period 1995–99 (and perhaps their relatively high cost made them unaffordable to young males).

7. Note that the Mercury Marquis, which is a twin of the Crown Vic but not sold as a police vehicle, has about the same risks as the average midsize car in Figure A2, and roughly the same risk to its drivers, but roughly a third lower risk to drivers of other vehicles, as the Crown Vic.

Figure A3 shows a simple linear model to predict the risk to the driver of a vehicle based on the fractions of the two driver groups presented in Table A6. The figure shows the observed risk to drivers of each vehicle type and the modeled risk to drivers using the fraction of young male and elderly driver fatalities in Table A6. The figure reveals that driver age plays a strong role in the risk to drivers of particular vehicle types, with the exception of import luxury cars and sports cars (the linear model shown is fitted to the data of the other nine vehicle types, excluding import luxury cars and sports cars). However, when we plot the observed risk versus the modeled risk for individual, most popular models in the same way, we find a much weaker correlation ($r^2 = 0.35$). In other words, while 35% of the variation among models may be explained by the two driver-age variables, most of the variation depends on other factors.

Table A6. Fraction of Drivers in Sensitive Groups, Killed 1995–99 in Model Year 1995–99 Vehicles.

Vehicle Type	Young Male Drivers (<26)	Elderly Drivers (>65)
Subcompact Car	22%	12%
Compact Car	21%	11%
Midsize Car	14%	27%
Large Car	5%	53%
Import Luxury Car	26%	9%
Sports Car	36%	1%
Minivan	7%	20%
Pickup	24%	11%
SUV	14%	8%
All	20%	16%

Note in Figure A3 that both SUVs and large cars have observed risks higher than expected on the basis of driver age, whereas midsize cars have an observed risk lower than expected. Thus, if we corrected for the effect of these driver groups, the risk to drivers of SUVs and large cars would be greater and the risk to drivers of midsize cars would be less than shown in Figure 2.

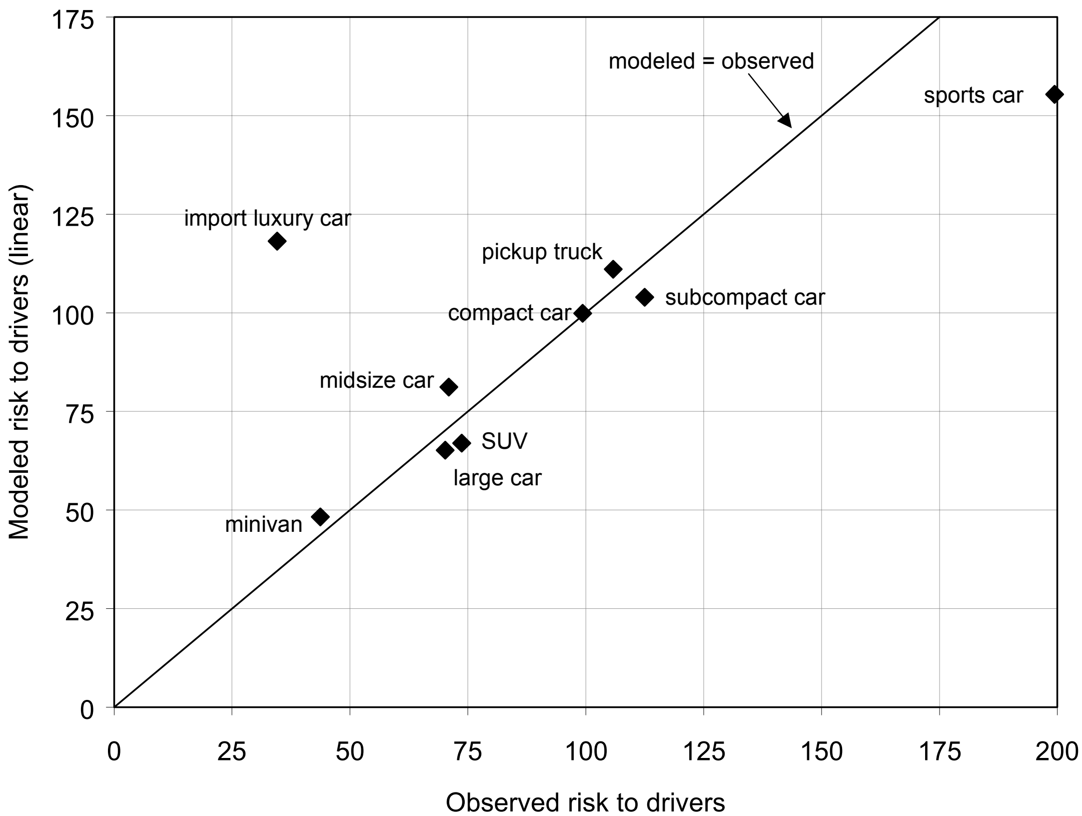
Deviation of the fraction of young male fatalities from the average may be a good indicator of the driver aggressiveness associated with a vehicle model. Figure A4 shows car models with either 30% or more of their driver fatalities being young males (symbols with light fill) or 50% or more of their fatalities being elderly drivers (symbols with dark fill). The figure includes all of the car models shown in Figure 3 plus two large luxury car models with high sales. The models of special interest are labeled. (Among the light truck models, only the Chevy S-10 is characterized by over 30% young male driver fatalities; Figure 3 indicates that this vehicle has a very high risk to drivers. None of the light truck models have over 50% of their fatalities as elderly drivers.)

Only two of the cars shown in Figure A4 have a high proportion of young male drivers; both are low-risk subcompacts. The Honda Civic is well known as popular with young people interested in modifying cars.[8] And the VW Jetta has a sporty reputation, although the Consumer Guide does not classify it as such. Note that the high proportion of young male

8. As noted in Table A2, the sporty Civic Del Sol is included with conventional Civics. This may also contribute to the relatively high fraction of young male driver fatalities in Civics, as well as slightly overstate the risk to drivers of the conventional Civic.

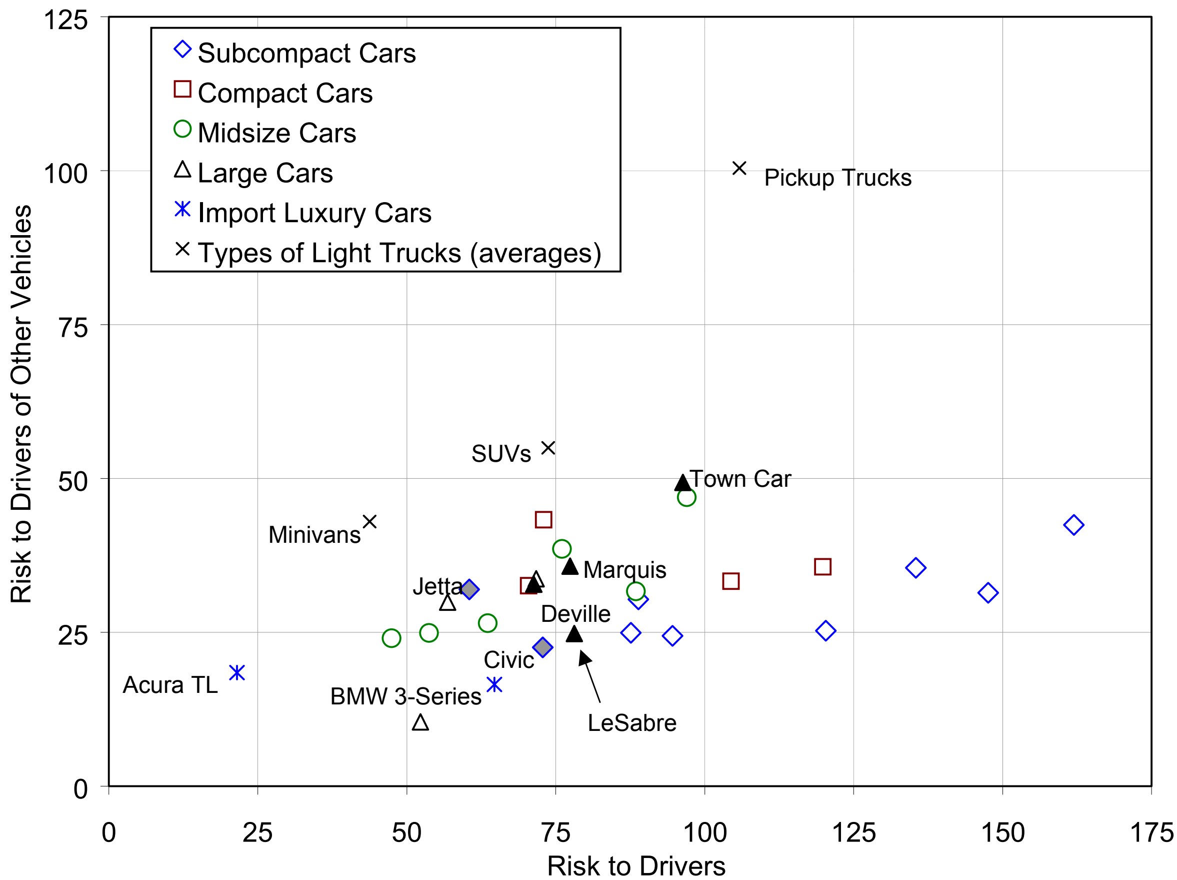
driver fatalities in Civics and Jettas does not result in them having higher risk than other car models; instead, they are among the safest of the popular vehicles. (In contrast, four of the five sports car models, the least safe of all car types to their drivers, also have over 30% of their driver fatalities from young males.) Four of the vehicles shown in Figure A4 have more than half of their fatalities coming from elderly drivers; they are all large car models. We suspect that these cars would appear to be safer if we could account for the driving behavior and frailty of these elderly drivers; however, it does not appear to be an important issue for the comparison of the relative risks of cars and, say, SUVs. As with SUVs, some popular sedans of the traditional U.S. manufacturers, like Ford Taurus/Sable and Chevy Lumina, are not characterized by large proportions of high-risk drivers.

Figure A3. Observed Risk to Drivers vs. Linear Model using the Percentage of Young Male and Elderly Fatalities. Risk = 4.22 * (% YM) + 0.80 * (% elderly) + 1.00. The correlation between driver age and risk to driver shown here for the average vehicle type is much less for individual models (see text). Note that the y-axis is not the same as in Figures 2 and 3.



A tentative conclusion is that although driver age likely affects the high risk of sports cars, it is not responsible for the most important results of this study. Regarding Conclusions 1 and 2, above, the high risks of some SUVs are not a result of driver age; there is no pattern of driver age among popular car models that would explain the low risk of several of those models. Regarding Conclusion 3, minivans may well be intrinsically less safe than shown in Figure 2, given that they tend not to be driven by the riskiest drivers, young males. And regarding Conclusion 4, with the exception of one model, the high risk of pickup trucks is not strongly associated with high-risk drivers, although pickups tend as a group, like subcompact and compact cars, to be driven somewhat more by young males. The relative riskiness of pickup trucks may be partly explained by the greater likelihood of them being driven on rural roads, as mentioned above. Similarly, seat belt use may affect the relative risks by vehicle type. As described in Footnote 4, one study found that belted SUV occupants are safer than belted car occupants, while unbelted occupants in each type of vehicle face the same risk (Malliaris and Digges 1999). However, this study also found that a lower percentage of drivers involved in fatal rollover crashes (54%) wear their seatbelts than drivers involved in other fatal crashes (70%) and that these percentages are identical for car and SUV drivers. Therefore, some of the higher risk in SUVs relative to cars is due to the tendency of SUVs to rollover and the danger of these types of crashes to unbelted drivers. Survey data also indicate that SUV drivers tend to use their seatbelts at the same rate as car drivers (Bondy and Glassbrenner 2001). We plan to investigate how seatbelt use and other behavior variables affect our estimates of risk by vehicle type and model.

Figure A4. Fraction of Driver Deaths in Risky Age/Sex Groups, Popular Models. Models with more than 30% male drivers under 26 shown by symbols with light fill. Models with more than 50% of drivers over 65 shown by dark fill.



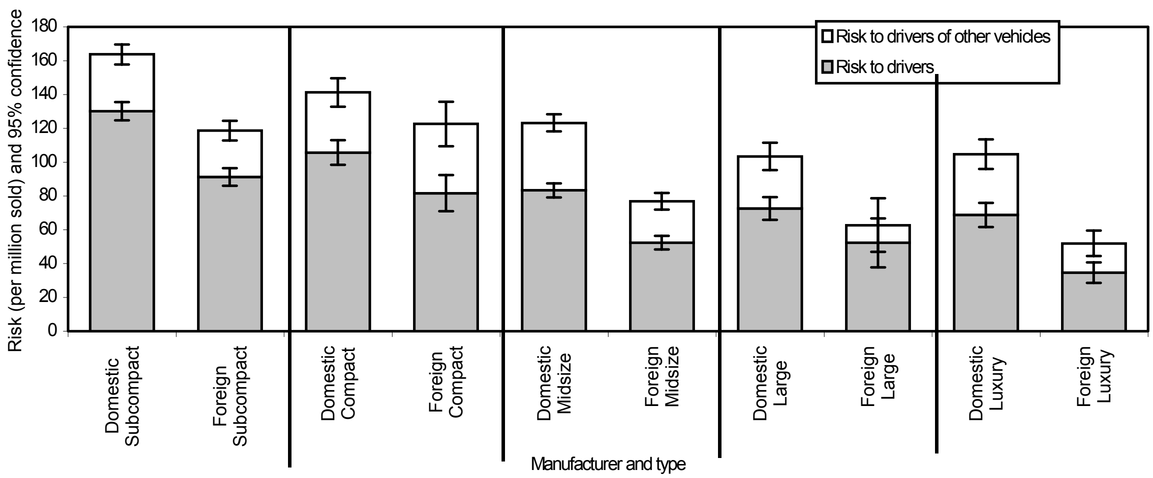
Comparison by Manufacturer

Figure A5 shows the three types of risk for the five major classes of cars by the home country of the manufacturer (labeled "domestic" and "foreign").[9] The risks to other drivers

9. We excluded cars weighing less than 2,500 lbs and sports cars from the analysis because there were not enough popular models to make the comparison by the home country of the manufacturer. We classified the relatively safe Mercedes Benz C-class and E-class cars as foreign (rather than domestic) luxury cars, as they were manufactured prior to the merger of Chrysler and Daimler-Benz. We classified the Mazda and Geo models

are stacked on the top of the risks to the drivers of each vehicle type; the combined risk is the total height of each column.[10] The figure suggests that foreign cars are substantially safer, as driven, than domestic cars, both to their drivers and to other drivers, for each class of cars. These results are statistically significant in all five major car classes, with the exception of risk to drivers of large cars (in part because there is only one foreign model, Toyota Avalon, in this class). In addition, the risks of the foreign compact and subcompact cars are comparable to those of the domestic midsize, large, and luxury cars.

Figure A5. Risk to Drivers and Risk to Drivers of Other Vehicles by Manufacturer and Car Type (60 Popular Car Models). Sum of risk to drivers and risk to other drivers is the combined risk. Whiskers represent 95% confidence intervals of risk to drivers and combined risk.



Careful vehicle design plays a more dominant role in vehicle safety than size or weight. For instance, the foreign subcompact and compact cars have almost the same risk as the domestic large and luxury models, while the foreign midsize cars have a substantially *lower* risk than the larger domestic models. While at first glance the figure may suggest that, at least within each manufacturer group, vehicle risk decreases as vehicle size increases, the design factors overwhelm the influence of size.

Figure A6 similarly compares risks of all cars (except mini-compacts and sports cars) by the nameplate manufacturer. Ford, DaimlerChrysler, and GM cars have the highest risks by manufacturer. Nissan has slightly lower risks than the domestic manufacturers, while Honda and Toyota have the lowest risks of all manufacturers. One could argue that SUVs and minivans should also be included in the analysis, as these vehicles are used essentially as substitutes for conventional cars. As about 70% of all minivan sales (one of the safest types of vehicle) and about 60% of all SUV sales are by domestic manufacturers, their inclusion has the greatest effect on the domestic manufacturers. When we include 14 popular models of minivans and SUVs in the analysis, the relative standing of the manufacturers are largely unchanged from Figure A5. The exception is one domestic manufacturer, DaimlerChrysler, whose risk improves such that its vehicles are comparable to those of Nissan and

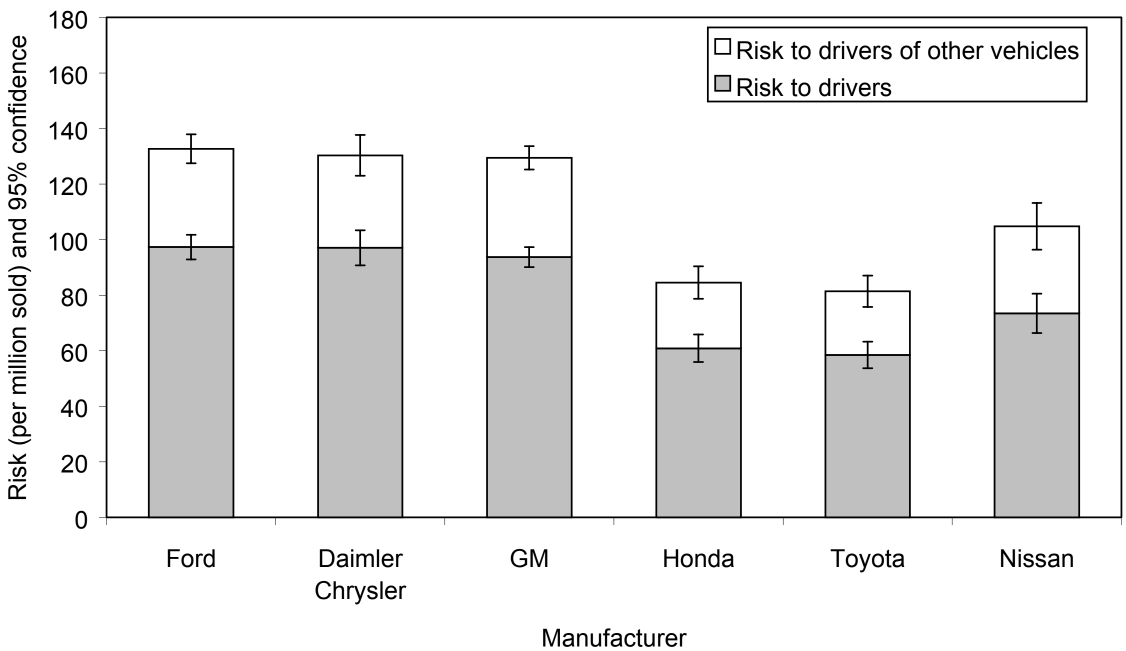
analyzed (626, Protegé, and Prizm) as domestic cars but the Toyota Corolla (a twin of the Geo Prizm) as a foreign model. We excluded the high-risk Geo Metro from the analysis.

10. The lines and whiskers in the figure represent the 95% confidence interval of the risk to drivers and the combined risk (the confidence intervals for the risks to drivers of other vehicles are not shown) .

approaching those of Honda and Toyota. This improvement is because DaimlerChrysler alone produced about one-third of all minivans sold in the United States between 1995 and 1999.

The results shown in Figures A5 and A6 do not appear to be biased by the relative fraction of risky drivers in each manufacturer's vehicles. For each car class shown in Figure A6, the foreign cars tend to have higher fractions of young male driver fatalities and lower fractions of elderly driver fatalities than the domestics. Across all car classes, Honda has a larger fraction of young male driver fatalities (25%) than the other manufacturers (14–18%), while Honda and Nissan have smaller fractions of elderly driver fatalities (11%) than the other manufacturers (18–27%). Since young male drivers appear to increase risk more than elderly drivers, discussed above, the risks of the foreign cars relative to those of the domestic cars are, if anything, slightly overstated in Figures A5 and A6.

Figure A6. Risk to Drivers and Risk to Drivers of Other Vehicles by Nameplate Manufacturer (60 Popular Car Models). Sum of risk to drivers and risk to other drivers is the combined risk. Whiskers represent 95% confidence intervals of risk to drivers and combined risk.



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