Dynamic Research, Inc.

AN ASSESSMENT OF THE EFFECTS OF VEHICLE WEIGHT ON FATALITY RISK IN MODEL YEAR 1985-98 PASSENGER CARS AND 1985-97 LIGHT TRUCKS

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We also express our thanks to R.L. Polk & Co. for providing us with licensed use of their National Vehicle Population Profile and vehicles in operation data. The vehicle registration data and any derivation thereof that includes a direct identification of vehicle registration units remains at all times the property of R.L. Polk & Co. The data shall not be republished, redistributed, used to create parallel databases or resold in any form whatsoever. The data is not warranted as error free and R. L. Polk & Co. shall not be held liable for any claims or damages resulting from the use of the licensed data.

Dynamic Research, Inc. staff members J. Boughton and S. Munoz assisted in reducing the induced-exposure data from the state crash data files. J. Boughton, S. Munoz, J. Brubacher, and P. Satrom and other DRI staff members also assisted in various aspects of the analysis, including preparing the VIN prefix tables, vehicle parameter data tables, and database

linkage tables.

Section I
INTRODUCTION

A. BACKGROUND

The effects of vehicle weight and size on overall safety are complex, involving human factors and vehicle crash avoidance, crashworthiness, and crash compatibility, in various types of crashes. There have been several studies regarding various aspects of effects of vehicle size and weight on safety during the last 10 years, most of which can be categorized as follows:

- Evans (Ref 1), IIHS (Ref 2), and others have reported that the occupants of lighter vehicles tend to have a higher risk of injury or fatality than do occupants of heavier vehicles, but do not address the effects of vehicle weight on the risks to other vehicle occupants or road users. These results were also cited and used by Crandall (Ref 3) and others.

- Joksch, et. al. (Refs 4 and 5) and others have investigated the relative risk of injury and fatality for the occupants of both vehicles involved in two-vehicle collisions (i.e. "vehicle collision compatibility"). Their results have indicated that the relative risk of occupant injury or fatality in the two vehicles is related to the weight ratio of the two vehicles, with occupants of the lighter vehicle tending to have more risk than the heavier vehicle. It was found that heavier vehicles tend to shift the risk of injury or fatality to the occupants of the lighter vehicle. However, these studies did not address the overall, net effects of vehicle weight on safety.

- Kahane, Partyka, and Hertz have investigated of effects of vehicle weight and size on the overall risk of injury and fatality, based on analysis 1985-93 passenger cars and light trucks in 1989-93 calendar year accident data, the results of which were summarized in Ref 6.

- Kahane reported on the effects of vehicle size and weight on US fatalities in Ref 7, and estimated that a 100 lb weight reduction would have resulted in a net increase of 262 fatalities (±159 fatalities, ±3-sigma value) in 1993 accidents. This was based on analysis of FARS data and traffic accident data from 11 states, for six crash types representing a majority of fatal crashes.

- Partyka reported on the effects of vehicle weight on serious or moderate injuries (AIS 2-6) in Refs 8 and 9, and estimated that a 100 lb weight reduction would have resulted in a net increase of 1222 (±859, 2-sigma) in AIS 2-6 injuries. This was based on analysis of driver injuries in NASS/CDS data, and did not include rollovers or collisions with pedestrians, bicyclists, or motorcyclists.

- Hertz reported on the effects of vehicle weight on less serious injuries in Ref 10, and estimated that a 100 lb weight reduction would have resulted in a net increase of 10,599 (±1518, 2-sigma) in these injuries. This was based on analysis of driver only injuries and fatalities in state accident data for Illinois (1990-92) and Florida (1991-93).

- Analyses of historical trends or other types of aggregate accident data (e.g. Coate 2001, Ref 11). These analyses generally do not address likely confounding factors such as driver experience, vehicle usage, or injury tolerance factors.

Results from these studies and others were reviewed and incorporated in the 2001 report on the effectiveness and impacts of Corporate Average Fuel Economy (CAFE) standards by the National Academy of Sciences (Ref 12).

B. OBJECTIVES

This report documents the results of a study to update the analysis of the effects of vehicle weight previously reported by NHTSA in Ref 7, using the latest available data.

The methodology used by Kahane in Ref 7 was selected because it was the broadest and most inclusive of any analysis to date on this subject. The Kahane 1997 analysis was widely referenced, used and relied upon, with some reservations, by both the majority and minority viewpoints in the National Academy of Sciences report (June 2001) on fuel economy measures (Ref 12), for example. The majority opinion stated that "*NHTSA's fatality analyses were most complete, in that they accounted for all crash types in which vehicles might be involved, for all involved road users, and for changes in crash likelihood as well as crashworthiness*" (p 2-24). The minority opinion stated that "*The most comprehensive assessment of the impacts of vehicle weight and size on traffic safety was undertaken by the National Highway Traffic Safety Administration, ... Because of its thoroughness, technical merit and comprehensiveness, it stands as the most substantial contribution to this issue to date.*" (p A-5).

The updated analyses are based on the most recent available data, and are presented in detail to enable verification by others.

C. DATA SOURCES

The analysis described herein involved the use of accident data, exposure data, and vehicle parameter data from many sources. These data include:

- 1995-99 Fatal Analysis Reporting System (FARS), providing coded information describing all fatal traffic accidents in the US, for calendar years 1995-99 (Ref 13).

- 1995-99 State crash data files, providing coded information describing reported traffic accidents in 7 states for calendar years

1995-99.

- R. L. Polk & Co. National Vehicle Population Profile (NVPP), providing numbers of registered vehicles by state, make, model, and body style, for calendar years 1995, 1997, and 1999. Passenger car curb weights were also derived from this database (Ref 14).

- Numerous other data sources, including data found in

  - Ward's Annual Almanacs (Ref 15),
  - NHTSA regulatory evaluation reports (Ref 16),
  - Automotive News Market Data Books (Ref 17),
  - NHTSA's Vehicle Parameter Database (Ref 18),
  - NASS/CDS databases for 1995-2000 calendar years (Ref 19).

D. REPORT ORGANIZATION

The organization of this report generally follows the format and topics found in Ref 7.

Section II describes the methodology used, including vehicle classification, accident data reduction, data linkage, and statistical methods.

Section III describes the assessment of fatalities per induced-exposure crashes in 7 states in accordance with Chapter 3 of Ref 7. The results of this analysis were used to determine the exogenous driver age and gender coefficients used in Section VI.

Section IV describes the assessment of induced-exposure crashes per vehicle registration year in accordance with Chapter 4 of Ref 7. The results of this analysis were also used to determine the driver age and gender coefficients in Section VI.

Section V describes the assessment of fatality risk in all 50 states plus the District of Columbia using the aggregate linear regression methods described in Chapter 5 of Ref 7.

Section VI describes the assessment of fatality risk in all 50 states plus the District of Columbia using exogenous coefficients for driver age and gender that were identified in Sections III and IV, using the methods described in Sections 5.5, 5.6, and Chapter 6 of Ref 7.

The results and conclusions are summarized in Chapter 7.

Section II
METHODOLGY

The analyses described herein involves the correlation of vehicle accident and exposure data with vehicle parameter data in order to empirically assess the effects of vehicle weight, using methods that were described in Ref 7, and extended to include the most recent available data.

A. VEHICLE CLASSIFICATION

In order to assess the risk of fatality vs vehicle weight, all road vehicles (and some off road vehicles) were classified according to the vehicle type and other identifiers described in Sections 2.2 and 6.3 and Appendices A-C of Ref 7. The top-level classification is vehicle type (VEHTYP), as listed in Table 2.1. Passenger cars (VEHTYP=1) and light trucks (including vans and SUVs) with Gross Vehicle Weight (GVW) $\leq$10,000 lbs (VEHTYP=2) were then classified according to the car or truck group (CG) and make and model (MM2) used in various NHTSA evaluation reports. Passenger cars were further classified by body type (BOD2) as listed in Table 2.2. Light trucks were also classified by truck type (TRKTYP) as listed in Table 2.3.

The vehicle types listed in Table 2.1 correspond to those described on page 136 of Ref 7. The vehicle type for 1981 or newer vehicles can usually be determined based on the first 10 characters of the Vehicle Identification Number (VIN), and in many cases only the first three characters are needed. A list of vehicle types vs the first three characters of the VIN are listed in Appendix A. This list was obtained by analysis of VINs occurring in the 1987-99 FARS databases, and verified against Appendix A of Ref 7.

The fundamental car group/truck group, make and model, body type, and truck type classification codes correspond to those used in various analyses at NHTSA, including the 1997 size and weight study. These car and truck classification codes can be determined from the first 10 characters of the VIN (available in the FARS or state crash data files) using algorithms supplied by C. Kahane. The VIN prefixes and applicable model years of each car group, make, and model are listed in Appendix B. The VIN prefixes and applicable model years for each light truck group, make, and model are listed in Appendix C.

Table 2.1 Basic Vehicle Types

VEHTYP	FARS BODY_TYP* (1991-99)	Description
1	1-9, 12	Passenger Cars
2	10-11, 14-49	Light Trucks (including vans, SUVs, and pickup cars) with GVW $\leq$ 10000
3	80-90	Motorcycles (including 2 wheel motor vehicles and ATVs)
4	50-79, 93	Medium and heavy trucks, buses, and vans (GVW > 10,000)
9	all other codes	Other/unknown

*Ref 7, page 136.

Table 2.2 Passenger Car Body Types

BOD2	Description
1	convertible
2	2 door coupe
3	3 door hatchback
4	4 door sedan
5	5 door hatchback
6	station wagon
7	2 door hardtop (not used)
8	other (not used)
9	Unknown (not used)

Table 2.3 Light Truck Types

TRKTYP	Description
1	Small Pickup Truck
2	Large Pickup Truck
3	Small SUV
4	Large SUV
5	Small Van
6	Large Van
7	Pickup Car
8	Other (not used)
9	Unknown (not used)

B. STATE DATA REDUCTION

State accident data were used to identify induced-exposure crashes, which were then used as a measure of vehicle accident exposure in the analyses described in Chapters 3 and 4. Induced-exposure crashes are vehicles that:

- were involved in a multiple vehicle collision,
- were stationary in the roadway for a legitimate reason before the collision,
- the driver of the vehicle was present,
- and the vehicle was hit by another vehicle.

Induced-exposure crashes are used as a measure of vehicle accident exposure because this data provides information about driver age and gender and other factors that are associated with fatality risk, that would not otherwise be available from some more widely used measures of exposure, such as vehicle registration years. Vehicle registration data is limited in this regard, as a measure of exposure, because it does not provide information about the driver of the vehicle, or other vehicle usage factors such as environmental conditions.

Induced-exposure crash data were obtained from accident data files from the seven states and calendar years listed in Table 2.4. These state accident data files met the following conditions:

- The data included 1995-99 calendar year traffic accidents.
- The data included the VIN of the vehicles involved in the crash, in order to identify and classify the vehicles using the methods described in the Section II.A.
- The data was available to Dynamic Research, Inc. in the time period this analysis was accomplished (July 2001 to January 2002).

Also listed in Table 2.4 are other states that were used in Ref 7 or might have been included in the analysis, and the reason that they are not included in this analysis. In general all five years of data were sought from and used for each of the states. The 1999 calendar year data for New Mexico were not used because only about 8% of the vehicles had VIN information.

Table 2.4. Induced-Exposure Crash Data States and Calendar Years

State		Calendar Years
FL	Florida (a)	1995-99
GA	Georgia	(d)
IL	Illinois (a)	1995-99
LA	Louisiana (a)	(b)
MD	Maryland (a)	1995-99
MI	Michigan (a)	(b)
MO	Missouri (a)	1995-99
NM	New Mexico (a)	1995-98
NC	North Carolina (a)	1995-99
OH	Ohio (a)	1995-99
PA	Pennsylvania (a)	(c)
UT	Utah (a)	(d)
	Total	34 State-Years

Notes:

(a) State data used in the 1989-93 calendar year study (Ref 7)

(b) VIN data not available for 1995-99 calendar years.

(c) Data request approved by state but have not yet been received.

(d) Data request declined by state.

The following criteria, based on Section 2.4 of Ref 7, were used to identify induced-exposure crash vehicles:

In general for all states,

- there were two or more vehicles in the collision,
- the induced-exposure case vehicle was a 1985-98 model year passenger car or 1985-97 model year light truck with a VIN that can be decoded using methods described in Section II.A,
- the age and gender of the induced-exposure vehicle driver were known, and
- the number of occupants in the induced-exposure vehicle was

known.

In addition, the following criteria was used on a state by state basis:

Florida	The vehicle maneuver must be "slowing/stopped/stalled" or "properly parked"; travel speed="0"; the vehicle condition was "no defects"; the vehicle fault code was "no fault"; the vehicle was not charged with moving violations; and the driver contributing cause is "no improper driving/action".
Illinois	The vehicle maneuver must be "slowing or stopping" or "parked", for any reason; and the striking/struck variable must be "struck vehicle".
Maryland	The vehicle maneuver must be "stopped in traffic lane" or "parked"; and the driver contributing circumstances did not include driver actions or vehicle defects.
Missouri	The vehicle maneuver must be "stopped" or "parked"; and the contributing circumstances must be "none".
N. Carolina	The vehicle maneuver must be "stopped" or "parked" for any reason; the estimated speed=0; the number of vehicle violations=0; the object struck must be "none" or "unknown"; and the vehicle condition must be "no defects" or "unknown".
Ohio	The vehicle must not be the vehicle "unit at fault"; the stated speed of the vehicle must be "stopped"; the object struck must be "nothing struck" or "not stated"; the driver action must be either "stopped to turn"; "stopped in traffic", or "parked", and the contributing factors must be "no driver errors" or not stated; and the driver citation must not be "Y".
New Mexico	The driver action must be either "stopped for traffic", "stopped

for sign/signal", or "parked"; the contributing factors must be "does not apply" or "none" with no other contributing factors; and the first harmful event must be either "other vehicle" or "parked vehicle".

The state, calendar year (CY), vehicle type (VEHTYP), car or truck group (CG), make and model (MM2), body type (BOD2) or truck type (TRKTYP), model year (MY), driver age (DAGE) and gender (DSEX), and the control variables NITE, SURCOND, SPDLIM55, and RURAL were determined for each qualifying induced-exposure crash based on the method described in Ref 7. The four control variables were derived from the state data as follows:

NITE equals 1 if the time of the crash was less than or equal to 7 A.M. or greater than 7 P.M.; 0 otherwise.

SURCOND equals 2 if the road surface was snowy or icy; 1 if the road surface was wet or other slippery condition; 0 otherwise.

SPDLIM55 equals 1 if the speed limit was 55 or higher; 0 otherwise. The speed limit was available for five of the seven states. Surrogate values were used for the other two states as follows:

Illinois - equals 1 if the class of trafficway is rural (except county and local roads and streets), or an urban controlled-access highway or toll road; 0 otherwise.

New Mexico - equals 1 if the roadway function class is "rural interstate", "rural arterial", "minor arterial – rural area"[1], or "urban interstate".

RURAL equals 1 if the accident location was rural; 0 otherwise. This

[1] According to Ref 20, pp 9 and 68, minor rural arterials should be expected to provide for relatively high travel speeds (e.g., a design speed of 70 mph).

value was determined based on the rural/urban variable in the data for Florida, N. Carolina, and Ohio; and roadway function class in Illinois and N. Mexico. The following surrogate values were used for the remaining two states:

Maryland - equals 1 if the accident did not occur within the limits of an incorporated municipality, 0 if it did.

Missouri - equals 1 if the accident occurred in an unincorporated area or a municipality with population less than 5,000[2].

The surrogate values for RURAL in Maryland were subsequently found to have very little variation between vehicles and little correlation with the RURAL values for the other states, and was therefore reset to 0. The RURAL value for Maryland was therefore treated in the same manner as the SPDLIM55 value in Michigan in Kahane 1997.

Table 2.4 lists the numbers of induced-exposure cases that were obtained based on these criteria by vehicle type and state.

[2] Urban areas are defined in AASHTO (Ref 20, p 8) as places with within boundaries having a population of 5,000 or more. Rural areas are those areas outside the boundaries of urban areas.

Table 2.5. Number of Induced-Exposure Crash Cases
by Vehicle Type and State[3]

State	Passenger Cars	Light Trucks
Florida	205,138	84,326
Illinois	155,137	64,894
Maryland	36,041	12,315
Missouri	56,402	27,383
New Mexico	12,598	9,874
North Carolina	74,460	32,845
Ohio	162,022	69,228
Total	701,798	300,865

As indicated in Ref 7, differences in the number of induced-exposure cases vary by state, calendar year, and vehicle type based on the number of registered vehicles in the state, accident reporting thresholds, and the number of calendar years of data.

C. FARS DATA REDUCTION AND ACCIDENT CLASSIFICATION

Fatal accident data were extracted and reduced from the 1995-99 FARS accident databases using the methods described in Sections 2.5 and 5.2 of Ref 7. The number of fatalities, two digit fatal crash type, state, calendar year (CY), vehicle type (VEHTYP), car or truck group (CG), make and model (MM2), body type (BOD2) or truck type (TRKTYP), model year (MY), driver age (DAGE) and gender (DSEX), and the control variables NITE, SURCOND, SPDLIM55, and RURAL were determined for each qualifying "case" vehicle

[3] The results previously reported to NHTSA staff on 15 January 2002 included 129 cases in N. Carolina with a "parking" or "unknown" maneuver, excluded 17 cases in Maryland with "pedestrian or cyclist action only" contributing circumstances, and were based on minor differences in the coding of SPDLIM55 and RURAL. SPDLIM55 = 1 included "rural county and local roads and streets" and did not include urban controlled access highways or urban toll roads in Illinois. SPDLIM55 = 1 also included minor arterials in rural areas in New Mexico. RURAL = 1 did not include local rural roads in New Mexico.

involved in a fatal accident. The qualifying case vehicles were 1985-98 model year passenger cars or 1985-97 model year light trucks with VIN decodable CG, MM2, BOD2, TRKTYP and MY. The fatal crash types were one of the 53 two-digit codes defined in Table 2-1 of Ref 7.

This involved the identification of the vehicle type (VEHTYP) for each vehicle involved in a one or two vehicle crash, creating a case for each qualifying "case" vehicle, and then determining the fatal crash type. The vehicle type was identified from the VIN, for 1981 and newer model year vehicles, or the FARS BODY_TYP variable, as described in Section II.A.

A case was then created for each qualifying "case" vehicle in the accident. If there were two qualifying vehicles in a two-vehicle collision, then two cases were created. One case was created with the first qualifying vehicle as the "case" vehicle and the second vehicle as the "other" vehicle, and another case with the second qualifying vehicle as the case vehicle and the first vehicle as the other vehicle.

The two digit crash type was determined according to Table 2-1 in Ref 7[4] based on the vehicle type, precrash maneuver (VEH_MAN), first and most harmful events (HARM_EV, M_HARM), initial impact point (IMPACT1), principal damage location (IMPACT2), and ROLLOVER variables of the case vehicle, and the vehicle type, precrash maneuver, and initial impact point of the other vehicle.

The 53 two digit crash type codes were then grouped into the seven fundamental crash types listed in Table 2.6. The first six of these groups are the subject of this analysis. The last group, "other" crashes, was not further analyzed because, in accordance with Ref 7, it includes crashes involving three or more vehicles, pedestrians with two or more vehicles, or crashes involving unknown types of vehicles, which would be difficult to correlate

[4] There was one minor exception, collisions with "other object not fixed" (M_HARM = 18) were excluded from impacts with fixed objects (two digit crash type codes 12-14) because they are not fixed objects.

with vehicle weight.

Table 2.6. Crash Type Groups
(From p. 90 of Ref 7)

Crash Type Group	Two Digit Crash Types
Principal rollover	11
Hit an object	12-17, 81
Hit a pedestrian, bike, or motorcycle	21, 22
Hit a big truck or bus	31-39
Hit a passenger car	41-59
Hit a light truck	61-79
Other	91, 98, 99

The numbers of vehicles involved in fatal accidents are listed in Table 2.7 for all 50 states by crash type group and vehicle type.

Table 2.7. Number of Case Vehicles Involved in Fatal Accidents by Crash Type and Vehicle Type

Crash Type Group	Passenger Cars	Light Trucks
Principal rollover	6,276	7,604
Hit an object	25,915	12,541
Hit a pedestrian, bike, or motorcycle	12,769	8,337
Hit a big truck or buss	8,245	4,038
Hit a passenger car	26,182	17,819
Hit a light truck	18,295	8,270
Other	19,275	11,228
Total	116,957	69,837

D. POLK DATA REDUCTION

The R. L. Polk & Co. National Vehicle Population Profile (NVPP) database provides the number of registered passenger cars and light trucks and passenger car curb weights by state, calendar year, make, model, model year, and body style description. It was necessary to transform the NVPP database into the numbers of registrations and curb weights by the CG, MM2, and BOD2 identifiers used throughout this analysis. This was accomplished by using the linkage tables listed in Appendices F and G. The linkage tables list the CG, MM2, and BOD2 identifiers corresponding to each NVPP make, model, body style, and model year used in the analysis. A blank value for the NVPP body style in the linkage table indicates that all of the body styles for the NVPP make and model have the same CG and MM2 codes and that the NVPP body styles were translated to the BOD2 values according to Table 2.8. Specific body styles were listed in the linkage table to differentiate between NVPP models that had different car groups (CG) depending on the body style, or had BOD2 translations that were different than the nominal values.

There was a small number cases in which the CG, MM2, and BOD2 could not be uniquely determined from the NVPP make, model, and body style, and therefore data for those CG, MM2, BOD2, and MY combinations were not included in the analysis. For example, the NVPP database did not distinguish between the 1985-88 Nissan 300 ZX (CG=3514) and 300 ZX 2+2 (CG=3515), and therefore data for these two vehicle models were not used in the analysis. Certain low production vehicles such as Ferraris and Rolls Royces do not have assigned CG, MM2, and BOD2 codes and data for these vehicles were not used.

Table 2.8. Nominal BOD2 Values Corresponding to NVPP Body Styles

BOD2	Description	NVPP Body Styles (s)
1	convertible	CONVERTIBLE
		ROADSTER
2	2 door coupe	2 DOOR HARDTOP
		2 DOOR SEDAN
		COUPE
		NOTCHBACK
		2 DR. PILLARED H/T
3	3 door hatchback	3 DOOR COUPE
		3 DOOR HATCHBACK
		3 DOOR LIFTBACK
		3 DOOR SEDAN
4	4 door sedan	4 DOOR HARDTOP
		4 DOOR SEDAN
		4 DR. PILLARED H/H
5	5 door hatchback	5 DOOR HATCHBACK
		5 DOOR LIFTBACK
6	station wagon	STATION WAGON

In cases where there was more than one NVPP make, model, and/or body style with the same CG, MM2, and BOD2 or TRKTYP variables, then the number of registrations were added together and the curb weight is the registration weighted average value.

NVPP data for the 1996 and 1998 calendar years was interpolated from adjacent calendar years according to the equation:

$$n_{i,my,cy} = n_{i,my,cy-1} + \left(\frac{N_{my,cy} - N_{my,cy-1}}{N_{my,cy+1} - N_{my,cy-1}} \right) \left(n_{i,my,cy+1} - n_{i,my,cy-1} \right)$$

where

$n_{i,my,cy}$ is the number of registered vehicles in the *i*th combination of CG/MM2/BOD2/Truck Type/State, *my* model year, and *cy* calendar year.

$N_{my,cy}$ is the total number of *my* model year vehicles registered in the *cy* calendar year, and

$$N_{my,cy} = \sum_i n_{i,my,cy}$$

The total numbers of registered vehicles by model year and calendar year ($N_{my,cy}$) were obtained from p 277 of the 2000 Ward's Automotive Yearbook (Ref 15).

Table 2.9 illustrates how this data interpolation method was used to estimate the numbers of 1995 vehicles that were registered in 1996 and 1998, given the overall number of vehicles in use. The number of registered vehicles 1 and 2 are example representative values. Values estimated from the foregoing equation are shown in *italics*. Note that the total number of 1995 model year vehicles registered in 1995 is less than the number in 1996 because some of the 1995 model year vehicles were not registered until after 1 July 1995. This interpolation method takes this effect into account and proportions the larger number of 1996 calendar year registrations to each of the vehicles.

Table 2.9. Registration Data Interpolation Example for 1995 Model Year Cars

1995 MY Car	Number of Registered Vehicles in Calendar Year				
	1995	1996	1997	1998	1999
Vehicle 1*	3,340	*5,060*	4,945	*4,932*	4,898
Vehicle 2*	3,538	*5,600*	5,462	*5,441*	5,385
:	:	:	:	:	:
Total **	6,030,000	9,179,000	8,968,000	8,926,000	8,811,000

*Hypothetical but representative values

**2000 Ward's Automotive Yearbook, p 277.

E. VEHICLE PARAMETER DATA

The following vehicle parameters were used to assess the effects of vehicle weight on overall safety:

CURBWT	- the vehicle curb weight (lbs),
DRAIRBAG	- the vehicle has a driver side airbag (0-1),
RFAIRBAG	- the vehicle has a right front passenger airbag (0-1),
AWD	- the percentage of vehicles with all-wheel or 4-wheel drive[5]/ 100%, and
FWD	- the percentage of vehicles with front-wheel drive / 100%.
ABS2	- the percentage of vehicles with two wheel anti-lock brakes / 100%,
ABS4	- the percentage of vehicles with four wheel anti-lock brakes / 100%,

Passenger car curb weights by car group (CG), make/model (MM2), body type (BOD2), and model year (MY) were obtained from the R. L. Polk & Co. National Vehicle Population Profile (NVPP) data. These weights were weighted averages based on 1999 calendar year registrations. Registration weighted average passenger car curb weights by CG, MM2, BOD2 category, and MY are listed in Appendix D.

Light truck curb weights by CG, MM2, truck type (TRKTYP), and MY were obtained from Appendix E of Ref 7 for the 1985-93 model years and supplemented by data found in Ward's Automotive Yearbooks. The data was edited for consistency between model years and differences between 2-wheel and 4-wheel drive. The light truck data used is listed in Appendix E.

5 No distinction was made, for the purposes of this analysis, between 4-wheel drive and all-wheel drive vehicles. The variable "AWD" is used rather than "4WD" in order to use a variable name that begins with a letter.

The availability of the driver and right front passenger airbags were determined for each vehicle based on analysis of the VIN, using algorithms supplied by C. Kahane. The DRAIRBAG and RFAIRBAG variables were coded with a 1 if the vehicle had an airbag in the driver side or right front passenger positions respectively, or 0 if it did not. The availability of driver and passenger airbags was determined on a case by case basis in the disaggregate analysis described in Section III. Average values for DRAIRBAG and RFAIRBAG by CG, MM2, body type or truck type, and model year were then determined from the induced-exposure crash data for use in the aggregate analyses described in Chapters 4 through 6.

Fundamental passenger car and light truck groups (CG) were assumed to be either front-wheel drive or rear-wheel drive in basic configuration. Within a car group, a percentage of passenger cars might be equipped 4-wheel drive, depending on the model (MM2) and model year (MY). The following equations illustrate the drive train lookup procedure for cars:

$$AWD \Leftarrow AWD_{table}(CG, MM2, MY)$$
$$FWD \Leftarrow FWD_{table}(CG) - AWD$$

where

AWD_{table}(CG,MM2,MY) is a lookup table of percentages of passenger cars with 4-wheel drive / 100%.

FWD_{table}(CG) is a lookup table coded with 1 if the basic drive train configuration of the car group was front-wheel drive, otherwise 0 if it was not.

The percentages of passenger cars with 4-wheel drive and the car group drive train configuration data used in this analysis are listed in Appendix H. The 4-wheel drive percentages were obtained from Ward's Automotive Yearbooks; supplemented by analysis of the FRTWLDR and FOURWLDR variables in the 1995-2000 NASS/CDS databases. If the percentage of cars with 4-wheel drive is not known for a particular CG, MM2, and MY, then it was assumed that 4-wheel drive was not available and AWD=0.

Light trucks models were assumed to be either 4-wheel drive or not, depending on MM2. This is based on the conventions used to assign the light truck MM2 codes. The following equations illustrate the drive train lookup procedure for light trucks:

$$AWD \Leftarrow AWD_{table}(CG, MM2)$$
$$FWD \Leftarrow FWD_{table}(CG) - AWD$$

where

AWD_{table}(CG,MM2) is a lookup table coded with 1 if the MM2 is 4-wheel drive, otherwise 0 if it is not, and

FWD_{table}(CG) is a lookup table coded with 1 if the basic truck group is front-wheel drive, otherwise 0 if it is not.

The percentages of cars and light trucks with ABS were determined by the CG, MM2, BOD2, and model year using lookup tables (Appendices I and J). The ABS data were gathered from the following sources, in decreasing order of priority:

- Appendix A of Ref 16 (1985-92 passenger cars),
- Ward's Automotive Yearbooks (factory installed equipment tables),
- Automotive News Annual Almanacs,
- The percentages of unweighted cases with ABS according to the ANTILOCK variable in the 1995-2000 NASS/CDS databases,
- The percentages of models with ABS in the NHTSA Vehicle Parameter Database.

It was assumed that passenger cars and light trucks did not have ABS prior to the 1989 model year, unless there was sufficient information about ABS installations from the sources indicated above. The values for ABS2 and ABS4 used in this analysis are tabulated in Appendices G and H.

F. STATISTICAL METHODS

The statistical methods used were the same as described in Ref 7, as follows:

- Logistic regression was used to assess the fatality risk per induced-exposure crash in Section III. Logistic regression analysis methods are described in Ref 21.

- Aggregate linear regression was used to assess the induced-exposure crash risk per vehicle-year in Section IV, and the fatality risk per vehicle-year in Chapters 5 and 6. Linear regression methods are described in Ref 22.

Section III
FATALITIES PER INDUCED-EXPOSURE CRASH IN 7 STATES

The risk of fatality per induced-exposure crash was assessed using 1995-99 calendar year data using the same methods described in Chapter 3 of Ref 7, in order to preview the effects of weight on fatality risk, and to determine the effects of driver age and gender on fatality risk for subsequent use in Section VI. This analysis involved combining the fatal accident cases (reduced according to Section 2.C) with the induced-exposure cases (reduced according to Section 2.B), selecting and calculating the logistic regression model variables, and estimating the logistic regression model coefficients.

A. LOGISTIC REGRESSION MODEL

The following logistic regression model was assumed that expresses the log-odds of a fatality as a linear combination of independent variables:

$$\log\left(\frac{F}{(IE+F)-F}\right)=\log\left(\frac{F}{IE}\right)=A_0+A_1\times CURBWT+\sum_{i=2}A_i\times V_i$$

where

F is the number of fatalities, where each fatality is treated as a separate case,

IE is the number of cases without a fatality (i.e., induced-exposure crash),

IE + F is the total number of cases,

V_i are the independent variables listed in Tables 3-1 and 3-2, and

A_i are the model coefficients to be estimated.

Given this assumed model form, the risk of fatality was assessed for each of the six fatal crash type groups using the variables listed in Table 3.1 for passenger cars and Table 3.2 for light trucks. These models included a relatively large number of possible risk factors, and this was possible because of the large numbers of degrees of freedom available in the disaggregate case by case data.

All of the variables except for the airbag variables were defined the same as in Ref 7. In particular, it was assumed that the basic shape of the fatality risk curves for driver age and gender were the same as illustrated in Fig 1-1 of Ref 7 and that the following variables defined would be used:

$$FEMALE = \begin{cases} 1 & for\ female\ drivers \\ 0 & for\ male\ drivers \end{cases}$$

$$YOUGDRV = \begin{cases} 35 - DAGE & if\ DAGE < 35 \\ 0 & for\ all\ other\ drivers \end{cases}$$

$$OLDMAN = \begin{cases} DAGE - 50 & for\ male\ drivers\ over\ 50 \\ 0 & for\ all\ other\ drivers \end{cases}$$

$$OLDWOMAN = \begin{cases} DAGE - 45 & for\ female\ drivers\ over\ 45 \\ 0 & for\ all\ other\ drivers \end{cases}$$

Separate airbag variables were defined for the driver and right front passenger because right front airbags were being phased in during the mid-1990s and achieved more than 50% market share in 1994 (Ref 23, Exhibit 2). DRAIRBAG was set to 1 if the vehicle had a driver side airbag, as determined by the VIN; 0 otherwise. RFAIRBAG was set to 1 if the vehicle had a right front passenger side airbag. RFAIRBAG was not included in the light truck regressions because it was highly correlated with DRAIRBAG.

All of the variables except CURBWT, YOUNGDRV, OLDMAN, OLDWOMAN, and VEHAGE were dichotomous variables. Dichotomous variables were set to 1 if true, as the variable name would indicate, or 0 otherwise. For example, IL would be set to 1 if the crash occurred in Illinois, or 0 if it did not. The dependent variable FATAL was set to 1 for the fatal case, and 0 for the induced-exposure crashes.

Table 3.1. Variables Used to Assess Passenger Car Fatality Risk per Induced-Exposure Crash

Independent Variables	Fatal Crash Type Group (run identifier)					
	Rollovers (3-C1)	Hit an Object (3-C2)	Hit a Ped-Bike-MC (3-C3)	Hit a Big Truck (3-C4)	Hit another Pass. Car (3-C5)	Hit a Light Truck (3-C6)
Intercept	Yes	Yes	Yes	Yes	Yes	Yes
CURBWT	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
YOUNDRV	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
OLDMAN	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
OLDWOMAN	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
FEMALE	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
NITE	Yes	Yes	Yes	Yes	Yes	Yes
SPDLIM55	Yes	Yes	Yes	Yes	Yes	Yes
CONVRTBL	Yes	Yes	Yes	Yes	Yes	Yes
TWODOOR	Yes	Yes	Yes	Yes	Yes	Yes
STAWAGON	Yes	Yes	Yes	Yes	Yes	Yes
VEHAGE	Yes	Yes	Yes	Yes	Yes	Yes
BRANDNEW	Yes	Yes	Yes	Yes	Yes	Yes
IL	Yes	Yes	Yes	Yes	Yes	Yes
MD	Yes	Yes	Yes	Yes	Yes	Yes
MO	Yes	Yes	Yes	Yes	Yes	Yes
NM	Yes	Yes	Yes	Yes	Yes	Yes
NC	Yes	Yes	Yes	Yes	Yes	Yes
OH	Yes	Yes	Yes	Yes	Yes	Yes
CY1996	Yes	Yes	Yes	Yes	Yes	Yes
CY1997	Yes	Yes	Yes	Yes	Yes	Yes
CY1998	Yes	Yes	Yes	Yes	Yes	Yes
CY1999	Yes	Yes	Yes	Yes	Yes	Yes
ABS4	Yes	Yes	Yes	Yes	Yes	Yes
AWD	Yes	Yes	Yes	Yes	Yes	Yes
FWD	Yes	Yes	Yes	Yes	Yes	Yes
WET	Yes	Yes	Yes	Yes	Yes	Yes
SNOW_ICE	Yes	Yes	Yes	Yes	Yes	Yes
DRAIRBAG	No	Yes	No	Yes	Yes	Yes
RFAIRBAG	No	Yes	No	Yes	Yes	Yes

Table 3.2. Variables Used to Assess Light Truck Fatality Risk per Induced-Exposure Crash

Independent Variable	Fatal Crash Type Group (run identifier)					
	Rollovers (3-T1)	Hit an Object (3-T2)	Hit a Ped-Bike-MC (3-T3)	Hit a Big Truck (3-T4)	Hit a Passenger Car (3-T5)	Hit another Light Truck (3-T6)
Intercept	Yes	Yes	Yes	Yes	Yes	Yes
CURBWT	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
YOUNDRV	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
OLDMAN	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
OLDWOMAN	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
FEMALE	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
NITE	Yes	Yes	Yes	Yes	Yes	Yes
SPDLIM55	Yes	Yes	Yes	Yes	Yes	Yes
SUV	Yes	Yes	Yes	Yes	Yes	Yes
VAN	Yes	Yes	Yes	Yes	Yes	Yes
VEHAGE	Yes	Yes	Yes	Yes	Yes	Yes
BRANDNEW	Yes	Yes	Yes	Yes	Yes	Yes
IL	Yes	Yes	Yes	Yes	Yes	Yes
MD	Yes	Yes	Yes	Yes	Yes	Yes
MO	Yes	Yes	Yes	Yes	Yes	Yes
NM	Yes	Yes	Yes	Yes	Yes	Yes
NC	Yes	Yes	Yes	Yes	Yes	Yes
OH	Yes	Yes	Yes	Yes	Yes	Yes
CY1996	Yes	Yes	Yes	Yes	Yes	Yes
CY1997	Yes	Yes	Yes	Yes	Yes	Yes
CY1998	Yes	Yes	Yes	Yes	Yes	Yes
CY1999	Yes	Yes	Yes	Yes	Yes	Yes
ABS2	Yes	Yes	Yes	Yes	Yes	Yes
ABS4	Yes	Yes	Yes	Yes	Yes	Yes
AWD	Yes	Yes	Yes	Yes	Yes	Yes
WET	Yes	Yes	Yes	Yes	Yes	Yes
SNOW_ICE	Yes	Yes	Yes	Yes	Yes	Yes
DRAIRBAG	No	Yes	No	Yes	Yes	Yes

B. REDUCTION OF THE INDUCED-EXPOSURE DATA

There were 701,798 passenger cars and 300,865 light trucks in the induced-exposure cases extracted from the state data files, with varying accident-reporting thresholds. For the purposes of the logistic regression analysis described in this Section, and in accordance with Ref 7, the number of induced-exposure cases were reduced on a state and calendar year basis to achieve a uniform ratio of 333 $^{1}/_{3}$ fatalities per 1000 induced-exposure crashes. The ratio of 1 fatality per 3 induced exposure crashes was selected in order to achieve a reduced number of induced-exposure crashes that were comparable to the number of cases used in Ref 7. The number of fatalities and the reduced number of induced-exposure crash cases are listed by vehicle type in Table 3.3.

The reduction in the number of cases was achieved by decimation in order to obtain a repeatable, uniformly distributed subsample of the induced-exposure cases. If, for example, there were 1,000 fatalities and 12,000 induced-exposure cases in a particular state and calendar year, then the desired number of induced-exposure cases would be 3,000. These 3,000 cases would have been selected from every 4th case in the induced-exposure file.

Table 3.3. Number of Fatalities and Reduced Number of Induced-Exposure Crash Cases (1995-99, 7 states)

Vehicle Type	Number of fatalities	Reduced number of induced-exposure crashes
Passenger cars	33,036	99,220
Light trucks	16,910	50,719

C. PASSENGER CAR LOGISTIC REGRESSION RESULTS

Logistic regressions were done using fatal and induced-exposure cases, in which the “case” vehicle was a passenger car, for each of the six fatal crash type groups listed in Table 2.6. The dependent variable for each regression was FATAL, which was coded as 1 for each fatality, and 0 for each induced-exposure case. The dependent variables that were used for each fatal crash type group are listed in Table 3.1.

Table 3.4 lists the regression results for passenger car rollovers, referred to as run 3-C1 (for Section III, cars, fatal crash group 1). 100,447 cases were used in this regression, comprising 1,227 rollover fatalities and 99,220 induced-exposure cases in 7 states. The independent variables are listed in the first column and the resulting regression coefficient, standard error, Wald Chi-Square statistic, and the probability value for each value listed in the last four columns. These results for the 1995-99 calendar years are in generally good agreement with the results for 1989-93 listed in Table 3-1 of Ref 7, taking into consideration the differences in the states and calendar years used. One exception is the coefficient for OLDMAN; the new value is not statistically significantly different from 0, which would suggest that any increased vulnerability to fatal injury in older drivers is offset by less risk taking tendency and increased driving experience. The coefficients for both older men and women indicate a possible downward trend compared to Ref 7.

Table 3.4. Logistic Regression Results for Passenger Car Principal Rollover Fatalities

Run 3-C1
(Compare to Table 3-1 in Kahane 1997)

Logistic Regression of Passenger Car Principal rollover Fatalities

Based on data for:
1995 to 1999 calendar years
1985 to 1998 model years
7 states: FL IL MD MO NM NC OH

FATAL	Count	
0	99220	(induced-exposure involvement)
1	1227	(fatalities)
N of Observations:	100447	

-2 Log likelihood (Deviance)= 9244.12

Indep. Variable	Regression Coefficient	Standard Error	Wald Chi-Square	Pr > Chi-Square
INTERCPT	-6.5339	0.3274	398.2475	0.0000
CURBWT	**-0.000170**	**0.000087**	**3.8149**	**0.0508**
YOUNGDRV	**0.08962**	**0.00487**	**339.1490**	**0.0000**
OLDMAN	**0.00275**	**0.00822**	**0.1117**	**0.7383**
OLDWOMAN	**0.04573**	**0.00709**	**41.6263**	**0.0000**
FEMALE	**-0.8993**	**0.0691**	**169.4761**	**0.0000**
NITE	1.0228	0.0660	240.2896	0.0000
SPDLIM55	3.2029	0.0725	1949.1218	0.0000
CONVRTBL	0.8236	0.1916	18.4816	0.0000
TWODOOR	0.5081	0.0688	54.5638	0.0000
STAWAGON	0.2722	0.1783	2.3303	0.1269
VEHAGE	0.0728	0.0115	40.3672	0.0000
BRANDNEW	0.1852	0.1377	1.8098	0.1785
IL	-0.2520	0.0951	7.0283	0.0080
MD	-1.1022	0.2315	22.6624	0.0000
MO	0.3129	0.1018	9.4463	0.0021
NM	1.5822	0.1270	155.1559	0.0000
NC	0.3618	0.0958	14.2772	0.0002
OH	-0.5802	0.1257	21.3225	0.0000
CY1996	-0.0770	0.0982	0.6148	0.4330
CY1997	0.0718	0.0984	0.5326	0.4655
CY1998	-0.0839	0.1000	0.7041	0.4014
CY1999	-0.0601	0.1059	0.3220	0.5704
ABS4	0.4715	0.1045	20.3767	0.0000
AWD	0.5630	0.4950	1.2934	0.2554
FWD	0.0411	0.0999	0.1696	0.6805
WET	-0.8796	0.1034	72.3461	0.0000
SNOW_ICE	-0.0615	0.2222	0.0767	0.7818

Table 3.5 lists the regression results for passenger cars hitting pedestrians, bicyclists or motorcyclists (Run 3-C3). The format of these results is the same as for rollovers. There were 3,540 fatalities involving a car hitting a smaller road user, and the number of induced-exposure cases remains the same as before, 99,220. Again, these results are in generally good agreement with the results for the 1989-93 calendar years listed in Table 3-3 of Ref 7.

Table 3.5. Logistic Regression Results for Passenger Car Hit Pedestrian-Bike-Motorcycle Fatalities

```
Run 3-C3
(Compare to Table 3-3 in Kahane 1997)

Logistic Regression of Passenger Car Ped-bike-motorcycle Fatalities

Based on data for:
   1995 to 1999 calendar years
   1985 to 1998 model years
    7 states: FL IL MD MO NM NC OH

           FATAL         Count
             0           99220  (induced-exposure involvement)
             1            3540  (fatalities)
  N of Observations:    102760

  -2 Log likelihood (Deviance)=  28839.3
```

Indep. Variable	Regression Coefficient	Standard Error	Wald Chi-Square	Pr > Chi-Square
INTERCPT	-3.7227	0.1810	422.8109	0.0000
CURBWT	**0.000153**	**0.000048**	**10.0444**	**0.0015**
YOUNGDRV	**0.04666**	**0.00291**	**256.6148**	**0.0000**
OLDMAN	**0.02638**	**0.00294**	**80.2820**	**0.0000**
OLDWOMAN	**0.03024**	**0.00318**	**90.7090**	**0.0000**
FEMALE	**-0.5582**	**0.0397**	**197.1811**	**0.0000**
NITE	-0.0826	0.0467	3.1363	0.0766
SPDLIM55	0.9488	0.0414	525.6378	0.0000
CONVRTBL	-0.0961	0.1414	0.4618	0.4968
TWODOOR	0.0329	0.0411	0.6435	0.4224
STAWAGON	0.0868	0.0885	0.9636	0.3263
VEHAGE	0.07199	0.00639	126.8781	0.0000
BRANDNEW	0.0555	0.0835	0.4423	0.5060
IL	-0.5884	0.0536	120.6679	0.0000
MD	-0.0354	0.0640	0.3058	0.5803
MO	-1.0730	0.0772	193.3226	0.0000
NM	-0.4718	0.1146	16.9551	0.0000
NC	-0.3921	0.0520	56.9189	0.0000
OH	-0.7092	0.0614	133.3621	0.0000
CY1996	-0.0583	0.0536	1.1833	0.2767
CY1997	-0.1382	0.0550	6.3222	0.0119
CY1998	-0.1972	0.0553	12.7327	0.0004
CY1999	-0.3345	0.0587	32.4594	0.0000
ABS4	-0.0992	0.0625	2.5240	0.1121
AWD	-0.2821	0.3539	0.6353	0.4254
FWD	-0.0715	0.0558	1.6417	0.2001
WET	-0.8446	0.0558	228.9743	0.0000
SNOW_ICE	-1.1877	0.2391	24.6760	0.0000

Table 3.6 summarizes the effects of a 100 lb reduction in the weight of the “case” car curb weight on the fatality risk relative to induced exposure. These values are the curb weight coefficients x -100 lbs x 100%. The “case” vehicle terminology is used to distinguish between the vehicle for which the curb weight and other risk factors are known and is the subject of the analysis, and the “other” vehicle that is not further specified. Again there is good agreement with the results for 1995-99 and 1989-93 calendar years (Table 3-2 of Ref 7), with a slight downward trend (fewer fatalities associated with weight reduction) overall.

Table 3.6. Effects of a 100 lb “Case” Car Curb Weight Reduction on the Risk of Fatality per Induced-Exposure Crash.

Crash Type Group	1995-99 Result		1989-93 Result*	
	% change per 100 lb weight reduction	X^2	% change per 100 lb weight reduction	X^2
Principal Rollover	1.70	3.81	2.48	6.50
Hit object	1.03	6.66	1.91	17.36
Ped-Bike-Motorcycle	-1.53	10.04	-1.00	3.45
Hit big truck	3.12	24.36	2.62	13.12
Hit passenger car	-0.62	3.14	0.78	4.57
Hit light truck	2.31	26.65	3.17	34.53

* From Table 3-2 of Ref 7.

D. LIGHT TRUCK LOGISTIC REGRESSION RESULTS

Logistic regressions were also done for light trucks for each of the six fatal crash type groups. The dependent variables listed in Table 3.2 were used for these regressions.

Table 3.7 lists the regression results for light truck car rollovers (Run 3-T1). The format for these results is the same as for passenger cars. This regression used 52,245 cases, comprising 1,526 rollover fatalities and 50,719 induced-exposure cases. These results for the 1995-99 calendar years are in generally good agreement with the results for 1989-93 listed in Table 3-4 of Ref 7. Note that the CURBWT coefficient is not statistically significantly different from 0 at the 5% probability level in either the 1989-93 and 1995-99 results. The coefficients for both older men and women have a downward trend, compared to Kahane 1997, which is similar to the trend observed for passenger cars.

Table 3.7. Logistic Regression Results for Light Truck Principal Rollover Fatalities

Run 3-T1
(Compare to Table 3-4 in Kahane 1997)

Logistic Regression of Light Truck Principal rollover Fatalities

Based on data for:
1995 to 1999 calendar years
1985 to 1997 model years
7 states: FL IL MD MO NM NC OH

FATAL	Count	
0	50719	(induced-exposure involvement)
1	1526	(fatalities)
N of Observations:	52245	

-2 Log likelihood (Deviance)= 8959.84

Indep. Variable	Regression Coefficient	Standard Error	Wald Chi-Square	Pr > Chi-Square
INTERCPT	-5.8662	0.2201	710.2559	0.0000
CURBWT	**-0.000063**	**0.000056**	**1.2702**	**0.2597**
YOUNGDRV	**0.07452**	**0.00473**	**248.5498**	**0.0000**
OLDMAN	**0.02013**	**0.00687**	**8.5911**	**0.0034**
OLDWOMAN	**0.0118**	**0.0122**	**0.9451**	**0.3310**
FEMALE	**-0.0977**	**0.0713**	**1.8780**	**0.1706**
NITE	1.0141	0.0662	234.5902	0.0000
SPDLIM55	3.5220	0.0733	2310.7237	0.0000
SUV	0.5925	0.0803	54.4605	0.0000
VAN	-0.0356	0.0925	0.1479	0.7006
VEHAGE	0.0878	0.0126	48.5461	0.0000
BRANDNEW	0.3105	0.1318	5.5475	0.0185
IL	-0.9553	0.0976	95.8435	0.0000
MD	-1.0329	0.1744	35.0598	0.0000
MO	-0.4085	0.0940	18.8877	0.0000
NM	1.0230	0.0999	104.8323	0.0000
NC	-0.5007	0.0953	27.6144	0.0000
OH	-1.3257	0.1288	105.8580	0.0000
CY1996	-0.2073	0.0943	4.8320	0.0279
CY1997	-0.0837	0.0916	0.8342	0.3611
CY1998	-0.2440	0.0992	6.0529	0.0139
CY1999	-0.1721	0.1029	2.7976	0.0944
ABS2	0.2185	0.0905	5.8225	0.0158
ABS4	0.2535	0.1282	3.9067	0.0481
AWD	0.1911	0.0802	5.6819	0.0171
WET	-1.0715	0.1077	98.9914	0.0000
SNOW_ICE	0.7345	0.1476	24.7664	0.0000

Table 3.8 summarizes the effects of a 100 lb reduction in the weight of the “case” light truck curb weight on the fatality risk relative to induced exposure. Again there is generally good agreement with the results for 1995-99 and 1989-93 calendar years (Table 3-5 of Ref 7), with a slight trend towards decreasing overall effect of light truck weight.

Table 3.8. Effects of a 100 lb “Case” Light Truck Curb Weight Reduction on Risk of Fatality per Induced-Exposure Crash.

Crash Type Group	1995-99 Result		1989-93 Result*	
	% change per 100 lb weight reduction	X^2	% change per 100 lb weight reduction	X^2
Principal Rollover	0.63	1.27	-0.80	1.42
Hit object	-0.14	0.11	-1.30	6.84
Ped-Bike-Motorcycle	-2.51	36.27	-4.40	80.07
Hit big truck	0.65	0.92	0.49	0.37
Hit passenger car	-3.25	121.51	-3.40	101.91
Hit light truck	-2.00	18.45	-3.30	31.96

* From Table 3-5 of Ref 7.

Section IV
INDUCED-EXPOSURE CRASHES PER VEHICLE YEAR IN 7 STATES

The risk of induced-exposure crash per vehicle registration year was assessed using the same methods described in Chapter 4 of Ref 7, in order to quantify and correct for possible biases in the fatality rates based on induced-exposure, due to vehicle weight, driver age and gender, and other factors. The driver age and gender coefficients from this step are then used in the analysis described in Section VI.

A. METHOD

The effects of vehicle weight on the risk of induced-exposure crash per vehicle registration year were assessed using the aggregate linear regression method described in Chapter 4 of Ref 7. This involved aggregating the induced-exposure crash cases into cells having corresponding vehicle registration data, calculating the induced-exposure crash involvement rate per vehicle registration year, and fitting the logarithm of the crash involvement rate to the vehicle, driver, and environmental factors.

This was accomplished by linear regression in two steps in order to achieve a good compromise between the number of cells, the cell size, and number of regression variables. More cells are desirable in order to increase the degrees of freedom in the regression. Larger cells are desirable in order to calculate meaningful crash rates, provided the cells comprise a homogenous set of vehicles and other factors. Regressions with too many variables can be overparameterized, resulting in large coefficient standard deviations, and a lack of predictive capability.

For each regression step the original induced-exposure crash cases (all 1,002,663 cases before reduction) were aggregated into to cells. This involved counting the number of induced-exposure crash cases and calculating the average values for the independent variables (.e.g., CURBWT, YOUNGDRV) in each cell. The number of induced-exposure crash cases used in the Step 2 regression were adjusted based on the results from the Step 1 regression. Variables such as SPDLIM55 and ABS4, which had values of 0 or 1 in the disaggregate analysis in Section III, have real values between 0 and 1 in this aggregate analysis, representing the portion of vehicles in the cell with these factors present. The data for Maryland was not used to calculate the average values for RURAL. The dependent variable in each cell is LOGRATE, the natural logarithm of the induced-exposure crash rate; the induced-exposure crash rate is the number of induced-exposure cases divided by the number of vehicle registration years (REGS). Each cell was weighted by REGS as was done in Ref 7.

The aggregated values for the driver age and gender were also used in the analysis described in Sections V and VI.

B. PASSENGER CAR RESULTS

The regressions for passenger cars were accomplished in two steps according to the method described in Section 4.4 of Ref 7. The Step 1 regression results are listed in Table 4.1, and are comparable to the results in Table 4-1 of Ref 7, except for differences in states and calendar years. Two categorical variables were also added for 1996 Illinois data and 1998 Ohio data because there were fewer induced-exposure cases for these years compared to the other years, and the magnitude of the coefficient values confirms this. The Step 1 results are based on 434 state-calendar year-model year aggregate cells, up from the 318 cells in the Kahane 1997 report mainly because the number of model years increased. This data for 7 states represents 115 million vehicle registration years, 23.3% of the 1985-98 passenger cars registered in the US in the 1995-99 time period. The data in each cell is weighted by the number of vehicle registration years in the cell. The R^2 value for this regression is 0.92, down slightly from Kahane's 0.96. This may also be due to the increased model year range in the data, and the nearly complete state-calendar year matrix in the 1995-99 data.

The Step 2 regression results for rollovers are listed in Table 4.2, and are comparable to the results for 1989-93 in Table 4-3 of Ref 7. These results are based on 2785 CG-MM2-BOD2-MY aggregate cells, up from the 1879 cells in the 1997 Kahane report. Again the increased number of cells is attributed to the increased number of model years. The Step 2 regressions were also weighted by the number of vehicle registration years in each cell. The R^2 value for this regression is 0.42.

Table 4.1. Aggregate Linear Regression of Passenger Car Induced-Exposure Crashes per Vehicle Registration Year, Step 1 Results

Run 4-C1
(Compare to Table 4-1 in Kahane 1997)
Passenger Car: Aggregate Linear Regression
of Induced-Exposure Crashes per 1000 Vehicle Registration Years

Step 1: By Vehicle Age, State and Calendar Year

Dependent Variable: LOGRATE
Aggregation Method: by State, Calandar Year and Model Year

Based on data for:
1995 to 1999 calendar years
1985 to 1998 model years
7 states: FL IL MD MO NM NC OH
114669260 vehicle registration years, 23.3%

NOBS = 434
NDOF = 419
R2 = 0.921

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-4.66797	(0.03353)	-273.70	0.0000	0.01706
VEHAGE	-0.069811	(0.003024)	-45.38	0.0000	0.001538
BRANDNEW	-0.07125	(0.04945)	-2.83	0.0046	0.02515
IL	0.00230	(0.03180)	0.14	0.8867	0.01618
MD	-0.68237	(0.03846)	-34.87	0.0000	0.01957
MO	-0.11900	(0.03999)	-5.85	0.0000	0.02034
NM	-0.03515	(0.07991)	-0.86	0.3872	0.04065
NC	-0.17930	(0.03537)	-9.97	0.0000	0.01799
OH	0.17317	(0.03236)	10.52	0.0000	0.01646
CY1996	-0.00683	(0.03546)	-0.38	0.7051	0.01804
CY1997	0.04046	(0.03258)	2.44	0.0146	0.01658
CY1998	0.08107	(0.03473)	4.59	0.0000	0.01767
CY1999	0.01374	(0.03304)	0.82	0.4136	0.01681
IL-CY96	-0.42902	(0.06245)	-13.51	0.0000	0.03177
OH-CY98	-0.87943	(0.06120)	-28.25	0.0000	0.03114

Table 4.2. Aggregate Linear Regression of Passenger Car Induced-Exposure Crashes per Vehicle Registration Year, Step 2 Results

Run 4-C2
(Compare to Table 4-2 in Kahane 1997)
Passenger Car: Aggregate Linear Regression
of Induced-Exposure Crashes per 1000 Vehicle Registration Years

Step 2: By Curb Weight, Controlling for Driver Age, Sex
And other vehicle and accident factors

Dependent Variable: LOGRATE
Aggregation Method: by Car Group, Make-Model, Body Style, and Model Year

Based on data for:
1995 to 1999 calendar years
1985 to 1998 model years
7 states: FL IL MD MO NM NC OH
114323954 vehicle registration years, 23.2%

NOBS = 2785
NDOF = 2771
R2 = 0.424

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-4.8687	(0.1399)	-68.25	0.0000	0.0713
CURBWT	**0.00005038**	**(0.00002178)**	**4.54**	**0.0000**	**0.00001111**
YOUNGDRV	**0.028974**	**(0.007099)**	**8.00**	**0.0000**	**0.003620**
OLDMAN	**-0.047314**	**(0.009551)**	**-9.71**	**0.0000**	**0.004871**
OLDWOMAN	**-0.03170**	**(0.01048)**	**-5.93**	**0.0000**	**0.00535**
FEMALE	**0.2161**	**(0.1031)**	**4.11**	**0.0000**	**0.0526**
NITE	0.5995	(0.2313)	5.08	0.0000	0.1179
RURAL	-0.4122	(0.1844)	-4.38	0.0000	0.0940
CONVRTBL	-0.34457	(0.04953)	-13.64	0.0000	0.02526
TWODOOR	-0.12605	(0.02000)	-12.36	0.0000	0.01020
STAWAGON	-0.06666	(0.03431)	-3.81	0.0001	0.01750
SPDLIM55	-0.1833	(0.2402)	-1.50	0.1346	0.1225
WET	0.0638	(0.2088)	0.60	0.5492	0.1065
SNOW_ICE	-0.6789	(0.5902)	-2.26	0.0241	0.3010

C. LIGHT TRUCK RESULTS

The regressions for light trucks were also accomplished in two steps. The regression results for light trucks are listed in Tables 4.3 and 4.4, and are comparable to the results for 1989-93 in Tables 4-4 and 4-5 of Kahane 1997. This data for 7 states represents 49 million vehicle registration years, 17.9% of the 1985-97 trucks (including larger trucks) registered in the US in the 1995-99 time period. This percentage is less than passenger cars because only light trucks are considered here, and also because vans over 4,000 lbs and incomplete pickups were excluded according to pages 17 and 65 of Ref 7.

Table 4.3. Aggregate Linear Regression of Light Truck Induced-Exposure Crashes per Vehicle Registration Year, Step 1 Results

```
Run 4-T1
(Compare to Table 4-4 in Kahane 1997)
Light Truck: Aggregate Linear Regression
of Induced-Exposure Crashes per 1000 Vehicle Registration Years
(excluding vans weighing over 4000 lbs)

Step 1: By Vehicle Age, State and Calendar Year

Dependent Variable: LOGRATE
Aggregation Method: by State, Calandar Year and Model Year

Based on data for:
    1995 to 1999 calendar years
    1985 to 1997 model years
     7 states: FL IL MD MO NM NC OH
     48996669 vehicle registration years,  17.9%

NOBS   =   421
NDOF   =   406
R2     = 0.922
```

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-4.74665	(0.03554)	-262.55	0.0000	0.01808
VEHAGE	-0.072555	(0.003230)	-44.16	0.0000	0.001643
BRANDNEW	-0.09216	(0.05291)	-3.42	0.0006	0.02691
IL	0.07452	(0.03558)	4.12	0.0000	0.01810
MD	-0.80777	(0.04321)	-36.75	0.0000	0.02198
MO	-0.26894	(0.03890)	-13.59	0.0000	0.01979
NM	-0.08310	(0.06279)	-2.60	0.0093	0.03194
NC	-0.32848	(0.03575)	-18.06	0.0000	0.01819
OH	0.16232	(0.03491)	9.14	0.0000	0.01776
CY1996	0.00284	(0.03699)	0.15	0.8801	0.01882
CY1997	0.07666	(0.03430)	4.39	0.0000	0.01745
CY1998	0.14108	(0.03709)	7.48	0.0000	0.01887
CY1999	0.11590	(0.03583)	6.36	0.0000	0.01822
IL-CY96	-0.39714	(0.06994)	-11.16	0.0000	0.03558
OH-CY98	-0.78998	(0.06560)	-23.67	0.0000	0.03337

Table 4.4. Aggregate Linear Regression of Light Truck Induced-Exposure Crashes per Vehicle Registration Year, Step 2 Results

```
Run 4-T2
(Compare to Table 4-5 in Kahane 1997)
Light Truck: Aggregate Linear Regression
of Induced-Exposure Crashes per 1000 Vehicle Registration Years

Step 2: By Curb Weight, Controlling for Driver Age, Sex
And other vehicle and accident factors

Dependent Variable: LOGRATE
Aggregation Method: by Car Group, Make-Model, Body Style, and Model Year

Based on data for:
    1995 to 1999 calendar years
    1985 to 1997 model years
     7 states: FL IL MD MO NM NC OH
     48591880 vehicle registration years,  17.8%

NOBS   =  1700
NDOF   =  1689
R2     = 0.396
```

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-3.7807	(0.1700)	-43.63	0.0000	0.0867
CURBWT	**-0.00019913**	**(0.00002750)**	**-14.20**	**0.0000**	**0.00001402**
YOUNGDRV	**-0.01554**	**(0.01420)**	**-2.15**	**0.0318**	**0.00724**
OLDMAN	**-0.04805**	**(0.01914)**	**-4.93**	**0.0000**	**0.00976**
OLDWOMAN	**-0.06540**	**(0.04647)**	**-2.76**	**0.0058**	**0.02369**
FEMALE	**0.4067**	**(0.1478)**	**5.40**	**0.0000**	**0.0753**
NITE	0.4577	(0.3090)	2.91	0.0037	0.1576
RURAL	-1.0361	(0.1978)	-10.27	0.0000	0.1008
SUV	0.08673	(0.04434)	3.84	0.0001	0.02261
VAN	-0.08814	(0.04732)	-3.65	0.0003	0.02412
AWD	-0.12439	(0.03329)	-7.33	0.0000	0.01697

D. EFFECTS OF A 100 LB WEIGHT REDUCTION ON THE RISK OF FATALITY PER VEHICLE REGISTRATION YEAR

The effects of a 100 lb weight on the risk of fatality per **vehicle registration year** can now be calculated from the risk of fatality per induce-exposure crash and the risk of induced-exposure crash per vehicle registration year, based on the derivation in Section 5.5 of Ref 7. The effective CURBWT coefficient for fatalities per vehicle registration year is the sum of the CURBWT regression coefficient from this Section and the CURBWT coefficient from Section III. For example, a 100 lb curb weight reduction results in an estimated +1.70% change in the risk of fatality per induced-exposure crash, and an estimated -0.50% change in the risk of induced-exposure crash per vehicle registration year, therefore the estimated change in the risk of fatality per vehicle registration year is 1.20%. The results are listed in Table 4.5.

Table 4.5. Effects of a 100 lb Reduction in the "Case" Vehicle Curb Weight on the Risk of Fatality per Vehicle Registration Year, Based on 7 or 11 States

Crash Type Group	% change per 100 lb weight reduction			
	1995-99 Result		1989-93 Result*	
	Cars	Light Trucks	Passenger Cars	Light Trucks
Principal Rollover	1.20	2.62	2.75	1.70
Hit object	0.53	1.85	2.18	1.20
Ped-Bike-Motorcycle	-2.03	-0.52	-0.73	-1.90
Hit big truck	2.62	2.64	2.89	2.99
Hit passenger car	-1.12	-1.26	1.05	-0.90
Hit light truck	1.81	-0.01	3.44	-0.80

* From table on page 78 of Ref 7.

Section V
FATALITIES PER VEHICLE YEAR IN THE UNITED STATES, INITIAL APPROACH

As stated in Section I, the objective is to assess the effects of a reduction in vehicle weight on the risk of fatality in all crashes in the United States. The analyses in Sections III and IV were based on data for only seven states. At the US level, vehicle registration years are a readily available and commonly used measure of exposure. Induced-exposure data as defined for this analysis were not available for the remaining states. Other measures such as vehicle miles traveled and person miles traveled might provide a better measure of risk exposure, but are difficult to measure at the level of detail and accuracy needed for this type of analysis.

A. METHOD

The effects of vehicle weight on the fatality risk per vehicle registration year were initially assessed using aggregate linear regressions as described in Chapter 5 of Ref 7. This involved fitting the data in two steps, similar to the approach used in Section IV.

The first step involved aggregating the data in order to estimate and remove the effects of vehicle age, state group, and calendar year. The same state groups used in Ref 7 were used in this analysis, which is repeated here in Table 5.1. The second step involved re-aggregating the data in order to estimate the effects of vehicle curb weight while controlling for other factors.

The variables used in each of the regressions are listed in Table 5.2 and 5.3. The values in the table indicate whether the variable was used in Step 1 or 2, or not at all.

Table 5.1. State Groups

State Group	States*
1	Colorado, Connecticut, Hawaii, Iowa, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, North Dakota, Ohio, Rhode Island, Virginia, Washington
2	Alaska, Illinois, Maine, Michigan, Nebraska New York, Oregon, Pennsylvania, South Dakota Wisconsin
3	California, Delaware, District of Columbia, Idaho Indiana, Kansas, Montana, Oklahoma, Utah, Vermont
4	Florida, Georgia, Missouri, Tennessee, Texas, Wyoming
5	Alabama, Arizona, Arkansas, Kentucky, Louisiana, Mississippi, Nevada, New Mexico, North Carolina, South Carolina, West Virginia

*From Table 5-1 of Ref 7.

Table 5.2. Variables Used to Assess Passenger Car Fatalities per Vehicle Registration year

Independent Variables	Fatal Crash Type Group					
	(C1) Rollovers	(C2) Hit an Object	(C3) Hit a Ped-Bike-MC	(C4) Hit a Big Truck	(C5) Hit another Pass. Car	(C6) Hit a Light Truck
Intercept	Yes	Yes	Yes	Yes	Yes	Yes
CURBWT	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
YOUNDRV	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
OLDMAN	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
OLDWOMAN	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
FEMALE	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
NITE	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
RURAL	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
CONVRTBL	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
TWODOOR	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
STAWAGON	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
VEHAGE	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
BRANDNEW	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP1	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP2	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP4	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP5	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1996	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1997	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1998	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1999	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
ABS4	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
DRAIRBAG	No	Step 2	Step 2	Step 2	Step 2	Step 2
RFAIRBAG	No	Step 2	Step 2	Step 2	Step 2	Step 2

Table 5.3. Variables Used to Assess Light Truck Fatalities per Vehicle Registration year

Independent Variables	Fatal Crash Type Group					
	(C1) Rollovers	(C2) Hit an Object	(C3) Hit a Ped-Bike-MC	(C4) Hit a Big Truck	(C5) Hit another Pass. Car	(C6) Hit a Light Truck
Intercept	Yes	Yes	Yes	Yes	Yes	Yes
CURBWT	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
YOUNDRV	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
OLDMAN	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
OLDWOMAN	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
FEMALE	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**	**Step 2**
NITE	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
RURAL	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
SUV	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
VAN	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
VEHAGE	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
BRANDNEW	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP1	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP2	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP4	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
STGP5	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1996	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1997	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1998	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
CY1999	Step 1	Step 1	Step 1	Step 1	Step 1	Step 1
AWD	Step 2	Step 2	Step 2	Step 2	Step 2	Step 2
ABS2	No	No	Step 2	No	No	No
ABS4	No	No	Step 2	No	No	No
DRAIRBAG	No	Step 2	Step 2	Step 2	Step 2	Step 2

B. INITIAL PASSENGER CAR ROLLOVER RESULTS

The Step 1 regression for passenger car rollovers was done using the independent variables for Step 1 listed in Table 5.2. The results of this regression are listed in Table 5.4, and with the exception of vehicle age are in very good agreement with the results for 1989-93 in Table 5-2 of Ref 7. These results are based on 320 state-calendar year-model year aggregate cells, compared to 195 cells in Kahane 1997. Again this increase in number of cells is due to the increase in the number of model years. This represents 482 million vehicle registration years, which is 97.7% of the 1985-98 passenger cars during the 1995-99 time period and 77% of all registered passenger cars during this time period.

Table 5.4. Step 1 Regression Results for Passenger Car Rollovers.

```
Run 5-C1.1
(Compare to Table 5-2 in Kahane 1997)

Passenger Car: Aggregate Linear Regression
of Principal rollover fatalities per Vehicle Registration Years

Step 1: By Vehicle Age, State and Calendar Year

Dependent Variable: LOGRATE
Aggregation Method: by State, Calendar Year and Model Year

Based on data for:
    1995 to 1999 calendar years
    1985 to 1998 model years
    51 states (50 states plus the District of Columbia)
    481502879 vehicle registration years,  97.7%

NOBS   =   320
NDOF   =   309
R2     = 0.710

Independent       Regression  (95% Conf.      T for H0:   Pr > |T|  Std Error of
Variable          Coefficient    Interval)   Parameter=0              Estimate

Intercept        -10.9515     (0.1160    )       -185.79    0.0000    0.0589
VEHAGE            -0.012724   (0.009463  )         -2.65    0.0081    0.004809
BRANDNEW           0.2316     (0.1611    )          2.83    0.0047    0.0819
STGP1             -0.74845    (0.09958   )        -14.79    0.0000    0.05061
STGP2             -0.60600    (0.09972   )        -11.96    0.0000    0.05067
STGP4              0.0180     (0.1060    )          0.33    0.7377    0.0539
STGP5              0.4697     (0.1165    )          7.93    0.0000    0.0592
CY1996             0.0169     (0.1036    )          0.32    0.7481    0.0526
CY1997            -0.1140     (0.1027    )         -2.18    0.0289    0.0522
CY1998            -0.0630     (0.1020    )         -1.22    0.2243    0.0518
CY1999            -0.0270     (0.1034    )         -0.51    0.6078    0.0525
```

The initial Step 2 rollover regression was then done using the independent variables for Step 2 listed in Table 5.2. The results of this regression are listed in Table 5.5, and are comparable to the results for 1989-93 in Table 5-3 in Ref 7. The data was aggregated according to the method described in Section 5.4 of Ref 7 in order to achieve a minimum cell size of 364,996 vehicle registration years. This minimum cell size was determined so there would be at least 5 expected rollover fatalities, based on the overall number of fatalities and vehicle-registration years. In practice, some cells do not have any fatalities due to differences in fatality risk between cells and random variation in the data. When this occurs, the zero fatality count is changed to 0.1 for the purposes of calculating the natural logarithm of the cell fatality rate (LOGRATE).

There were 660 cells after aggregation for rollovers, representing 451 million vehicle registration years. The number of vehicle registration years is somewhat less than the Step 1 regression because some vehicle cells did not have the minimum number of vehicle registration years after the aggregation was done. In general, the number of cells remaining after aggregation increases as the number of fatalities in the crash type increases because the minimum cell size decreases.

Kahane expressed concern in the 1997 report about the results he obtained using this initial Step 2 regression approach because the coefficients for curb weight and driver age and gender did not seem to be "intuitively reasonable". He indicated that the initial Step 2 regressions had failed, and attributed this to the inter-correlation of the curb weight and driver-age variables in the aggregated data, resulting in unstable coefficient estimates. There was less correlation between the curb weight and the driver-age variables in the disaggregate data, and therefore the logistic regression results from Chapter 3 of Ref 7 and Section III were more reliable estimates of the driver age and gender factors. The approach used in Section VI uses exogenous coefficients for driver age and gender to address this concern.

Table 5.5. Initial Step 2 Regression Results for Passenger Car Rollovers

```
Run 5-C1.2
(Compare to Table 5-3 in Kahane 1997)

Passenger Cars: Aggregate Linear Regression
of Principal rollover fatalities per Vehicle Registration Years

Step 2: By Curb Weight, Controlling for Driver Age, Sex
and other vehicle and accident factors

Dependent Variable: LOGRATE
Aggregation Method: by Car Group, Make-Model, Body Style, and Model Year

Based on data for:
    1995 to 1999 calendar years
    1985 to 1998 model years
    51 states
    451189996 vehicle registration years,  91.6%

Data has been aggregated according to the method described in Section 5.4 of Kahane
1997
in order to achieve a minimum cell size of    364996 vehicle registration years.

NOBS   =   660
NDOF   =   648
R2     = 0.345
```

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-11.747	(1.458)	-15.82	0.0000	0.743
CURBWT	**-0.0000256**	**(0.0002117)**	**-0.24**	**0.8121**	**0.0001078**
YOUNGDRV	**0.25873**	**(0.07662)**	**6.63**	**0.0000**	**0.03902**
OLDMAN	**-0.0988**	**(0.1119)**	**-1.73**	**0.0830**	**0.0570**
OLDWOMAN	**0.0196**	**(0.1233)**	**0.31**	**0.7552**	**0.0628**
FEMALE	**-0.542**	**(1.168)**	**-0.91**	**0.3620**	**0.595**
NITE	-3.753	(3.393)	-2.17	0.0298	1.728
RURAL	-0.078	(2.650)	-0.06	0.9539	1.349
CONVRTBL	0.3560	(0.5695)	1.23	0.2196	0.2900
TWODOOR	0.2048	(0.1932)	2.08	0.0374	0.0984
STAWAGON	0.1543	(0.3421)	0.89	0.3757	0.1742
ABS4	0.4633	(0.2115)	4.30	0.0000	0.1077

C. INITIAL LIGHT TRUCK ROLLOVER RESULTS

The Step 1 regression for light truck rollovers was done using the Step 1 variables listed in Table 5.3. The results for this regression are listed in Table 5.6, and they are in good agreement with the results for 1989-93 in Table 6-3 of Ref 7. These results are based on 310 state-calendar year-model year aggregate cells, compared to 190 cells in Kahane 1997. Again this increase in number of cells is due to the increase in the number of model years. This represents 233 million vehicle registration years, which is 85.3% of the 1985-97 trucks during the 1995-99 time period and 61% of all registered trucks during this time period.

Table 5.6. Step 1 Regression Results for Light Truck Rollovers

Run 5-T1.1
(Compare to Table 6-3 in Kahane 1997)

Light Truck: Aggregate Linear Regression
of Principal rollover fatalities per Vehicle Registration Years
(excluding vans weighing over 4000 lbs)

Step 1: By Vehicle Age, State and Calendar Year

Dependent Variable: LOGRATE
Aggregation Method: by State, Calandar Year and Model Year

Based on data for:
    1995 to 1999 calendar years
    1985 to 1997 model years
    51 states
    233250521 vehicle registration years, 85.3%

NOBS = 310
NDOF = 299
R2 = 0.736

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-10.2667	(0.1098)	-183.98	0.0000	0.0558
VEHAGE	-0.009986	(0.009181)	-2.14	0.0323	0.004665
BRANDNEW	0.1764	(0.1559)	2.23	0.0259	0.0792
STGP1	-0.67019	(0.09653)	-13.66	0.0000	0.04905
STGP2	-0.58194	(0.09758)	-11.74	0.0000	0.04958
STGP4	0.26347	(0.09772)	5.31	0.0000	0.04965
STGP5	0.4558	(0.1049)	8.55	0.0000	0.0533
CY1996	0.0487	(0.1006)	0.95	0.3412	0.0511
CY1997	0.01991	(0.09912)	0.40	0.6926	0.05037
CY1998	0.0105	(0.1002)	0.21	0.8360	0.0509
CY1999	0.0841	(0.1022)	1.62	0.1056	0.0520

The initial Step 2 regression for light truck rollovers was done using the Step 2 variables listed in Table 5.3. The results for this regression are listed in Table 5.7, although these results were not used in the final analysis. The data was aggregated according to the method described in Section 5.4 of Ref 7 in order to achieve a minimum cell size of 148,510 vehicle registration years. This resulted in 660 cells (the same number as for passenger cars only by coincidence).

Table 5.7. Initial Step 2 Regression Results for Light Truck Rollovers

```
Run 5-T1.2

Light Trucks: Aggregate Linear Regression
of Principal rollover fatalities per Vehicle Registration Years
(excluding vans weighing over 4000 lbs)

Step 2: By Curb Weight, Controlling for Driver Age, Sex
and other vehicle and accident factors

Dependent Variable: LOGRATE
Aggregation Method: by Car Group, Make-Model, Body Style, and Model Year

Based on data for:
    1995 to 1999 calendar years
    1985 to 1997 model years
    51 states
    228575188 vehicle registration years,  83.5%

Data has been aggregated according to the method described in Section 5.4 of Kahane
1997
in order to achieve a minimum cell size of    148510 vehicle registration years.

NOBS   =   660
NDOF   =   649
R2     = 0.351
```

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-12.217	(1.068)	-22.46	0.0000	0.544
CURBWT	**0.0000979**	**(0.0001512)**	**1.27**	**0.2039**	**0.0000770**
YOUNGDRV	**0.24783**	**(0.08800)**	**5.53**	**0.0000**	**0.04481**
OLDMAN	**-0.0601**	**(0.1236)**	**-0.95**	**0.3400**	**0.0630**
OLDWOMAN	**-0.2010**	**(0.3384)**	**-1.17**	**0.2434**	**0.1723**
FEMALE	**0.2602**	**(0.9438)**	**0.54**	**0.5883**	**0.4806**
NITE	-0.704	(2.470)	-0.56	0.5757	1.258
RURAL	1.638	(1.357)	2.37	0.0178	0.691
SUV	0.4902	(0.2379)	4.05	0.0000	0.1211
VAN	0.0712	(0.2720)	0.51	0.6070	0.1385
AWD	0.2858	(0.1733)	3.24	0.0012	0.0882

Section VI
FATALITIES PER VEHICLE YEAR IN THE UNITED STATES, WITH EXOGENOUS CONTROL FOR DRIVER AGE AND GENDER

The risk of fatality per vehicle registration year was assessed using the methods described in Sections 5.5, 5.6, and Chapter 6 of Ref 7. This involved the using exogenous driver age and gender coefficients from Sections III and IV to better control for these factors while estimating the effects of curb weight on the fatality risk.

Ref 7 had expressed concern that the initial Step 2 regression results described in Chapter 5 of Ref 7 had failed due to the high degree of correlation between the independent variables in the aggregate data, resulting in unstable regression coefficients. Ref 7 then used the driver age and gender results from Sections III and IV to stabilize the regressions and to better control for these factors while estimating the curb weight effect. The results from this approach were used to assess the overall effects of curb weight on the number of fatalities in the US.

A. METHOD

The effects of vehicle weight in on overall fatalities were estimated according to the methods described in Sections 5.5, 5.6, and Chapter 6 of Ref 7 as follows:

- The effect of curb weight on the fatality rate was estimated by aggregate linear regression, controlling for various vehicle, driver, and environmental factors, and using exogenous driver age and gender coefficients.

- The estimated curb weight coefficients were then used to estimate the effect of a 100 lb curb weight reduction on the number of US traffic fatalities in 1999.

The aggregate linear regressions were done in two steps, as described in Section V. The Step 1 results described in Section V were used without any change. The Step 2 regressions were done using exogenous driver age and gender coefficients. The exogenous coefficients were the sum of the regression coefficients estimated in Sections III and IV, based on the derivation in Section 5.5 of Ref 7. These regression coefficients are summarized in Table 6.1.

Table 6.1. Driver Age and Gender Regression Coefficients

Run	Type of Crash	Vehicle Type	Regression Coefficients			
			YOUNGDRV	OLDMAN	OLDWOMAN	FEMALE
Fatalities per Induced-Exposure Crash						
3-C1	Principal rollover	Cars	0.0896	0.0027	0.0457	-0.8993
3-T1		L. Trucks	0.0745	0.0201	0.0118	-0.0977
3-C2	Hit object	Cars	0.0839	0.0488	0.0736	-1.1078
3-T2		L. Trucks	0.0570	0.0427	0.0582	-0.5709
3-C3	Ped-bike-motorcycle	Cars	0.0467	0.0264	0.0302	-0.5582
3-T3		L. Trucks	0.0400	0.0176	0.0328	-0.5672
3-C4	Hit big truck	Cars	0.0572	0.0867	0.0877	-0.4844
3-T4		L. Trucks	0.0470	0.0719	0.0858	-0.3506
3-C5	Hit pass. car	Cars	0.0539	0.0582	0.0684	-0.6568
3-T5		L. Trucks	0.0448	0.0340	0.0410	-0.3591
3-C6	Hit light truck	Cars	0.0571	0.0812	0.0843	-0.5154
3-T6		L. Trucks	0.0453	0.0526	0.0648	-0.3206
Induced-Exposure Crashes per Vehicle Registration Year						
4-C2	Induced-Exposure	Cars	0.0290	-0.0473	-0.0317	0.2161
4-T2		L. Trucks	-0.0155	-0.0481	-0.0654	0.4067

B. PASSENGER CAR RESULTS

The Step 2 regression for passenger car rollovers was done using the Step 2 variables listed in Table 5.2. The results of this regression are listed in Table 6.2, which are in good agreement with the results for 1989-93 in Table 6-1 of Ref 7. The data used for this regression (and the initial results in

Table 5.5) are listed in Appendix L. The differences in the results are because exogenous coefficients are used for YOUNGDRV, OLDMAN, OLDWOMAN, and FEMALE. For example, the coefficient for YOUNGDRV is 0.1186, which is equal to 0.0896 from Section III plus 0.0290 from Section IV. The regression coefficient for CURBWT is -0.000377 with a standard error of ±0.000070. This would indicate that a 100 lb weight reduction in passenger car weight would result in 3.77% increase in the risk of fatality in principle rollovers.

Table 6.2. Step 2 Regression Results for Passenger Car Rollovers.

Run 6-C1.2
(Compare to Table 6-1 in Kahane 1997)

Passenger Cars: Aggregate Linear Regression
of Principal rollover fatalities per Vehicle Registration Years

Step 2: By Curb Weight, Controlling for Driver Age, Sex
and other vehicle and accident factors

Dependent Variable: LOGRATE
Aggregation Method: by Car Group, Make-Model, Body Style, and Model Year

Based on data for:
1995 to 1999 calendar years
1985 to 1998 model years
51 states
451189996 vehicle registration years, 91.6%

Data has been aggregated according to the method described in Section 5.4 of Kahane 1997
in order to achieve a minimum cell size of 364996 vehicle registration years.

NOBS = 660
NDOF = 652
R2 = 0.320

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-10.5819	(0.7927)	-26.21	0.0000	0.4037
CURBWT	**-0.0003769**	**(0.0001373)**	**-5.39**	**0.0000**	**0.0000699**
YOUNGDRV	0.118600				
OLDMAN	-0.044600				
OLDWOMAN	0.014000				
FEMALE	-0.683200				
NITE	-0.096	(2.452)	-0.08	0.9390	1.249
RURAL	-0.818	(2.602)	-0.62	0.5370	1.325
CONVRTBL	0.5169	(0.5732)	1.77	0.0766	0.2919
TWODOOR	0.4584	(0.1558)	5.78	0.0000	0.0793
STAWAGON	0.0161	(0.3198)	0.10	0.9211	0.1628
ABS4	0.3581	(0.1992)	3.53	0.0004	0.1014

Note: R2=1-SSres/SStot

Fig 1 illustrates the fatality rate vs. curb weight trend, adjusted for all of the other control variables, for passenger car principal rollovers. This figure is comparable to the 1989-93 results in Figure 6-1 of Kahane 1997. The circles are the adjusted actual fatality rate (ADJACTL) aggregated into 100 lb curb weight class intervals. The area of each circle is proportional to the number of Step 1 adjusted vehicle registration years, and class intervals with less than 2 million vehicle registration years are not shown. The line is the predicted fatality rate (ADJEXP). Both ADJACTL and ADJEXP were calculated according the method described in Section 6.6 of Ref 7.

Regressions were also done for the other passenger car fatal crash types, using the variables listed in Table 5.2. The results from these regressions are listed in Appendix K. The adjusted fatality rate vs. curb weight trends for each crash type are illustrated in Figs 2 to 6. These figures are comparable to Figures 6-2 to 6-6 in Ref 7.

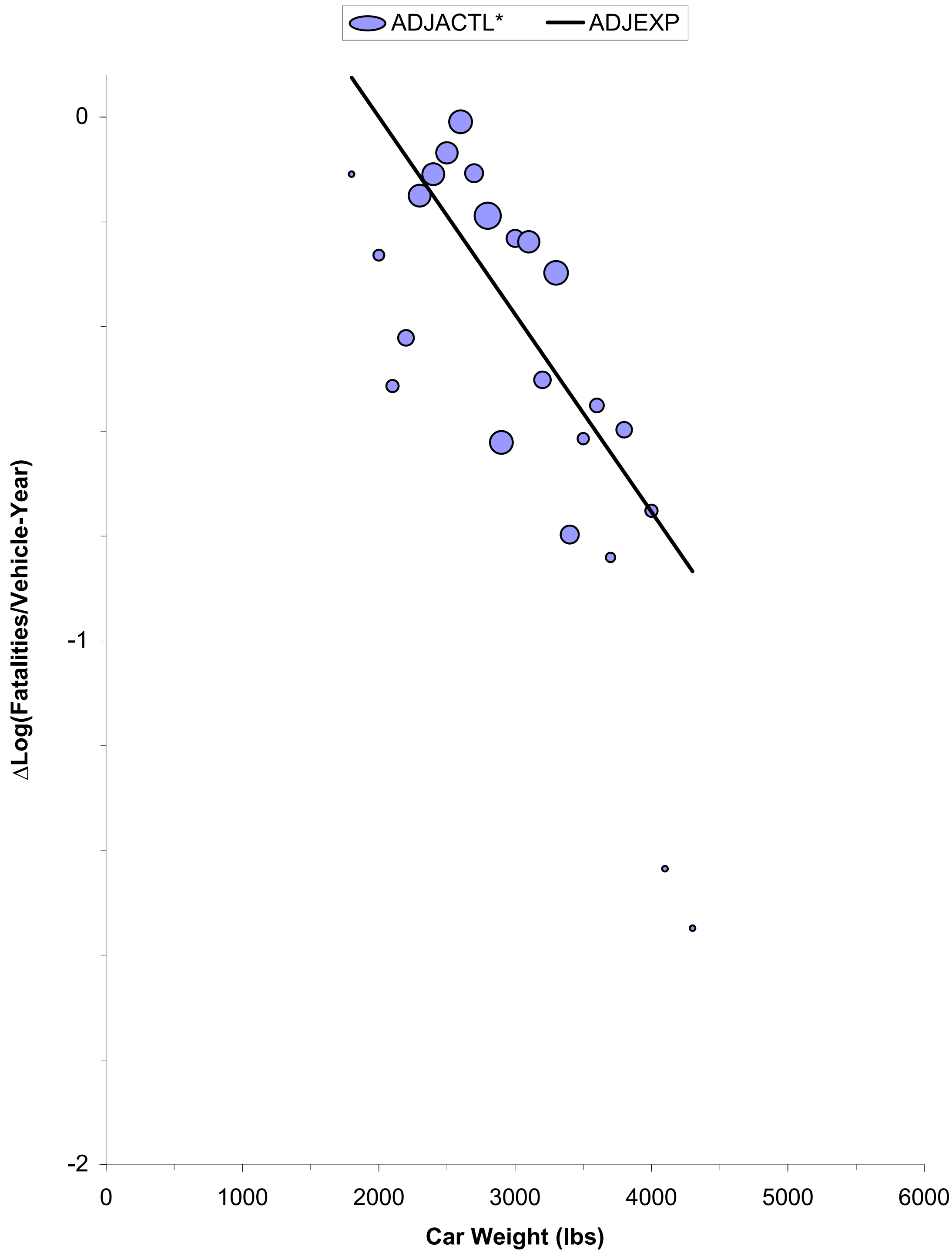

Figure 1. Risk of passenger car rollover fatality vs. passenger car weight (after adjustment for all other control variables)

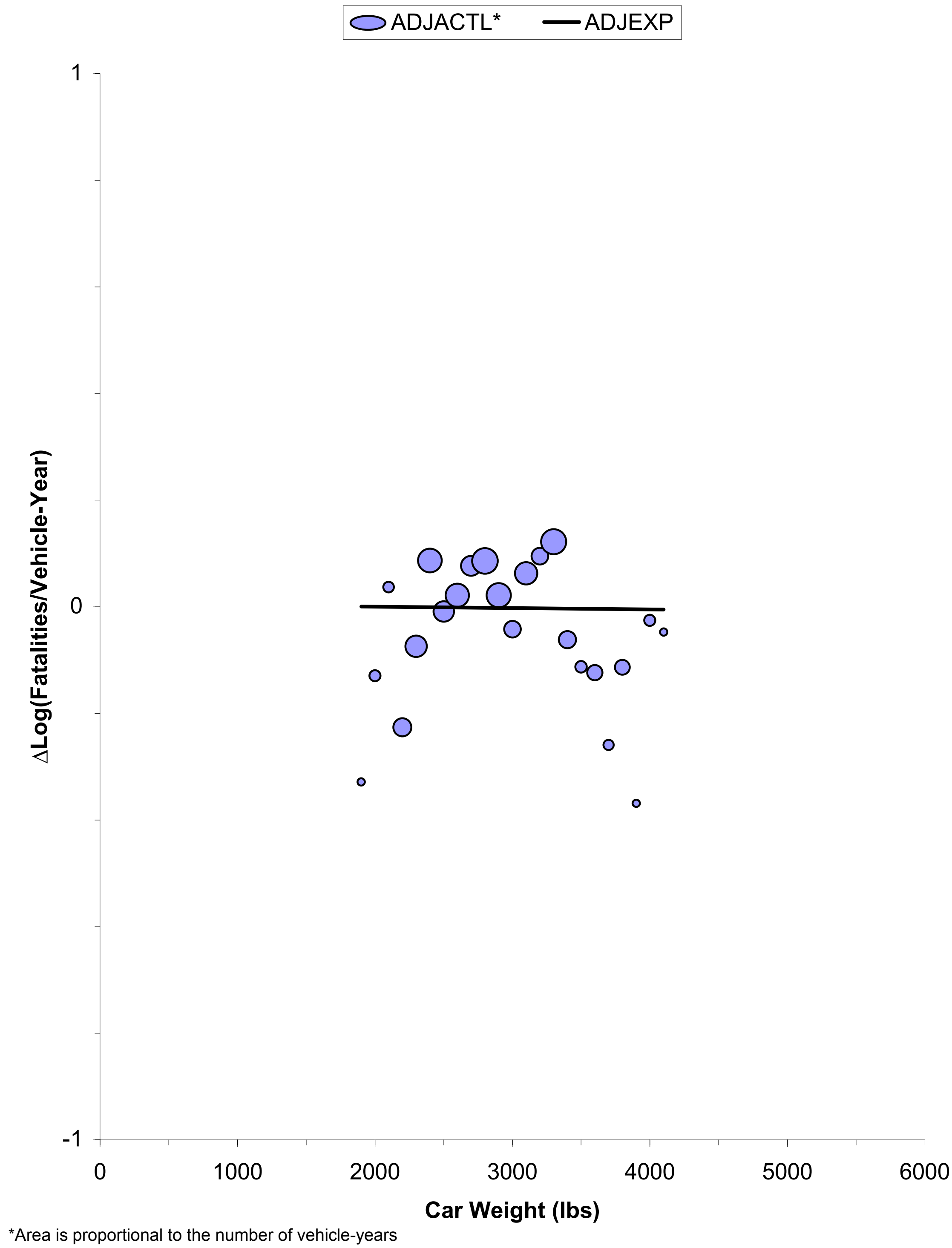

Figure 2. Risk of passenger car hit fixed object fatality vs. passenger car weight (after adjustment for all other control variables)

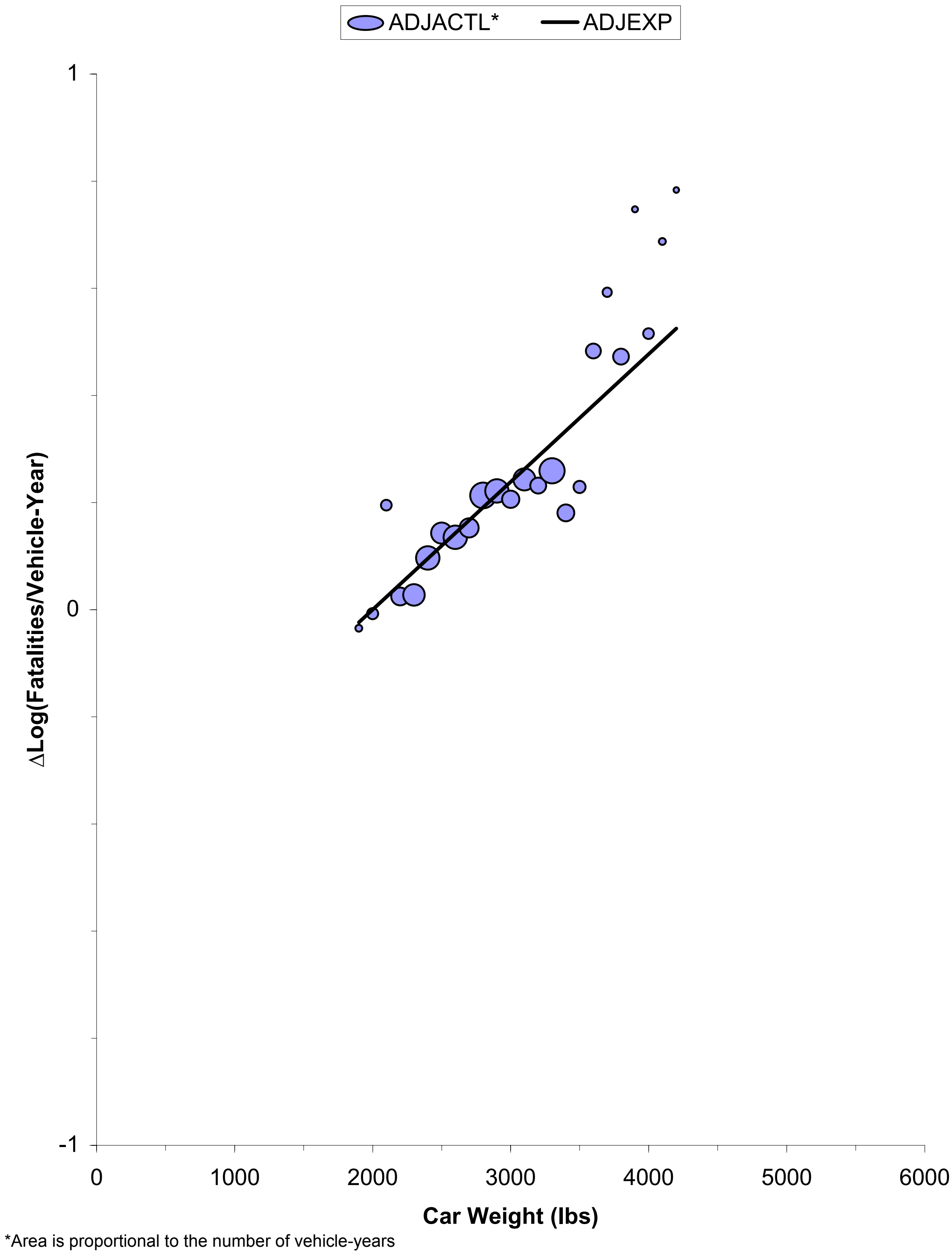

Figure 3. Risk of passenger car hit pedestrian-bike-motorcycle fatality vs. passenger car weight (after adjustment for all other control variables)

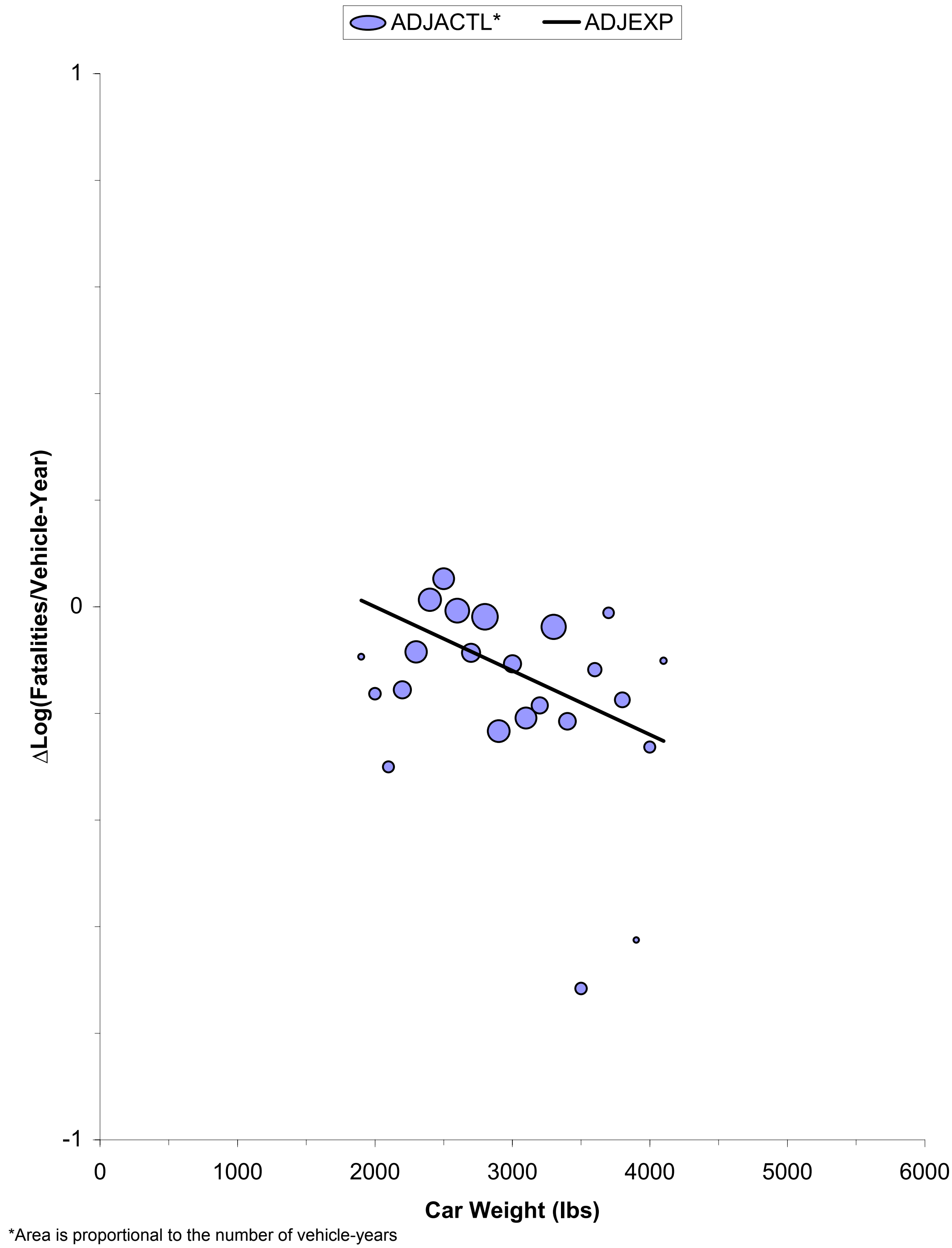

Figure 4. Risk of passenger car hit big truck fatality vs. passenger car weight (after adjustment for all other control variables)

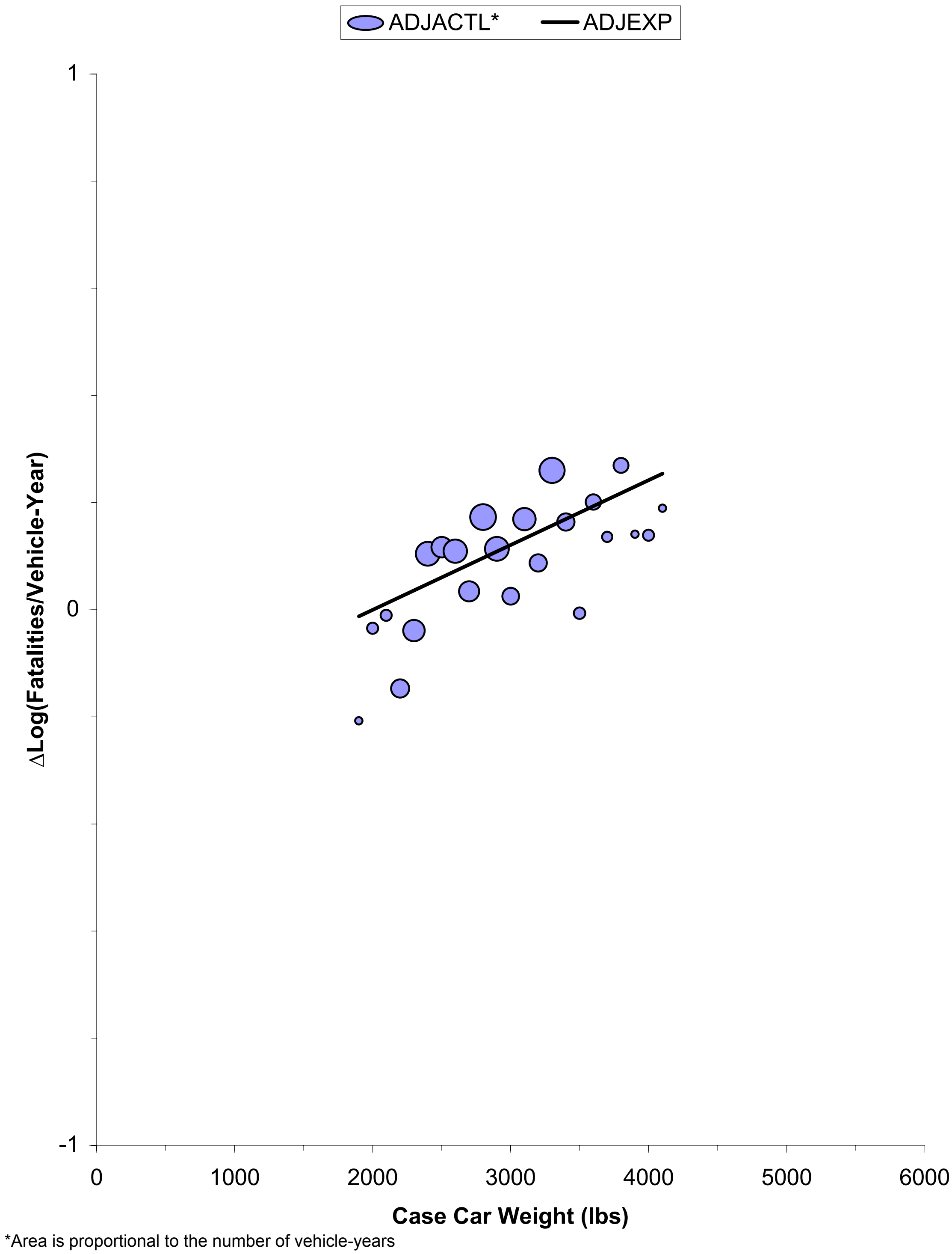

Figure 5. Risk of passenger car hit other passenger car fatality vs. "case" car weight (after adjustment for all other control variables)

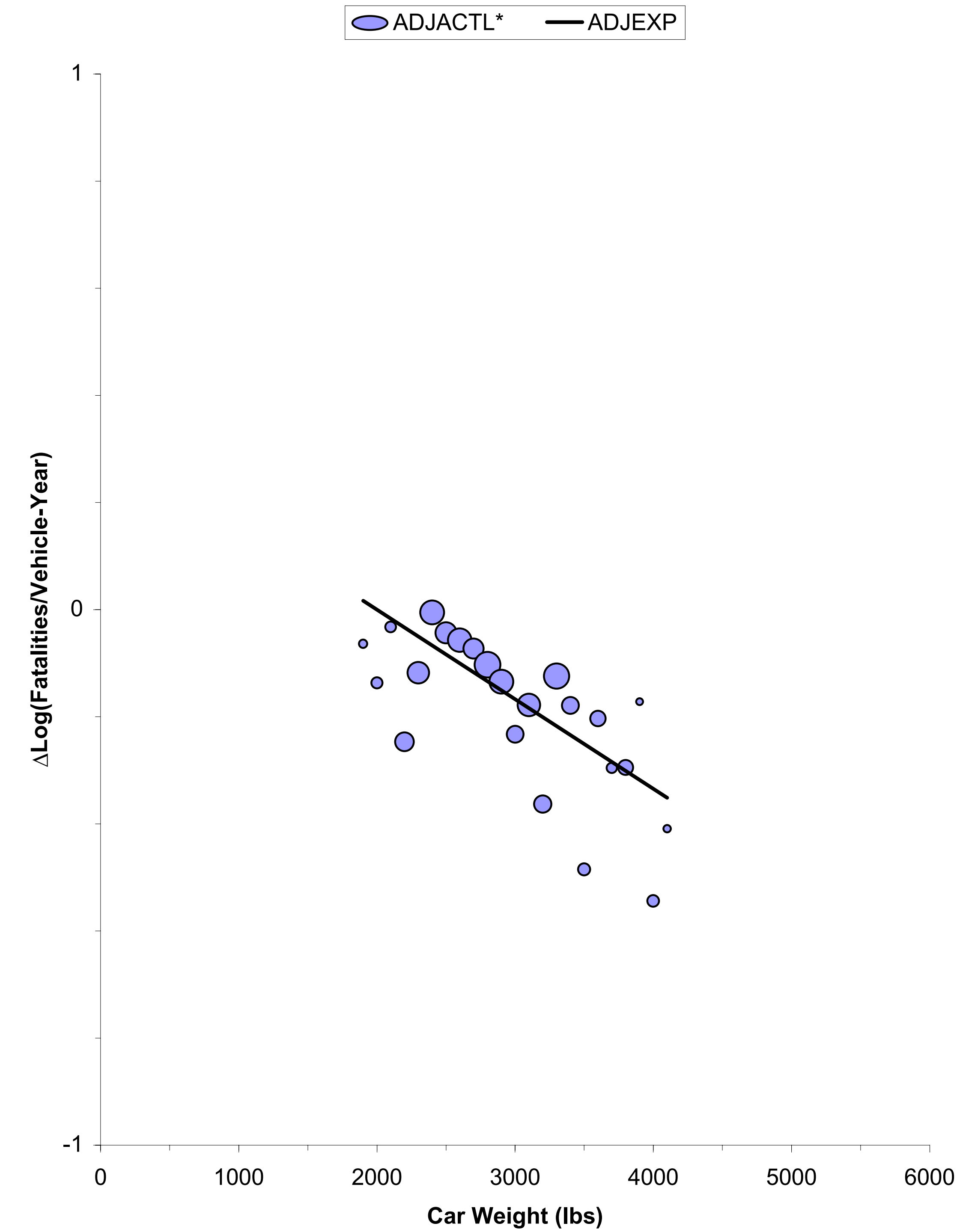

Figure 6. Risk of passenger car hit light truck fatality vs. passenger car weight (after adjustment for all other control variables)

C. LIGHT TRUCK RESULTS

Regressions for light truck rollovers were done using the independent variables listed in Table 5.3. The Step 1 regression results for rollovers are the same as listed in Table 5.6. The Step 2 regression results for rollovers are listed in Table 6.3, and are in generally good agreement with the results for 1989-93 listed in Table 6-4 of Ref 7. The CURBWT coefficient is more negative than before, and the FEMALE, SUV, and VAN coefficients are more positive than before. The change in the exogenous coefficient for FEMALE is mainly due the induced-exposure crash involvement per vehicle registration year term.

Table 6.3. Step 2 Regression Results for Light Truck Rollovers.

Run 6-T1.2
(Compare to Table 6-4 in Kahane 1997)

Light Trucks: Aggregate Linear Regression
of Principal rollover fatalities per Vehicle Registration Years
(excluding vans weighing over 4000 lbs)

Step 2: By Curb Weight, Controlling for Driver Age, Sex
and other vehicle and accident factors

Dependent Variable: LOGRATE
Aggregation Method: by Car Group, Make-Model, Body Style, and Model Year

Based on data for:
- 1995 to 1999 calendar years
- 1985 to 1997 model years
- 51 states
- 228575188 vehicle registration years, 83.5%

Data has been aggregated according to the method described in Section 5.4 of Kahane 1997
in order to achieve a minimum cell size of 148510 vehicle registration years.

NOBS = 660
NDOF = 653
R2 = 0.318

Independent Variable	Regression Coefficient	(95% Conf. Interval)	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept	-11.3044	(0.6295)	-35.26	0.0000	0.3206
CURBWT	**-0.00014172**	**(0.00009994)**	**-2.78**	**0.0054**	**0.00005089**
YOUNGDRV	0.059000				
OLDMAN	-0.028000				
OLDWOMAN	-0.053600				
FEMALE	0.309000				
NITE	2.023	(2.311)	1.72	0.0857	1.177
RURAL	1.993	(1.374)	2.85	0.0044	0.700
SUV	0.4061	(0.1587)	5.02	0.0000	0.0808
VAN	-0.2912	(0.1544)	-3.70	0.0002	0.0786
AWD	0.4948	(0.1543)	6.30	0.0000	0.0786

Note: R2=1-SSres/SStot

Regressions for the other light truck crash types were also done using the variables listed in Table 5.3. The results of these regressions are also listed in Appendix K. The adjusted fatality rate vs. curb weight trends for each crash type are illustrated in Figs 7 to 12. These figures are also comparable to Figures 6-7 to 6-12 of Ref 7.

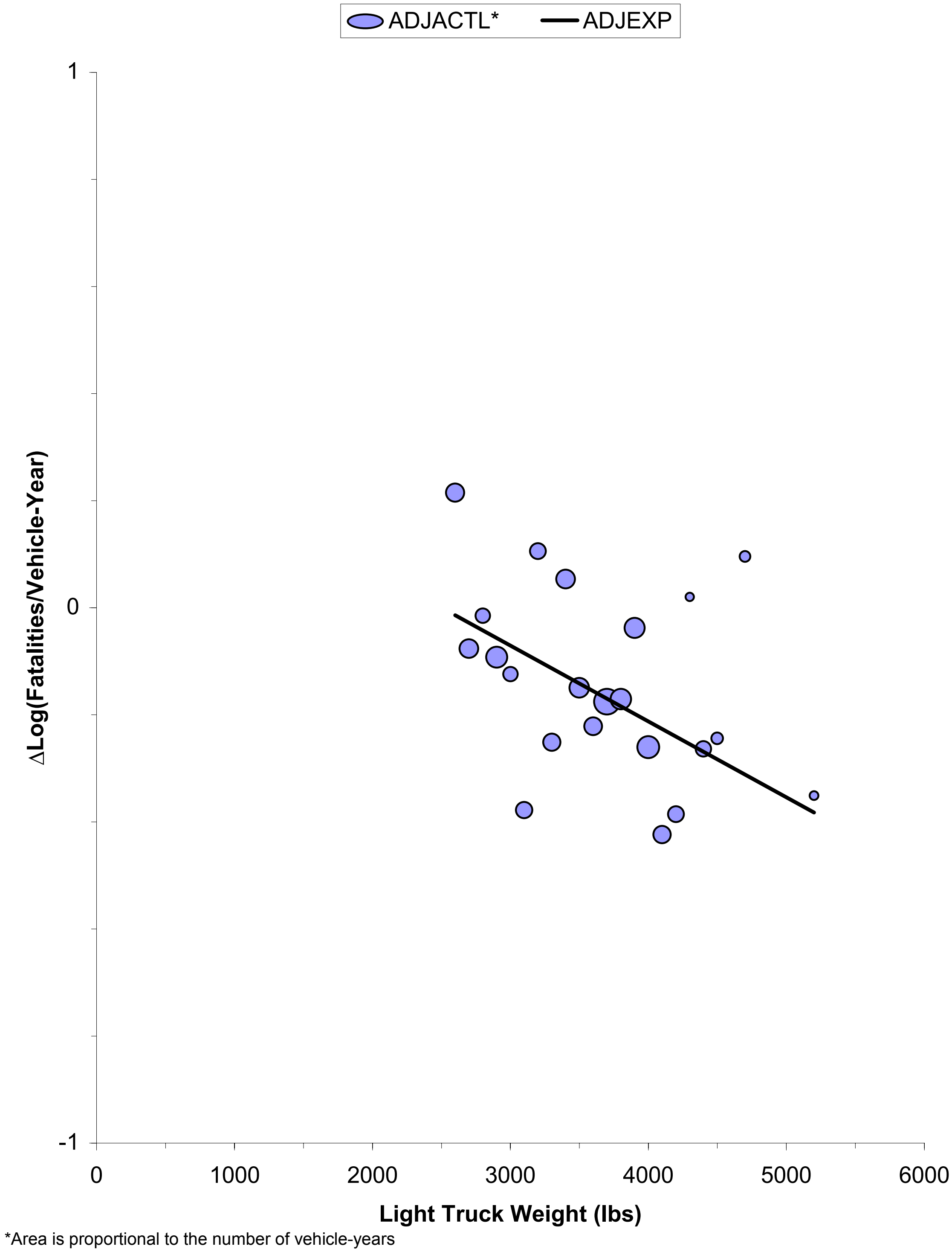

Figure 7. Risk of light truck rollover fatality vs. light truck weight (after adjustment for all other control variables)

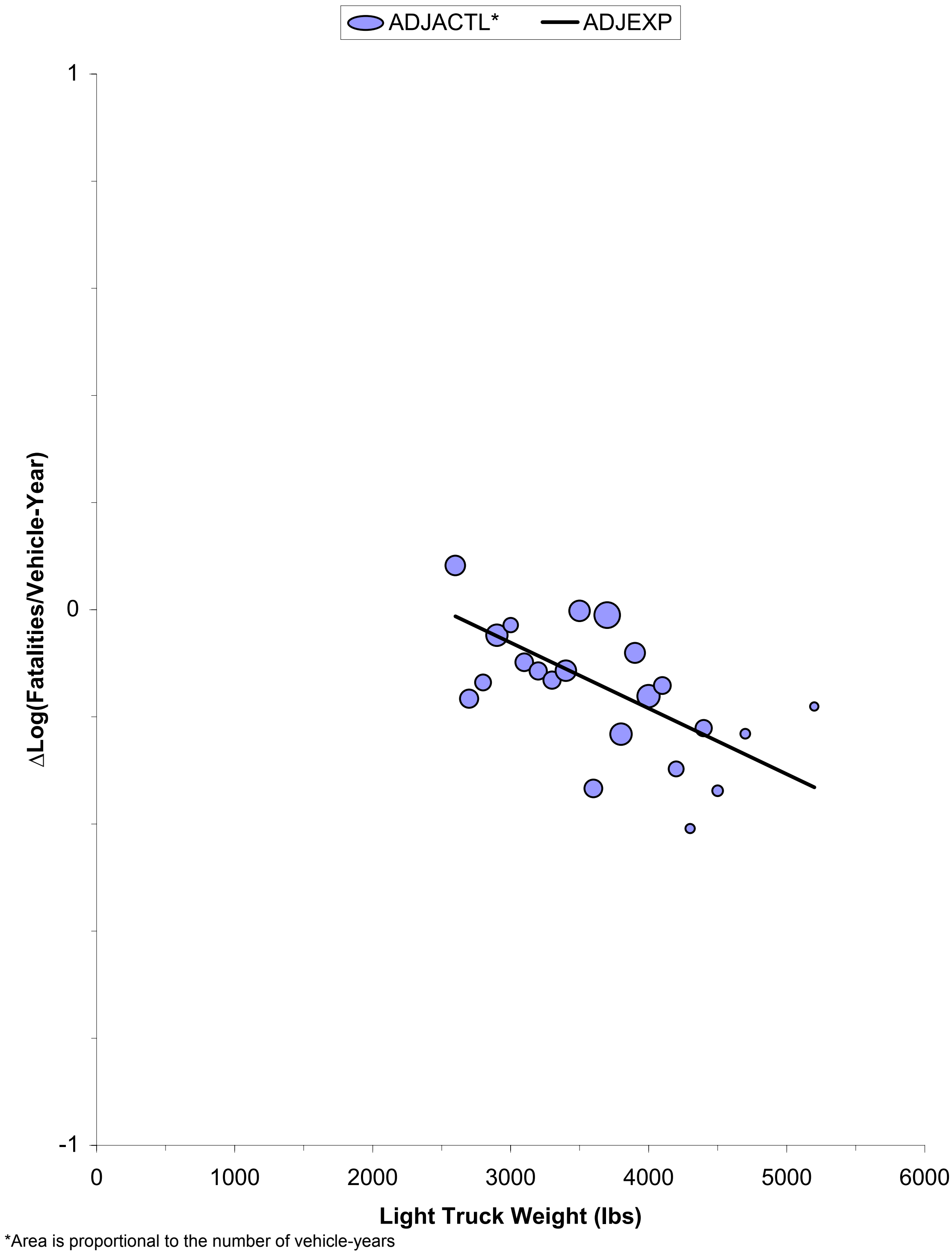

Figure 8. Risk of light truck hit fixed object fatality vs. light truck weight (after adjustment for all other control variables)

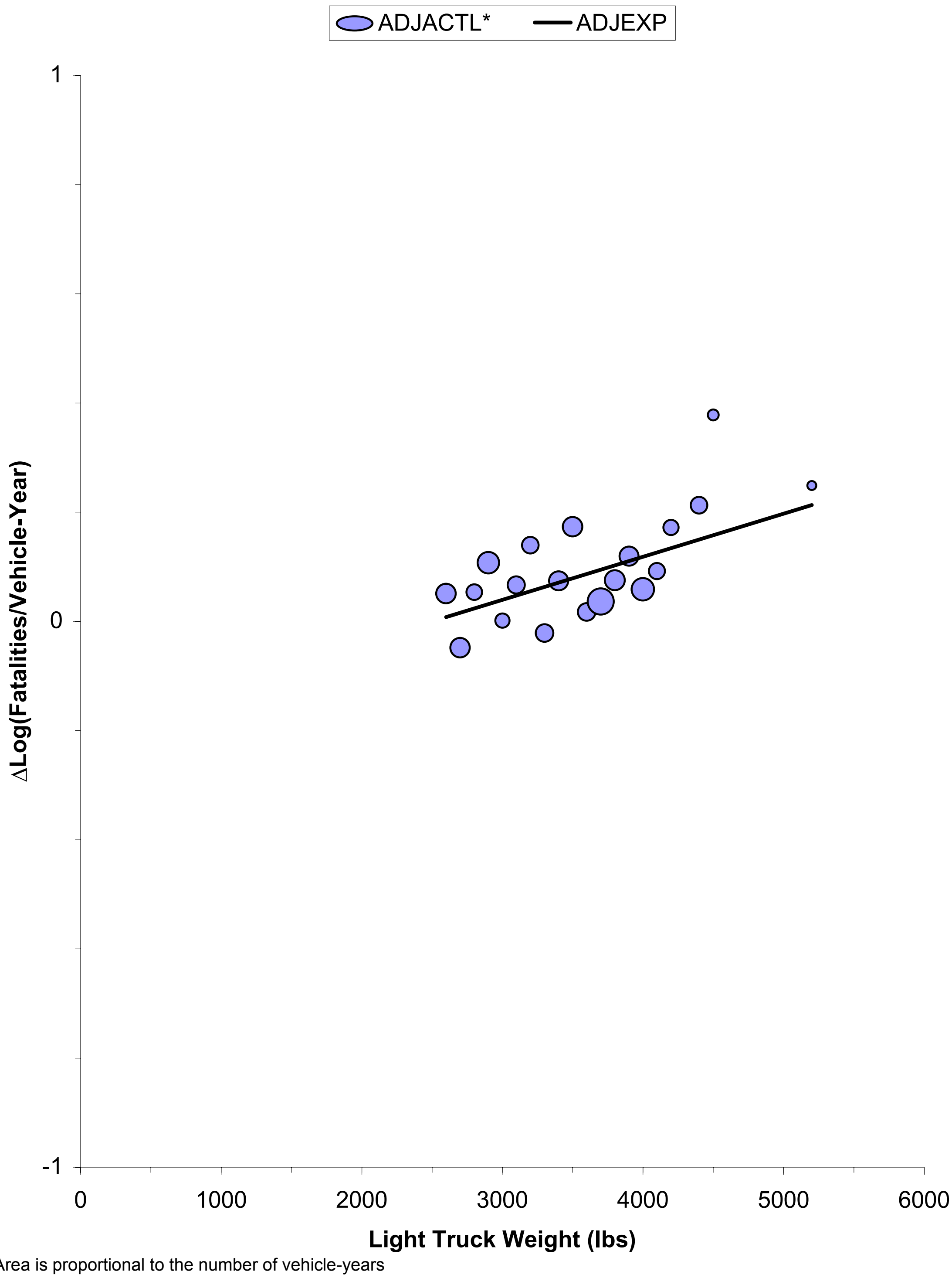

Figure 9. Risk of light truck hit pedestrian-bike-motorcycle fatality vs. light truck weight (after adjustment for all other control variables)

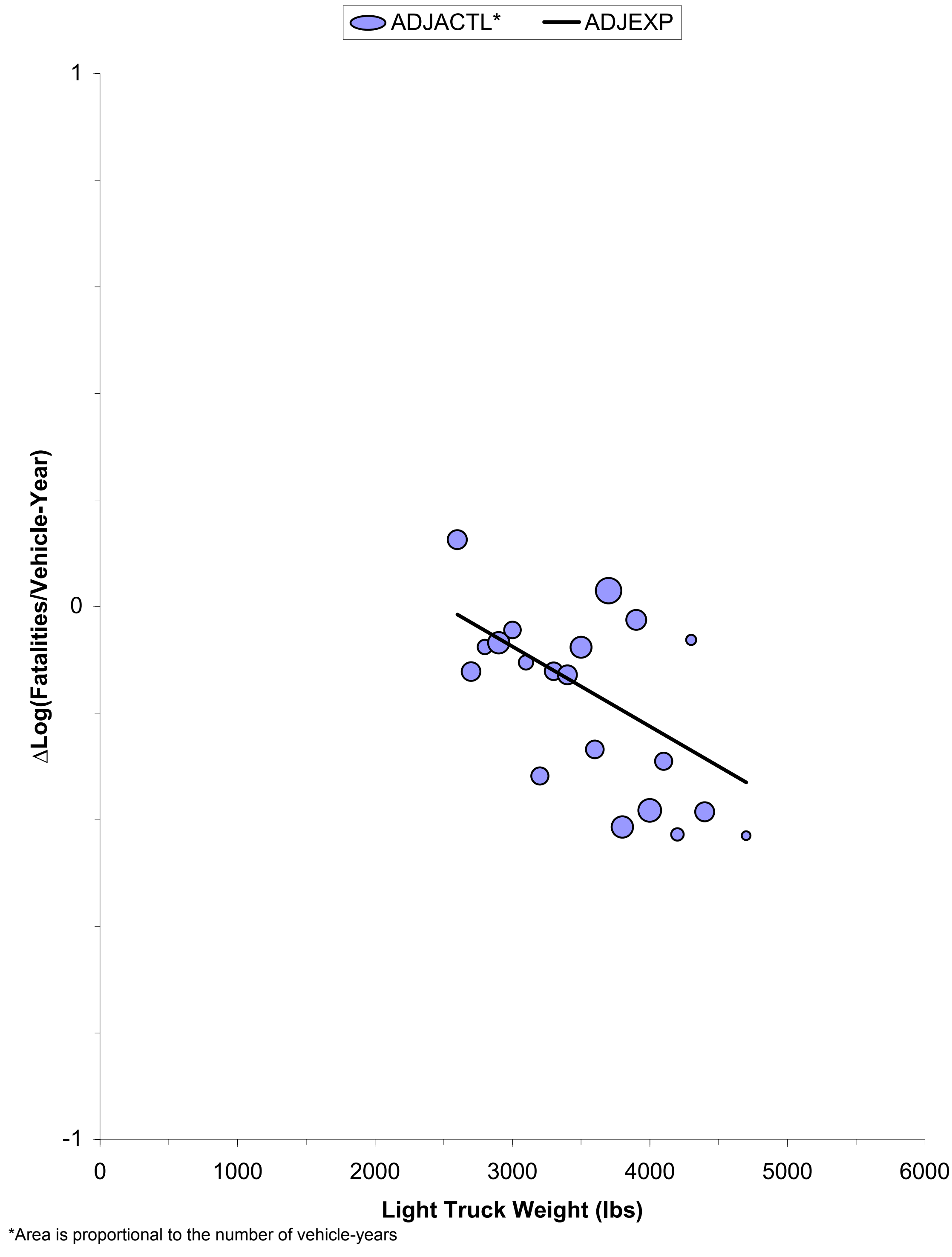

Figure 10. Risk of light truck hit big truck fatality vs. light truck weight (after adjustment for all other control variables)

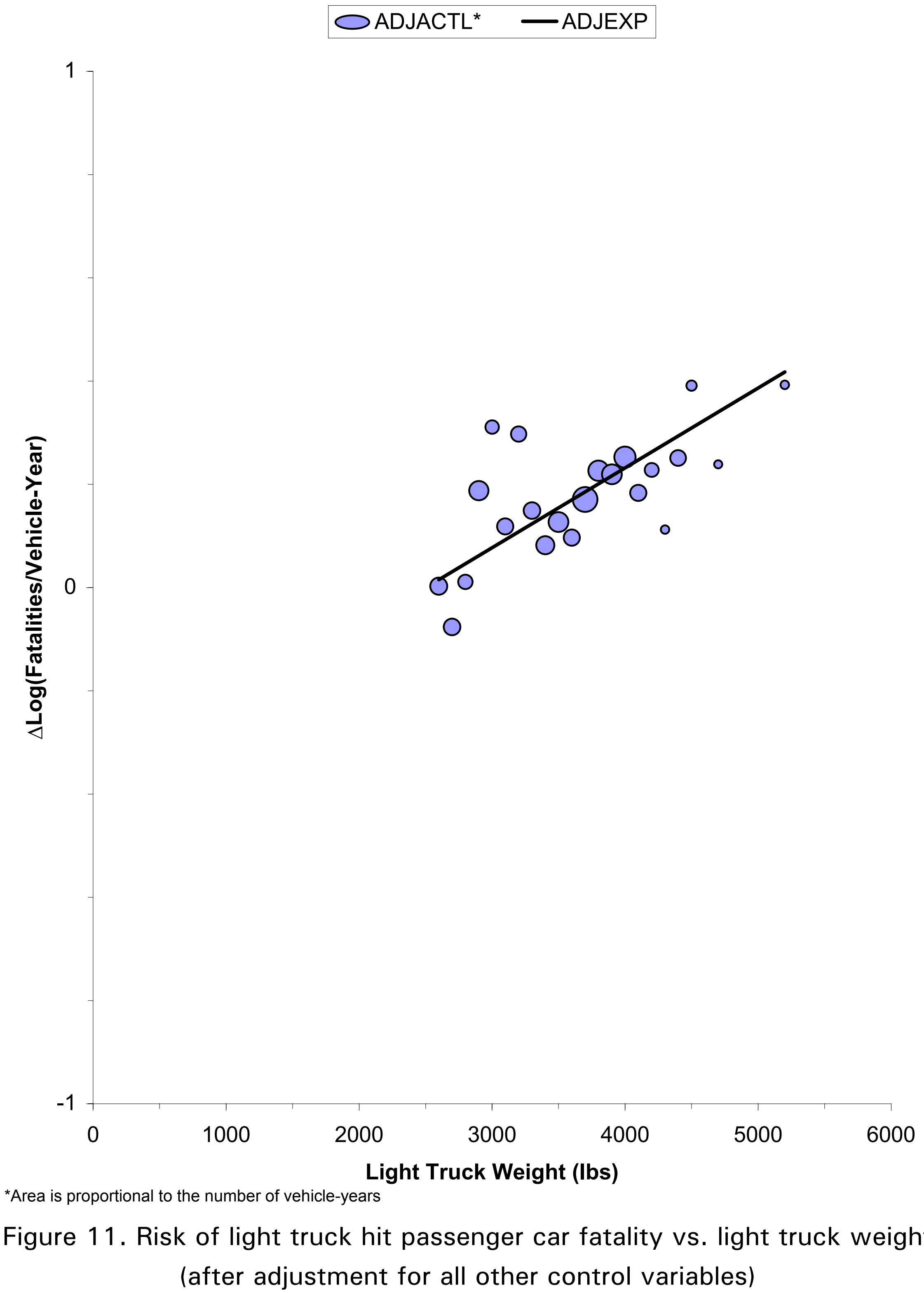

Figure 11. Risk of light truck hit passenger car fatality vs. light truck weight (after adjustment for all other control variables)

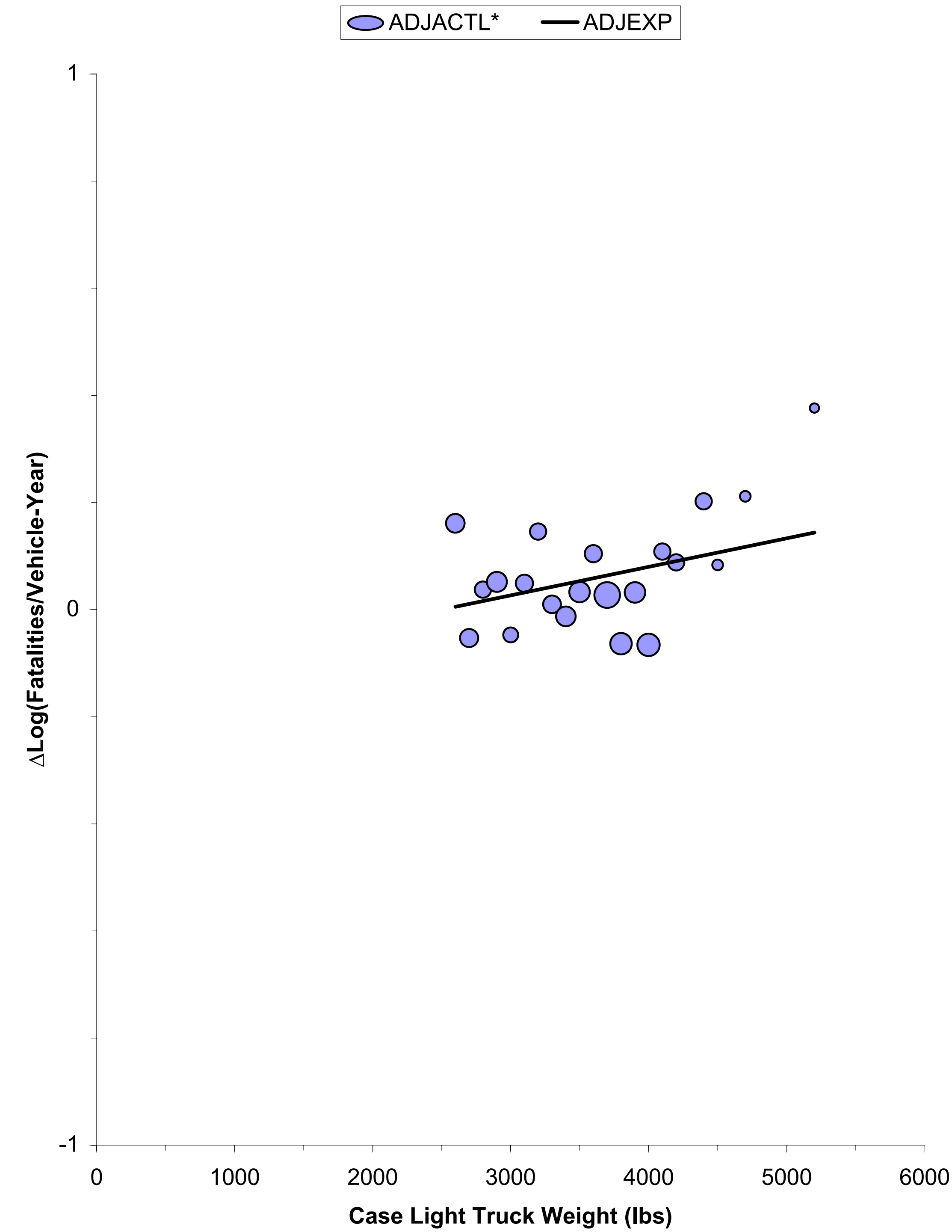

Figure 12. Risk of light truck hit other light truck fatality vs. "case" light truck weight (after adjustment for all other control variables)

D. Effect of a 100 lb Weight Reduction on the Number of Fatalities

The effects of vehicle weight reduction on numbers of fatalities can be estimated by applying the estimated changes in the fatality rates per vehicle registration year to the to the absolute numbers of fatalities in 1999, assuming the number of vehicle registration years remains constant when the weight is reduced, according the method described in Section 6.3 of Ref 7. The results for passenger cars and light trucks are listed in Tables 6.4 and 6.5 respectively and the overall results are summarized in Table 6.6.

The format of Tables 6.4 and 6.5 are the same as Tables 6.7 and 6.8 in Ref 7. The second column of the tables lists the number of fatalities in 1999 passenger car and light truck crashes, obtained from Table 2-3 of Ref 12. The Insurance Institute for Highway Safety calculated the data in this column using algorithms supplied by Kahane. The third column lists the effects of a 100 lb weight reduction, and are equal to the CURBWT coefficients x −100 lb x 100%. The fourth column lists the net fatality change, which is the number of fatalities in the second column x net effect / 100%. The last column lists the standard deviation of the net fatality change, which is the standard error of the CURBWT coefficient x 100 lb. The effect of vehicle weight reduction in car-to-car collisions and truck-to-truck collisions is doubled in each table, compared to the original regression coefficients, because the weight of both vehicles would be reduced, as was done in Ref 7. The overall net fatality change is the sum of the net fatality changes for each crash type, before rounding to the nearest integer value. The standard deviation of the overall value is the square root of the sum of squares of the 6 individual standard deviations.

Table 6.4. Estimated Effect of a 100 lb Passenger Car Weight Reduction on 1999 US Fatalities

Crash Type	Fatalities in 1999 Crashes[1]	Effect of 100 Pound Weight Red.	Net Fatality Change	One Standard Deviation
Principal rollover	1,663	3.77%	63	11.6
Hit object	7,003	0.03%	2	17.4
Ped-bike-motorcycle	3,245	-2.39%	-77	9.3
Hit big truck	2,496	1.20%	30	9.6
Hit passenger car	4,047	-2.42%	-98	19.4
Hit light truck	6,881	1.67%	115	21.0
Overall	25,335	0.13%	34 *	37.9 **
±2-sigma confidence bounds			-42 to +110	
±3-sigma confidence bounds			-80 to +148	

[1]IIHS, NAS 2001 Table 2-3 (Ref 12).

*Overall is calculated from the net fatality changes before rounding to the nearest integer value.

**Standard deviation for "overall" is the square root of the sum of the squares of the 6 individual standard deviations.

Based on the results in Table 6.3 the net effect of a 100 lb passenger car weight reduction would be an additional 34 fatalities from the 25,335 fatalities in 1999 passenger cars crashes. Kahane suggested in Ref 7 that a ±3-sigma confidence bounds would be appropriate to include the "likely range of possible error" resulting from propagated errors introduced by the iterative regression procedures and the use of exogenous coefficients, which is a net change of -80 to +148 fatalities. Using this criterion, the overall change in fatalities due to a 100 lb passenger car weight reduction is statistically insignificant.

Table 6.5. Estimated Effect of a 100 lb Light Truck Weight Reduction on 1999 US Fatalities

Crash Type	Fatalities in 1999 Crashes[1]	Effect of 100 Pound Weight Red.	Net Fatality Change	One Standard Deviation
Principal rollover	2,605	1.42%	37	13.3
Hit object	3,974	1.23%	49	12.4
Ped-bike-motorcycle	2,432	-0.79%	-19	8.5
Hit big truck	1,506	1.50%	23	8.6
Hit passenger car	6,881	-1.55%	-106	16.0
Hit light truck	1,781	-1.06%	-19	12.1
Overall	19,179	-0.19%	-36 *	29.6 **
±2-sigma confidence bounds			-95 to +23	
±3-sigma confidence bounds			-125 to +53	

[1]IIHS, NAS 2001 Table 2-3 (Ref 12).

*Overall is calculated from the net fatality changes before rounding to the nearest integer value.

**Standard deviation for "overall" is the square root of the sum of the squares of the 6 individual standard deviations.

Based on the results in Table 6.5 the net effect of a 100 lb reduction in light truck weight would result in 36 fewer fatalities than the 19,179 fatalities in 1999 light truck crashes. The ±3-sigma confidence bounds for this result is a net change of −125 to +53 fatalities, which is also statistically insignificant.

Table 6.6. Estimated Effect of a 100 lb Passenger Vehicle Weight Reduction on 1999 US Fatalities

Vehicle Type	Fatalities in 1999 Crashes[1]	Effect of 100 Pound Weight Red.	Net Fatality Change	One Standard Deviation
Passenger Cars	25,335	0.13%	34	37.9
Light Trucks	19,179	-0.19%	-36	29.6
Overall	37,633	-0.00%	-2	48.1 *
±2-sigma confidence bounds			-98 to +94	
±3-sigma confidence bounds			-146 to +142	

[1]IIHS, NAS 2001 Table 2-3 (Ref 12).

*Standard deviation for "overall" is the square root of the sum of the squares of the individual standard deviations.

The results in Table 6.6 indicate that the overall effect of a 100 lb weight reduction in both passenger cars and light trucks is estimated to be a net decrease of 2 fatalities out of 37,633 fatalities involving passenger cars and light trucks in 1999. The ±3-sigma confidence interval for this estimate is −146 to +142 fatalities. Therefore the overall net change is statistically insignificant.

E. SENSITIVITY TESTS

The sensitivity of the estimated absolute change in fatalities due to a 100 lb vehicle weight reduction were assessed for the following, in accordance with Ref 7:

- variations in the exogenous driver age and gender coefficients,
- the exclusion of all but 4 door sedans and hatchbacks, and
- the exclusion of all but pickup trucks.

1. Driver age and gender

The sensitivity in the estimated effects of a 100 lb vehicle weight reduction due to variations in the driver age and gender coefficients was assessed by multiplying the exogenous coefficients by a scaling factor ranging from 0 to 2, as described in Section 6.4 of Ref 7. The estimated effects are a linear function of the scaling factor, as illustrated in Fig 13. In this figure, the estimated change in rollover fatalities due to a 100 lb passenger car weight reduction varies linearly from 93 when the exogenous coefficients are zero to 32 when the coefficients are double the baseline value. Therefore the sensitivity in the estimated effect is -30.5 fatalities per unit change in the driver age and gender coefficients. The sensitivities in the passenger car and light truck results due to changes in the driver age and gender coefficients are listed in Tables 6.7 and 6.8. The corresponding results from Kahane 1997 are also listed in the last row of these tables.

Figure 13. Estimated net rollover fatalities due to a 100 lb car weight reduction vs. the driver age and gender coefficient scaling factor.

Table 6.7. Sensitivity of the Estimated Effects of a 100 lb Passenger Car Weight Reduction to the Exogenous Driver Age and Gender Coefficients

Crash Type	Sensitivity in the Estimated Number of Fatalities to the Driver Coefficients	
	1995-99 Results	1989-93 Results*
Principal rollover	-30.5	-25.0
Hit object	-45.5	-28.0
Ped-bike-motorcycle	-41.5	-25.5
Hit big truck	-6.0	1.0
Hit passenger car	-44.5	-29.0
Hit light truck	-21.0	-2.0
Overall	-188.5	-108.5

*Calculated from Table 6-9 in Ref 7.

Table 6.8. Sensitivity of the Estimated Effects of a 100 lb Light Truck Weight Reduction to the Exogenous Driver Age and Gender Coefficients

Crash Type	Sensitivity in the Estimated Number of Fatalities to the Driver Coefficients	
	1995-99 Results	1989-93 Results*
Principal rollover	-22.0	-24.0
Hit object	-20.0	-27.0
Ped-bike-motorcycle	-8.0	-14.0
Hit big truck	-5.5	-2.5
Hit passenger car	-29.5	-42.5
Hit light truck	-14.0	-15.0
Overall	-99.5	-125.0

*Calculated from Table 6-10 in Ref 7.

The results in Tables 6.7 and 6.8 indicate that the net change in the estimated number of fatalities due to a 100 lb passenger car and/or light truck weight reduction would decrease (i.e., more negative) if the driver coefficients were doubled, which was also observed in Ref 7. However, the new results for passenger cars are more sensitive to the driver coefficients than before, and the results for light trucks are less sensitive than before.

Based on these results, the passenger car driver coefficients would need to be less than 0.58 times the baseline values for the estimated change in the number of fatalities due to a 100 pound passenger car weight reduction to be significantly greater than 0 at the $\pm$3-sigma confidence level. The light truck driver coefficients would need to be less than −0.25 times the baseline values for the estimated change in the number of fatalities due to a 100 pound light truck weight reduction to be significantly greater than 0. Therefore, the driver age and gender coefficients would need to be much smaller than the values determined in Sections III and IV for the results to indicate a statistically significant increase in the number of fatalities due to a 100 lb vehicle weight reduction. However, the relative stability of these coefficients observed by comparing the Ref 7 to the current values in Sections III and IV would suggest that such large variations are not likely.

2. Exclusion of sporty vehicles

The sensitivity of the results to sporty vehicles was assessed based on Section 6.5 in Ref 7. The results in Kahane 1997 indicated that the variation in sporty cars were bracketed by the baseline results with included all cars, and the results obtained using only 4-door sedans and hatchbacks. The new results for this comparison are listed in Table 6.9.

Table 6.9. Sensitivity of the Estimated Effects of a 100 lb Passenger Car Weight Reduction to Sporty Cars.

Crash Type	Estimated Change in Fatalities due to a 100 Lb Weight Reduction	
	All Cars (Baseline results)	4-Door Sedans and Hatchbacks Only
Principal rollover	63	80
Hit object	2	56
Ped-bike-motorcycle	-77	-86
Hit big truck	30	22
Hit passenger car	-98	-85
Hit light truck	115	110
Overall	34	96

These results indicate that the same trend observed in Ref 7, that excluding more sporty vehicles would increase the estimated weight effect. However, the overall sensitivity is less than was found in Ref 7.

Ref 7 also observed an increase in the estimated number of fatalities due to a 100 lb light truck weight reduction if the Step 2 regression was limited to only pickup trucks. The results in Table 6.10 do not show as much sensitivity as Ref 7, except for principal rollovers.

Table 6.10. Sensitivity of the Estimated Effects of a 100 lb Passenger Car Weight Reduction to Sporty Light Trucks.

Crash Type	Estimated Change in Fatalities due to a 100 Lb Weight Reduction	
	All Light Trucks expect large vans (Baseline results)	Pickup Trucks Only
Principal rollover	37	80
Hit object	49	57
Ped-bike-motorcycle	-19	-17
Hit big truck	23	20
Hit passenger car	-106	-125
Hit light truck	-19	-29
Overall	-36	-14

In addition, the sensitivity of the overall result was assessed with regard to the treatment of logarithm of the fatality rate in cells with 0 fatalities. In Ref 7 and in these results, the number of fatalities in these cells was changed from 0 to 0.1 for the purpose of calculating the logarithm, as described on page 114 of Ref 7. This can result in larger residuals, which for this analysis was uncorrelated with vehicle weight. Another possible alternative is to change the number of fatalities from 0 to 0.4, as was described on page 119 in Ref 25. The net results listed in Table 6.11 indicate that the effect of this change is relatively small.

Table 6.11. Sensitivity of the Results to Treatment of Cells with 0 Fatalities.

Vehicle Type	Estimated Change in Fatalities due to a 100 lb Weight Reduction	
	Log of 0.1 Fatalities	Log of 0.4 Fatalities
Passenger Cars	34	24
Light Trucks	-36	-41
Overall	-2	-17

Section VII
CONCLUSIONS

The effects of vehicle weight on overall safety have been assessed, in terms of the net change in the total number of US fatalities, based on 1995-99 calendar year accident data involving 1985-98 passenger cars and 1985-97 light trucks, using the methods developed by Kahane in Ref 7. These results represent an update and expansion of the results for 1985-93 passenger cars and light trucks in 1989-93 calendar year accident data reported in Ref 7.

These results, which are based on analysis of the six fatal crash types used by Kahane in Ref 7, and controlling for driver, environmental, and additional vehicle factors according to Ref 7, indicate that a 100 lb vehicle weight reduction for all passenger cars and light trucks would have resulted in a net decrease of 2 fatalities out of the 37,633 US fatalities that occurred in 1999[6]. The estimated effect of a 100 lb weight reduction by vehicle type is as follows:

Vehicle Type	Fatalities in 1999 Crashes[1]	Effect of a 100 Pound Weight Reduction	Net Fatality Change	±3-sigma confidence bounds
Passenger Cars	25,335	0.13%	34	-80 to +148
Light Trucks	19,179	-0.19%	-36	-125 to +53
Total	37,633	-0.00%	-2	-146 to +142

[1]IIHS, Table 2-3 of Ref 12.

[6] There were 41,611 US traffic fatalities in 1999 (Ref 24), including collisions involving three or more vehicles, two or more vehicles and pedestrians or bicyclists, and also collisions not involving passenger cars or light trucks (i.e., collisions involving motorcycles or larger trucks but not passenger cars or light trucks). The 37,633 fatalities analyzed herein were only those involving passenger cars or light trucks, or both, in one or two vehicle collisions. There were 6,881 fatalities involving both cars and light trucks, which are affected by both passenger car and light truck weight reduction, but which were counted only once in the total.

Kahane suggested in Ref 7 that a ±3-sigma confidence bounds would be appropriate to include the "likely range of possible error" resulting from propagated errors introduced by the iterative regression procedures and the use of exogenous coefficients, which is a net change of -146 to +142 fatalities. Therefore, the results indicate that the overall net effect of a 100 pound reduction in passenger vehicle weight on the total number of traffic fatalities is small and statistically insignificant.

The methodology used (i.e., that of Ref 7) indicates that weight changes larger or smaller than 100 lb would also have statistically insignificant effects on overall fatalities, based on the latest accident data.[7]

The statistically non-significant effect of weight reduction is not due to large uncertainty in the data, but rather to the effects of opposing trends in the data. Regarding the uncertainty level, the ±3 standard deviations confidence interval used by Kahane and in this analysis is equivalent to just ±0.4% of the total number of fatalities. Regarding the opposing trends, the results in Tables 6.4 and 6.5 indicate that a 100 lb reduction in vehicle weight would significantly increase the number of fatalities associated with some types of crashes, and significantly decrease the number of fatalities with other types of crashes. For example, a 100 lb reduction in passenger car weight: 1) would significantly increase fatalities associated with principle rollovers and collisions with trucks; and 2) would significantly decrease fatalities associated with collisions with other passenger cars, pedestrians, bicycles, and motorcycles. These and other trends in the data effectively cancel, resulting in no significant overall effect of weight, at current levels of safety technology, and with the current distribution of vehicle types in use.

Sensitivity analyses indicate results that are similar to those of Kahane in Ref 7. The sensitivity results indicate that the estimated net effects of vehicle weight reduction are within ±3 standard deviations for a reasonable

[7] This result is based on a linear assumption that should be reexamined for weight changes much larger than 100 lb.

range of driver age and gender effects, based on the similarity of the driver coefficients in this study to those in Ref 7; and with regard to the inclusion or exclusion of sporty vehicles. The results therefore appear to be stable with regard to such variations.

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