Title

Effect of Accounting for Crash Severity on the Relationship between Mass Reduction and Crash Frequency and Risk per Crash:

Author
Wenzel, Tom, P

Publication Date
2016-05-20

LBNL-1005832

Effect of Accounting for Crash Severity on the Relationship between Mass Reduction and Crash Frequency and Risk per Crash

Final report prepared for the Office of Energy Efficiency and Renewable Energy, US Department of Energy

Prepared by

Tom Wenzel
Building Technology and Urban Systems Division
Energy Technologies Area
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

May 2016

This work was supported by the Vehicle Technologies Program, Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Acknowledgements

This report was funded by Carol Schutte of the Vehicle Technologies Program in the Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy. We are grateful for her support of this research.

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Executive Summary

Previous analyses have indicated that mass reduction is associated with an increase in crash frequency (crashes per VMT), but a decrease in fatality or casualty risk once a crash has occurred, across all types of light-duty vehicles. These results are counter-intuitive: one would expect that lighter, and perhaps smaller, vehicles have better handling and shorter braking distances, and thus should be able to avoid crashes that heavier vehicles cannot. And one would expect that heavier vehicles would have lower risk once a crash has occurred than lighter vehicles. However, these trends occur under several alternative regression model specifications.

This report tests whether these results continue to hold after accounting for crash severity, by excluding crashes that result in relatively minor damage to the vehicle(s) involved in the crash. Excluding non-severe crashes from the initial LBNL Phase 2 and simultaneous two-stage regression models for the most part has little effect on the unexpected relationships observed in the baseline regression models. This finding suggests that other subtle differences in vehicles and/or their drivers, or perhaps biases in the data reported in state crash databases, are causing the unexpected results from the regression models.

Table of Contents

List of Tables and Figures

1. Introduction

Reducing vehicle mass is perhaps the easiest and least-costly method to reduce fuel consumption and greenhouse gas emissions from light-duty vehicles. However, the extent to which government regulations should encourage manufacturers to reduce vehicle mass depends on what effect, if any, light-weighting vehicles is expected to have on societal safety. As part of an interagency analysis effort between the National Highway Traffic Safety Administration (NHTSA), the Environmental Protection Agency (EPA), and the Department of Energy (DOE), Lawrence Berkeley National Laboratory (LBNL) has been examining the relationship between vehicle mass and size and U.S. societal fatality and casualty risk, using historical data on recent vehicle designs. This research effort informs the agencies on the extent to which vehicle mass can be reduced in order to meet fuel economy and greenhouse gas emissions standards, without compromising the safety of road users.

In 2012 NHTSA updated its 2003 and 2010 logistic regression analyses of the effect a reduction in light-duty vehicle mass has on US societal fatality risk[1] per vehicle mile of travel (VMT; Kahane 2012); the 2012 analysis is the most thorough investigation of this issue to date. In 2012 LBNL completed two studies that replicated NHTSA's analysis of fatality risk per VMT (the "Phase 1" study, Wenzel 2012a), and analyzed the relationship between mass reduction and the two components of risk per VMT, crashes per VMT (or crash frequency) and risk once a crash has occurred (or crashworthiness; the "Phase 2" study, Wenzel 2012b).

The 2012 LBNL Phase 2 study, which analyzed the effect of mass reduction on crash frequency and casualty risk per crash, as well as the DRI and LBNL simultaneous two-stage regression models, which analyzed the effect on crash frequency and US fatality risk per crash, found that mass reduction was associated with increases in crash frequency but no effect on, or even decreases in, risk per crash, for all types of vehicles (Wenzel 2012b, Wenzel 2016a). These results were unexpected: one would expect that lighter vehicles, with better maneuverability and shorter braking distances, would have lower crash frequency than heavier vehicles; and that heavier vehicles would have lower risk once a crash has occurred than lighter vehicles. LBNL examined the sensitivity of the results on crash frequency to adding several additional explanatory variables to the baseline NHTSA regression model; none of these variables, either independently or combined, changed the relationship between mass reduction and increased crash frequency (Wenzel 2016b).

In his 2012 report Kahane suggested two possible explanations for these unexpected results: that the analysis did not account for the severity of the crash, and possible bias in the crashes reported to police in different states, with less severe crashes being under-reported for certain vehicle types (Kahane 2012). The full text from Kahane 2012 is included in the Appendix. (In his preliminary 2011 report Kahane speculated that owners of heavier vehicles such as SUVs and pickups would be less likely to report minor crashes than owners of lighter passenger cars, because the heavier vehicles would sustain less damage in a two-vehicle crash; however this suggestion was removed from the final report. It would seem just as likely that owners of

[1] Societal fatality risk includes the risk to both the occupants of the case vehicle as well as any crash partner or pedestrians.

vehicles that are un- or under-insured would refrain from reporting a minor crash; their vehicles are likely to be inexpensive passenger cars rather than heavier and more expensive pickups or SUVs.)

This report analyzes the first of Kahane's explanations for the unexpected result of mass reduction being associated with decreased risk per crash: that the regression models do not account for the severity of the crash.

2. Effect on results using crash data from 13-states

Of the 13 states whose police-reported crash data were used, seven report the severity of the damage sustained by the subject vehicle, two report whether the vehicle had to be towed from the crash scene, and three report both. Because Washington does not report either of these measures of crash severity, it had to be excluded from the analysis. For the seven states that report crash damage severity, vehicles that were described as "disabled" were included, while vehicles with functional, none, or unknown damage were excluded. 95% of crashes involving a casualty occurred in states other than Washington; of these crashes, 46% were severe crashes. 98% of casualties occurred in states other than Washington; of these casualties, 90% occurred in severe crashes.

Table 1 compares the estimates for selected variables for the crash frequency and casualty risk per crash regression models, under two regression models: the "Base" estimates are from the NHTSA baseline model, while the "Ex WA" are from a model which excludes all crashes that occurred in Washington. Values in red are statistically significant at the 95% level, while the estimates shaded green are in the expected direction, and those shaded yellow are in the opposite direction. Table 1 indicates that excluding the Washington crashes has only a small effect on the estimated coefficients for crash frequency and casualty risk per crash. (Estimated coefficients for all variables included in the model are shown in Appendix A.)

Table 2 compares the estimates for selected variables from the "Ex WA" model in Table 1 with a model that includes only vehicles in crashes in which at least one involved vehicle was so disabled from the crash that it had to be towed from the crash scene (i.e. excludes non-severe crashes, labeled "Ex NS" in the table). Again, values in red are statistically significant at the 95% level, while the estimates shaded green are in the expected direction, and those shaded yellow are in the opposite direction (estimated coefficients for all variables included in the model are shown in Appendix A.)

As Kahane and LBNL noted in their 2012 studies, certain vehicle technologies, such as ABS and ESC, should reduce crash frequency, while others, such as side airbags in cars and CUVs/minivans, and supplementary frontal bumpers (BLOCKER1) or greater bumper overlap (BLOCKER2) on light trucks, should reduce casualty risk once a crash has occurred. And one might expect that, all else held equal, mass reduction would reduce braking distance, and footprint reduction (or more specifically wheelbase) would improve maneuverability, both of which would result in reduced crash frequency. On the other hand, one might expect that the added mass of AWD might increase braking distance, and thus increase crash frequency, while decreasing risk per crash in the subject vehicle but perhaps increasing societal risk per crash.

Table 1. Estimated effect on crash frequency (crashes per mile traveled, Cr/M) and casualty risk per crash (C/Cr), NHTSA baseline model and excluding crashes in Washington

	Crash frequency (crashes per VMT)						Casualties per crash					
	Cars		Light Trucks		CUVs/minivans		Cars		Light Trucks		CUVs/minivans	
Variable	Base	Ex WA	Base	Ex WA	Base	Ex WA	Base	Ex WA	Base	Base	Ex WA	Base
UNDRWT00	1.97%	2.02%	1.43%	1.46%	—	—	0.17%	0.22%	-0.12%	-0.15%	—	—
OVERWT00	1.34%	1.37%	0.93%	0.86%	—	—	-1.01%	-1.03%	-0.71%	-0.73%	—	—
LBS100	—	—	—	—	0.93%	0.85%	—	—	—	—	-0.26%	-0.22%
FOOTPRNT	0.85%	0.86%	1.09%	1.12%	-0.53%	-0.40%	0.42%	0.36%	-0.17%	-0.14%	0.79%	0.87%
TWODOOR	4.98%	5.48%	—	—	—	—	1.29%	1.24%	—	—	—	—
SUV	—	—	-0.80%	-0.47%	—	—	—	—	1.85%	1.50%	—	—
HDPU	—	—	-3.40%	-3.72%	—	—	—	—	-0.28%	-0.94%	—	—
BLOCKER1	—	—	-0.21%	-1.09%	—	—	—	—	0.60%	0.67%	—	—
BLOCKER2	—	—	-0.69%	-0.28%	—	—	—	—	-4.82%	-4.75%	—	—
MINIVAN	—	—	—	—	2.68%	1.96%	—	—	—	—	13.0%	14.36%
ROLLCURT	-1.93%	-1.88%	—	—	-0.89%	-0.81%	-3.97%	-3.91%	—	—	-1.85%	-1.81%
CURTAIN	-0.10%	0.00%	—	—	-3.40%	-2.94%	-3.02%	-2.94%	—	—	-3.63%	-3.03%
COMBO	2.36%	2.55%	—	—	-0.37%	-0.79%	-1.58%	-1.66%	—	—	5.13%	5.49%
TORSO	-5.43%	-5.07%	—	—	-4.81%	-4.59%	-10.4%	-10.4%	—	—	-2.80%	-2.91%
ABS	-6.14%	-5.73%	—	—	-19.6%	-19.0%	-1.82%	-1.98%	—	—	-9.11%	-9.08%
ESC	-16.8%	-16.7%	-15.7%	-15.1%	-1.20%	-1.28%	-12.0%	-12.4%	-18.2%	-18.3%	-10.1%	-10.2%
AWD	—	—	44.9%	39.4%	10.7%	8.84%	—	—	0.96%	1.07%	-4.86%	-4.14%
DRVMALE	6.43%	6.66%	-0.95%	-1.12%	1.90%	2.02%	-0.28%	-0.01%	-0.14%	-0.06%	7.94%	8.09%
M14_30	4.41%	4.36%	3.83%	3.76%	5.11%	5.03%	1.05%	1.02%	0.64%	0.63%	0.58%	0.52%
M30_50	0.35%	0.33%	0.39%	0.40%	0.18%	0.18%	0.02%	0.02%	-0.16%	-0.17%	-0.15%	-0.15%
M50_70	0.16%	0.16%	0.33%	0.31%	0.61%	0.63%	1.30%	1.27%	1.12%	1.11%	1.26%	1.28%
M70_96	3.98%	3.93%	4.42%	4.42%	3.40%	3.27%	2.37%	2.36%	1.87%	1.87%	1.87%	1.95%
F14_30	3.49%	3.46%	3.57%	3.53%	3.62%	3.61%	0.73%	0.75%	0.60%	0.62%	1.25%	1.24%
F30_50	-0.04%	-0.05%	0.01%	0.03%	-0.01%	0.00%	-0.45%	-0.43%	-0.14%	-0.12%	-0.25%	-0.18%
F50_70	0.71%	0.70%	0.93%	0.91%	1.10%	1.09%	1.09%	1.08%	1.34%	1.32%	2.06%	2.08%
F70_96	4.37%	4.33%	3.37%	3.31%	3.43%	3.36%	1.84%	1.86%	-0.37%	-0.16%	0.65%	0.58%
NITE	32.4%	32.4%	37.8%	37.2%	25.2%	25.2%	44.2%	43.1%	42.2%	40.9%	32.1%	32.0%
RURAL	21.3%	20.9%	20.3%	19.3%	15.6%	15.2%	48.5%	48.4%	42.2%	41.4%	43.7%	43.3%
SPDLIM55	62.1%	60.4%	41.9%	41.7%	34.5%	33.4%	81.9%	82.9%	86.3%	88.2%	87.3%	88.3%

* Values in red are statistically significant at the 95% level. Estimates shaded green are in the expected direction, those shaded yellow are in the opposite direction.

Table 2 presents the estimated effects on crash frequency (crashes per VMT) and casualty risk per crash by vehicle type. For cars, two-door cars are associated with a higher crash frequency (5.48%) and risk per crash (1.24%) than four-door cars, in the "Ex WA" model. Excluding the most severe crashes (the "Ex NS" model) has little effect on the TWODOOR variable (5.93%, 1.40%).

As expected, the four side airbag variables all are associated with a decrease in risk per crash (although only two are statistically-significant) in the "Ex WA" model; however, two are also associated with an unexpected decrease in crash frequency, and COMBO is associated with an unexpected increase in crash frequency. Excluding the most severe crashes in the "Ex NS" model has little effect on these variables.

Table 2. Estimated effect on crash frequency (crashes per mile traveled) and casualty risk per crash, excluding crashes in Washington ("Ex WA") and excluding non-severe crashes ("Ex NS")

	Crash frequency (crashes per VMT)						Casualties per crash					
	Cars		Light Trucks		CUVs/minivans		Cars		Light Trucks		CUVs/minivans	
Variable	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS
UNDRWT00	2.02%	2.08%	1.46%	1.65%	—	—	0.22%	0.13%	-0.15%	-0.42%	—	—
OVERWT00	1.37%	1.17%	0.86%	0.98%	—	—	-1.03%	-0.65%	-0.73%	-1.16%	—	—
LBS100	—	—	—	—	0.85%	0.95%	—	—	—	—	-0.22%	-0.26%
FOOTPRNT	0.86%	1.48%	1.12%	1.07%	-0.40%	-0.03%	0.36%	-0.29%	-0.14%	-0.11%	0.87%	1.17%
TWODOOR	5.48%	5.93%	—	—	—	—	1.24%	1.40%	—	—	—	—
SUV	—	—	-0.47%	-0.27%	—	—	—	—	1.50%	0.19%	—	—
HDPU	—	—	-3.72%	-3.35%	—	—	—	—	-0.94%	-2.25%	—	—
BLOCKER1	—	—	-1.09%	-0.35%	—	—	—	—	0.67%	1.64%	—	—
BLOCKER2	—	—	-0.28%	-2.04%	—	—	—	—	-4.75%	-2.69%	—	—
MINIVAN	—	—	—	—	1.96%	-1.67%	—	—	—	—	14.4%	24.3%
ROLLCURT	-1.88%	-1.74%	—	—	-0.81%	-0.74%	-3.91%	-3.75%	—	—	-1.81%	-1.80%
CURTAIN	0.00%	0.20%	—	—	-2.94%	-0.58%	-2.94%	-3.48%	—	—	-3.03%	-5.99%
COMBO	2.55%	2.82%	—	—	-0.79%	-1.60%	-1.66%	-1.58%	—	—	5.49%	7.26%
TORSO	-5.07%	-5.93%	—	—	-4.59%	-7.09%	-10.4%	-9.12%	—	—	-2.91%	-0.26%
ABS	-5.73%	-7.62%	—	—	-19.0%	-19.0%	-1.98%	-1.39%	—	—	-9.08%	-6.16%
ESC	-16.7%	-16.4%	-15.1%	-19.8%	-1.28%	-5.08%	-12.4%	-12.2%	-18.3%	-14.4%	-10.2%	-7.65%
AWD	—	—	39.4%	37.6%	8.84%	10.5%	—	—	1.07%	0.42%	-4.14%	-6.69%
DRVMALE	6.66%	10.2%	-1.12%	-0.54%	2.02%	3.76%	-0.01%	-4.53%	-0.06%	-1.94%	8.09%	7.50%
M14_30	4.36%	5.51%	3.76%	4.42%	5.03%	6.06%	1.02%	-0.07%	0.63%	-0.32%	0.52%	-0.78%
M30_50	0.33%	0.66%	0.40%	0.56%	0.18%	0.40%	0.02%	-0.25%	-0.17%	-0.37%	-0.15%	-0.35%
M50_70	0.16%	0.35%	0.31%	0.34%	0.63%	0.85%	1.27%	1.22%	1.11%	1.16%	1.28%	1.12%
M70_96	3.93%	4.86%	4.42%	5.05%	3.27%	4.03%	2.36%	1.66%	1.87%	1.52%	1.95%	1.17%
F14_30	3.46%	4.70%	3.53%	4.72%	3.61%	4.85%	0.75%	-0.20%	0.62%	-0.44%	1.24%	0.03%
F30_50	-0.05%	0.06%	0.03%	-0.11%	0.00%	-0.04%	-0.43%	-0.67%	-0.12%	-0.14%	-0.18%	-0.23%
F50_70	0.70%	1.13%	0.91%	0.93%	1.09%	1.34%	1.08%	0.86%	1.32%	1.39%	2.08%	1.86%
F70_96	4.33%	5.21%	3.31%	3.42%	3.36%	4.18%	1.86%	1.23%	-0.16%	-0.03%	0.58%	-0.18%
NITE	32.4%	41.1%	37.2%	47.3%	25.2%	30.5%	43.1%	33.7%	40.9%	29.2%	32.0%	29.7%
RURAL	20.9%	23.8%	19.3%	22.1%	15.2%	19.1%	48.4%	44.1%	41.4%	37.5%	43.3%	42.9%
SPDLIM55	60.4%	98.0%	41.7%	79.6%	33.4%	68.5%	82.9%	60.6%	88.2%	62.3%	88.3%	71.7%

* Values in red are statistically significant at the 95% level. Estimates shaded green are in the expected direction, those shaded yellow are in the opposite direction.

The crash avoidance technologies ABS and ESC are associated with a large decrease in crash frequency, as expected, in the "Ex WA" model (a 5.73% and 16.7% decrease, respectively); however, they also are associated with large unexpected decreases in risk per crash (a 1.98% decrease for ABS, and a 12.4% decrease for ESC). Excluding the most severe crashes has little effect on crash frequency for ABS (from a 5.73% decrease to a 7.62% decrease) or ESC (from a 16.7% decrease to a 16.4% decrease); excluding severe crashes has little effect on casualty risk per crash for ESC (from a 12.4% decrease to a 12.2% decrease), but results in a small decrease in risk per crash for ABS (from a 1.98% decrease to a 1.39% decrease).

Regarding driver gender, male drivers are associated with an expected large increase in crash frequency (6.66%), but no effect on risk per crash, in the "Ex WA" model. Excluding severe crashes increases the expected large increase in crash frequency to 10.2%, but also results in a large decrease in risk per crash (to 4.53%), in the "Ex NS" model. This result is expected, as men are assumed to be more robust and better able to withstand injury than women in a severe crash. Regarding driver age, the youngest and oldest drivers are associated with the largest increase in crash frequency, as expected, in the "Ex WA" model; and seven of the eight age groups are also associated with increases in risk per crash, suggesting that drivers older than 50 are less robust than 50-year old drivers. Excluding the most severe crashes increases the association between driver age and crash frequency for the youngest and oldest drivers, while decreasing the association between driver age and risk per crash.

Under the "Ex WA" model, driving at night, in a rural county, and on a high-speed road are each associated with large increases in crash frequency (32.4%, 20.9%, and 60.4%, respectively), but even larger increases in risk per crash (43.1%, 48.4%, and 82.9%), particularly on high-speed roads. Excluding the most severe crashes shifts some of the estimated effect from risk per crash to crash severity, for each variable in the "Ex NS" model; however, each variable is still associated with a fairly large increase in risk per crash (33.7% for night, 44.1% for rural roads, and 60.6% for high-speed roads). For example, driving on a high speed road is associated with a 60% increase in crash frequency and a 83% using all crashes; excluding the most severe crashes increases the association of driving on a high speed road to a 98% increase in crash frequency, while reducing the association to a 61% increase in risk per crash.

The results described above for cars are similar for light trucks and CUVs/minivans:

- The two measures to make light trucks more compatible with car-like frontal structures, a secondary bumper (BLOCKER1) and greater overlap in bumper heights between light trucks and cars (BLOCKER2), are expected to have little association with crash frequency, but decrease casualty risk per crash. In the baseline model BLOCKER1 is associated with an unexpected decrease in crash frequency but not risk per crash, while BLOCKER2 has the expected relationship, no effect on crash frequency but a decrease in risk per crash. However, after removing non-severe crashes in the "Ex NS" model, BLOCKER2 is associated with a decrease in both crash frequency and risk per crash.

- For CUVs, three of the four side airbag variables are associated with an expected decrease in risk per crash; however, combination side airbags are associated with a statistically-significant increase in risk per crash, even after excluding non-severe crashes (from a 5.49% increase to a 7.26% increase. All four side airbag variables are associated with an unexpected decrease in crash frequency, particularly curtain (a 2.94% decrease) and torso side airbags (a 4.59% decrease). Excluding non-severe crashes decreases the estimated effect of curtain side airbags on crash frequency (from a 2.94% decrease to a 0.58% decrease, but increases the effect of torso side airbags (from a 4.59% decrease to a 7.09% decrease) on crash frequency.

- ABS in CUVs/minivans, and ESC in light trucks, is associated with a decrease in crash frequency, as expected, but an unexpected decrease in risk per crash. ESC in CUVs/minivans is associated with a much higher decrease in risk per crash than in crash frequency; removing non-severe crashes, increases the effect on crash frequency (from a 1.28% decrease to a 5.08% decrease), and decreases the effect on risk per crash from a 10.2% decrease to a 7.65% decrease), but the effect on crash frequency is still lower than that on risk per crash.

- AWD is associated with a large expected increase in crash frequency in both light trucks and CUVs/minivans, as well as an unexpected decrease in risk per crash in CUVs/minivans; these results do not change after excluding non-severe crashes.

- Male drivers have no effect on crash frequency or risk per crash in light trucks, but for CUVs/minivans are associated with an expected increase in crash frequency, as well as an unexpected increase in risk per crash. As with cars, the youngest and oldest drivers are associated with an increase in crash frequency in light trucks and CUVs/minivans, which increases after non-severe crashes are excluded.

- As with cars, driving at night, in a rural county, and on a high-speed road are each associated with large expected increases in crash frequency, but even larger unexpected increases in risk per crash, in light trucks and CUVS/minivans. Excluding non-severe crashes shifts only some of the estimated effect from risk per crash to crash frequency, for each variable.

3. Effect on results using simultaneous two-stage model

DRI developed a methodology to simultaneously estimate the two components of U.S. fatality risk per VMT, crash frequency and fatality risk per crash; LBNL attempted to replicate the results of the DRI model (Wenzel 2016a). Table 3 compares the results from the baseline simultaneous two-stage model with those after excluding the non-severe crashes. As in Tables 1 and 2, values in red are statistically significant at the 95% level, while the estimates shaded green are in the expected direction, and those shaded yellow are in the opposite direction.

Comparing the "Ex WA" estimates in Table 2 with the "Base" model estimates in Table 3, we see that the simultaneous two-stage model estimates several substantial differences in the effectiveness of side airbags in fatality risk per crash: a smaller decrease in fatality risk per crash for torso airbags in cars (a 1.36% vs. 10.4% decrease), and a large increase in risk per crash for combination side airbags (a 9.48% decrease vs. a 5.49% increase) and a large increase in risk per crash for torso side airbags (a 5.61% increase vs. a 2.91% decrease) in CUVs/minivans. While the two-stage fatality model estimates comparable decreases in crash frequency, as expected, from ABS and ESC to those in the casualty model for all three types of vehicles, the two-stage fatality model estimates larger decreases in risk per crash for ABS in cars (a 5.14% decrease vs. a 1.98% decrease), but unexpected increases in risk per crash for ESC in cars (a 6.22% increase rather than a 12.4% decrease), for ABS in CUVs/minivans (a 5.39% increase rather than a 9.08% decrease), and for ESC in light trucks (a 2.53% decrease rather than a 18.3% decrease) and CUVs/minivans (a 1.39% decrease rather than a 10.2% decrease). For AWD, the two-stage fatality model estimates a similar increase in crash frequency in light trucks and CUVs/minivans to the baseline casualty risk model, as expected, but also estimates unexpected, very large reductions in risk per crash (a 49.2% decrease for light trucks, and a 30.3% decrease for CUVs/minivans).

Table 3. Simultaneous two-stage model estimated effect on U.S. crash frequency (crashes per mile traveled) and fatality risk per crash, baseline and excluding non-severe crashes

	Crash frequency (crashes per VMT)						Casualties per crash					
	Cars		Light Trucks		CUVs/minivans		Cars		Light Trucks		CUVs/minivans	
Variable	Base	Ex NS	Base	Ex NS	Base	Ex NS	Base	Ex NS	Base	Ex NS	Base	Ex NS
UNDRWT00	1.83%	1.89%	1.47%	1.65%	—	—	-0.62%	-1.08%	-1.11%	-1.35%	—	—
OVERWT00	1.25%	0.95%	0.95%	0.96%	—	—	-1.05%	-1.20%	-1.53%	-1.59%	—	—
LBS100	—	—	—	—	0.84%	0.78%	—	—	—	—	-1.55%	-1.40%
FOOTPRNT	0.99%	1.66%	1.14%	1.07%	-0.35%	0.18%	1.14%	0.62%	-1.43%	-1.48%	2.45%	1.67%
TWODOOR	5.13%	5.77%	—	—	—	—	2.03%	1.15%			—	—
SUV	—	—	-2.32%	0.01%	—	—	—	—	16.7%	12.8%	—	—
HDPU	—	—	-3.08%	-3.57%	—	—	—	—	5.37%	5.83%	—	—
BLOCKER1	—	—	-0.93%	-1.38%	—	—	—	—	-1.86%	-1.01%	—	—
BLOCKER2	—	—	-0.70%	-2.26%	—	—	—	—	-1.18%	0.29%	—	—
MINIVAN	—	—	—	—	2.70%	-3.43%	—	—	—	—	-8.83%	-5.31%
ROLLCURT	-1.19%	-1.16%	—	—	-0.66%	-0.59%	-0.38%	-1.04%	—	—	-1.42%	-1.05%
CURTAIN	-0.04%	0.58%	—	—	-3.87%	-0.97%	-0.06%	-1.21%	—	—	1.11%	-1.92%
COMBO	2.00%	2.54%	—	—	0.00%	-2.68%	-2.45%	-4.36%	—	—	-9.48%	-6.70%
TORSO	-6.35%	-6.32%	—	—	-4.48%	-7.71%	-1.36%	-3.36%	—	—	5.61%	11.5%
ABS	-5.99%	-8.44%	—	—	-19.4%	-17.8%	-5.14%	-3.68%	—	—	5.39%	2.38%
ESC	-17.1%	-16.6%	-17.1%	-19.1%	-1.52%	-4.71%	6.22%	3.09%	-2.53%	-0.90%	-1.39%	-2.79%
AWD	—	—	44.8%	31.5%	10.0%	8.05%	—	—	-49.2%	-47.0%	-30.3%	-32.6%
DRVMALE	5.54%	9.77%	-2.86%	-1.68%	0.53%	2.59%	30.9%	23.1%	24.4%	21.5%	36.3%	32.5%
M14_30	4.48%	5.45%	3.71%	4.36%	4.93%	5.89%	0.24%	-0.79%	-0.07%	-0.82%	-1.01%	-2.28%
M30_50	0.50%	0.73%	0.44%	0.64%	0.26%	0.49%	0.97%	0.71%	0.79%	0.53%	0.71%	0.60%
M50_70	0.11%	0.30%	0.24%	0.26%	0.59%	0.83%	2.34%	2.17%	1.16%	1.09%	1.59%	1.53%
M70_96	4.26%	4.93%	4.33%	4.79%	3.47%	4.04%	4.00%	2.99%	3.35%	2.89%	3.66%	2.49%
F14_30	3.68%	4.77%	3.46%	4.72%	3.64%	4.97%	-0.53%	-1.69%	0.37%	-0.98%	1.36%	-0.25%
F30_50	0.05%	0.11%	0.01%	-0.12%	-0.01%	-0.08%	0.09%	-0.03%	0.27%	0.35%	-0.40%	-0.12%
F50_70	0.74%	1.08%	0.81%	0.82%	1.04%	1.22%	2.67%	2.24%	2.62%	2.53%	2.55%	2.50%
F70_96	4.51%	5.24%	3.68%	3.46%	3.42%	4.12%	3.55%	2.62%	2.21%	2.67%	3.93%	3.25%
NITE	31.2%	37.1%	41.0%	44.6%	30.5%	29.8%	119%	110%	93.0%	90.1%	86.2%	96.5%
RURAL	24.3%	22.4%	23.9%	19.4%	25.1%	20.8%	162%	177%	145%	159%	149%	167%
SPDLIM55	66.7%	97.4%	51.4%	80.8%	44.6%	69.7%	205%	153%	222%	164%	232%	186%

* Values in red are statistically significant at the 95% level. Estimates shaded green are in the expected direction, those shaded yellow are in the opposite direction.

For the most part, the estimated effects of driver age in the two-stage fatality risk model are comparable to those in the casualty risk model; however, the two-stage fatality risk model estimates large, unexpected increases in risk per crash for male drivers, for each vehicle type (31% for cars, 24% for light trucks, and 36% for CUVs/minivans). Similarly, the large unexpected increases in risk per crash in the casualty risk model are even higher in the two-stage fatality risk model.

The effect of removing non-severe crashes from the analysis using the two-stage fatality model can be seen by comparing the two sets of estimates in Table 3. As in Table 2, removing the non-severe crashes somewhat improves the estimated effects for some variables, but does not "correct" the unexpected results from the baseline model. For example, combination and torso side airbags in cars are associated with larger decreases in risk per crash after removing non-severe crashes (from a 2.45% to a 4.36% decrease for combination side airbags, and from a 1.36% decrease to a 3.36% decrease for torso side airbags); however, combination side airbags continue to be associated with an increase, and torso side airbags with a decrease, in crash frequency in cars. The crash avoidance technologies continue to be associated with expected large decreases in crash frequency, but also a large decrease in risk per crash in cars.

While removing severe crashes somewhat decreases the unexpected increases in risk per crash for male drivers, and in some cases driving at night, in rural counties, or on high-speed roads, these unexpected increases in risk per crash remain quite large in the two-stage fatality model after removing severe crashes.

4. Conclusions

These results suggest that accounting for crash severity, by excluding crashes where all involved vehicles were able to be driven away from the crash scene, for the most part has little effect on the unexpected relationships between crash frequency, casualty risk per crash, and vehicle characteristics, driver age and gender, and crash circumstances, in either the two separate crash frequency and casualty risk per crash models developed in LBNL Phase 2 (Table 2), or the simultaneous two-stage U.S. fatality risk model (Table 3). These findings suggest that other subtle differences in vehicle designs, driver characteristics or behavior, or perhaps biases in the data reported in state crash databases, are causing the unexpected results from the baseline regression models.

5. References

Kahane, C.J. 2012. *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs*. Final report prepared for the National Center for Statistics and Analysis, National Highway Traffic Safety Administration, DOT HS 811 665. August.

Wenzel, Tom. 2012a. *Assessment of NHTSA's Report "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs"*. Final report prepared for the Office of Energy Efficiency and Renewable Energy, US Department of Energy. Lawrence Berkeley National Laboratory. August. LBNL-5698E.

Wenzel, Tom. 2012b. *An Analysis of the Relationship between Casualty Risk per Crash and Vehicle Mass and Footprint for Model Year 2000-2007 Light-Duty Vehicles*. Final report prepared for the Office of Energy Efficiency and Renewable Energy, US Department of Energy. Lawrence Berkeley National Laboratory. August. LBNL-5697E.

Wenzel, Tom. 2016a. *Assessment of DRI's Two-Stage Logistic Regression Model Used to Simultaneously Estimate the Relationship between Vehicle Mass or Size Reduction and U.S. Fatality Risk, Crashworthiness/Compatibility, and Crash Avoidance*. Final report prepared for the Office of Energy Efficiency and Renewable Energy, US Department of Energy. Lawrence Berkeley National Laboratory. January. LBNL-1005830

Wenzel, Tom. 2016b. *Sensitivity of Light-Duty Vehicle Crash Frequency per Vehicle Mile of Travel to Additional Vehicle and Driver Variables*. Final report prepared for the Office of Energy Efficiency and Renewable Energy, US Department of Energy; Lawrence Berkeley National Laboratory, 2014. February. LBNL-1005831

Appendix A: Detailed regression model results

Table A-1. Estimated effect on crash *frequency* (crashes per mile traveled) and casualty risk per crash, NHTSA baseline model ("Base") and excluding crashes in WA ("Ex WA")

	Crash frequency (crashes per VMT)						Casualties per crash					
	Cars		Light Trucks		CUVs/minivans		Cars		Light Trucks		CUVs/minivans	
Variable	Base	Ex WA	Base	Ex WA	Base	Ex WA	Base	Ex WA	Base	Ex WA	Base	Ex WA
UNDRWT00	1.97%	2.02%	1.43%	1.46%	—	—	0.17%	0.22%	-0.12%	-0.15%	—	—
OVERWT00	1.34%	1.37%	0.93%	0.86%	—	—	-1.01%	-1.03%	-0.71%	-0.73%	—	—
LBS100	—	—	—	—	0.93%	0.85%	—	—	—	—	-0.26%	-0.22%
FOOTPRNT	0.85%	0.86%	1.09%	1.12%	-0.53%	-0.40%	0.42%	0.36%	-0.17%	-0.14%	0.79%	0.87%
TWODOOR	4.98%	5.48%	—	—	—	—	1.29%	1.24%	—	—	—	—
SUV	—	—	-0.80%	-0.47%	—	—	—	—	1.85%	1.50%	—	—
HDPU	—	—	-3.40%	-3.72%	—	—	—	—	-0.28%	-0.94%	—	—
BLOCKER1	—	—	-0.21%	-1.09%	—	—	—	—	0.60%	0.67%	—	—
BLOCKER2	—	—	-0.69%	-0.28%	—	—	—	—	-4.82%	-4.75%	—	—
MINIVAN	—	—	—	—	2.68%	1.96%	—	—	—	—	13.0%	14.36%
ROLLCURT	-1.93%	-1.88%	—	—	-0.89%	-0.81%	-3.97%	-3.91%	—	—	-1.85%	-1.81%
CURTAIN	-0.10%	0.00%	—	—	-3.40%	-2.94%	-3.02%	-2.94%	—	—	-3.63%	-3.03%
COMBO	2.36%	2.55%	—	—	-0.37%	-0.79%	-1.58%	-1.66%	—	—	5.13%	5.49%
TORSO	-5.43%	-5.07%	—	—	-4.81%	-4.59%	-10.4%	-10.4%	—	—	-2.80%	-2.91%
ABS	-6.14%	-5.73%	—	—	-19.6%	-19.0%	-1.82%	-1.98%	—	—	-9.11%	-9.08%
ESC	-16.8%	-16.7%	-15.7%	-15.1%	-1.20%	-1.28%	-12.0%	-12.4%	-18.2%	-18.3%	-10.1%	-10.2%
AWD	—	—	44.9%	39.4%	10.7%	8.84%	—	—	0.96%	1.07%	-4.86%	-4.14%
DRVMALE	6.43%	6.66%	-0.95%	-1.12%	1.90%	2.02%	-0.28%	-0.01%	-0.14%	-0.06%	7.94%	8.09%
M14_30	4.41%	4.36%	3.83%	3.76%	5.11%	5.03%	1.05%	1.02%	0.64%	0.63%	0.58%	0.52%
M30_50	0.35%	0.33%	0.39%	0.40%	0.18%	0.18%	0.02%	0.02%	-0.16%	-0.17%	-0.15%	-0.15%
M50_70	0.16%	0.16%	0.33%	0.31%	0.61%	0.63%	1.30%	1.27%	1.12%	1.11%	1.26%	1.28%
M70_96	3.98%	3.93%	4.42%	4.42%	3.40%	3.27%	2.37%	2.36%	1.87%	1.87%	1.87%	1.95%
F14_30	3.49%	3.46%	3.57%	3.53%	3.62%	3.61%	0.73%	0.75%	0.60%	0.62%	1.25%	1.24%
F30_50	-0.04%	-0.05%	0.01%	0.03%	-0.01%	0.00%	-0.45%	-0.43%	-0.14%	-0.12%	-0.25%	-0.18%
F50_70	0.71%	0.70%	0.93%	0.91%	1.10%	1.09%	1.09%	1.08%	1.34%	1.32%	2.06%	2.08%
F70_96	4.37%	4.33%	3.37%	3.31%	3.43%	3.36%	1.84%	1.86%	-0.37%	-0.16%	0.65%	0.58%
NITE	32.4%	32.4%	37.8%	37.2%	25.2%	25.2%	44.2%	43.1%	42.2%	40.9%	32.1%	32.0%
RURAL	21.3%	20.9%	20.3%	19.3%	15.6%	15.2%	48.5%	48.4%	42.2%	41.4%	43.7%	43.3%
SPDLIM55	62.1%	60.4%	41.9%	41.7%	34.5%	33.4%	81.9%	82.9%	86.3%	88.2%	87.3%	88.3%
VEHAGE	0.43%	0.43%	-0.02%	-0.04%	1.45%	1.57%	1.89%	1.87%	2.30%	2.35%	1.05%	0.88%
BRANDNEW	6.24%	6.44%	0.84%	1.20%	0.38%	0.87%	3.20%	3.17%	2.76%	2.76%	3.04%	2.90%
CY2002	-8.09%	-7.77%	-9.70%	-9.20%	-10.9%	-9.12%	4.16%	4.34%	10.2%	9.91%	11.7%	11.9%
CY2003	-6.03%	-5.66%	-3.12%	-2.49%	-5.21%	-3.84%	5.96%	6.03%	5.41%	5.59%	10.6%	11.6%
CY2004	-4.01%	-3.62%	-1.93%	-1.51%	-3.01%	-2.00%	1.81%	1.75%	1.94%	1.63%	-2.21%	-1.68%
CY2005	-1.64%	-1.42%	-0.16%	0.34%	-0.13%	0.71%	1.53%	1.50%	1.63%	1.62%	-0.42%	-0.08%
CY2007	3.89%	3.98%	2.73%	2.86%	3.58%	3.66%	-7.63%	-7.76%	-8.26%	-8.42%	-4.43%	-3.67%
CY2008	3.97%	4.17%	2.01%	1.98%	5.28%	5.30%	-10.1%	-10.2%	-12.2%	-12.3%	-7.48%	-6.89%
AL	143%	144%	91.5%	92.4%	130%	130%	-8.93%	-9.02%	-23.9%	-23.8%	-26.1%	-26.1%
KS	63.1%	63.3%	38.4%	40.9%	58.8%	59.5%	-85.7%	-85.7%	-87.4%	-87.4%	-88.1%	-88.1%
KY	157%	158%	134%	138%	198%	199%	-78.5%	-78.5%	-81.6%	-81.6%	-82.1%	-82.1%
MD	-1.84%	-1.96%	-14.2%	-13.3%	-4.9%	-4.7%	-60.3%	-60.4%	-54.4%	-54.4%	-51.0%	-51.1%
MI	97.3%	97.6%	62.1%	64.8%	78.0%	78.9%	-89.2%	-89.2%	-91.0%	-91.0%	-89.5%	-89.5%
MO	98.5%	98.8%	59.8%	63.0%	89.9%	90.8%	-70.8%	-70.9%	-71.8%	-71.9%	-73.3%	-73.3%
NE	85.4%	85.4%	55.4%	58.7%	65.4%	66.0%	-74.4%	-74.4%	-73.7%	-73.7%	-77.1%	-77.1%
NJ	85.0%	84.7%	66.9%	69.1%	79.1%	79.4%	-91.8%	-91.8%	-91.9%	-91.9%	-92.5%	-92.5%
PA	-28.2%	-28.2%	-25.5%	-23.9%	-25.3%	-24.9%	-75.6%	-75.6%	-75.4%	-75.4%	-76.5%	-76.5%
WA	23.4%	—	31.3%	—	45.1%	—	-87.4%	—	-86.5%	—	-87.1%	—
WI	49.5%	49.6%	34.8%	37.8%	36.8%	37.4%	-74.5%	-74.5%	-76.6%	-76.6%	-76.8%	-76.8%
WY	138%	138%	32.4%	36.6%	96.2%	97.8%	-75.0%	-75.0%	-77.6%	-77.6%	-75.5%	-75.5%

Values in red are statistically significant at the 95% level.

Table A-2. Estimated effect on crash frequency (crashes per mile traveled) and casualty risk per crash, excluding crashes in WA ("Ex WA") and excluding non-severe crashes ("Ex NS")

	Crash frequency (crashes per VMT)						Casualties per crash					
	Cars		Light Trucks		CUVs/minivans		Cars		Light Trucks		CUVs/minivans	
Variable	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS	Ex WA	Ex NS
UNDRWT00	2.02%	2.08%	1.46%	1.65%	—	—	0.22%	0.13%	-0.15%	-0.42%	—	—
OVERWT00	1.37%	1.17%	0.86%	0.98%	—	—	-1.03%	-0.65%	-0.73%	-1.16%	—	—
LBS100	—	—	—	—	0.85%	0.95%	—	—	—	—	-0.22%	-0.26%
FOOTPRNT	0.86%	1.48%	1.12%	1.07%	-0.40%	-0.03%	0.36%	-0.29%	-0.14%	-0.11%	0.87%	1.17%
TWODOOR	5.48%	5.93%	—	—	—	—	1.24%	1.40%	—	—	—	—
SUV	—	—	-0.47%	-0.27%	—	—	—	—	1.50%	0.19%	—	—
HDPU	—	—	-3.72%	-3.35%	—	—	—	—	-0.94%	-2.25%	—	—
BLOCKER1	—	—	-1.09%	-0.35%	—	—	—	—	0.67%	1.64%	—	—
BLOCKER2	—	—	-0.28%	-2.04%	—	—	—	—	-4.75%	-2.69%	—	—
MINIVAN	—	—	—	—	1.96%	-1.67%	—	—	—	—	14.4%	24.3%
ROLLCURT	-1.88%	-1.74%	—	—	-0.81%	-0.74%	-3.91%	-3.75%	—	—	-1.81%	-1.80%
CURTAIN	0.00%	0.20%	—	—	-2.94%	-0.58%	-2.94%	-3.48%	—	—	-3.03%	-5.99%
COMBO	2.55%	2.82%	—	—	-0.79%	-1.60%	-1.66%	-1.58%	—	—	5.49%	7.26%
TORSO	-5.07%	-5.93%	—	—	-4.59%	-7.09%	-10.4%	-9.12%	—	—	-2.91%	-0.26%
ABS	-5.73%	-7.62%	—	—	-19.0%	-19.0%	-1.98%	-1.39%	—	—	-9.08%	-6.16%
ESC	-16.7%	-16.4%	-15.1%	-19.8%	-1.28%	-5.08%	-12.4%	-12.2%	-18.3%	-14.4%	-10.2%	-7.65%
AWD	—	—	39.4%	37.6%	8.84%	10.5%	—	—	1.07%	0.42%	-4.14%	-6.69%
DRVMALE	6.66%	10.2%	-1.12%	-0.54%	2.02%	3.76%	-0.01%	-4.53%	-0.06%	-1.94%	8.09%	7.50%
M14_30	4.36%	5.51%	3.76%	4.42%	5.03%	6.06%	1.02%	-0.07%	0.63%	-0.32%	0.52%	-0.78%
M30_50	0.33%	0.66%	0.40%	0.56%	0.18%	0.40%	0.02%	-0.25%	-0.17%	-0.37%	-0.15%	-0.35%
M50_70	0.16%	0.35%	0.31%	0.34%	0.63%	0.85%	1.27%	1.22%	1.11%	1.16%	1.28%	1.12%
M70_96	3.93%	4.86%	4.42%	5.05%	3.27%	4.03%	2.36%	1.66%	1.87%	1.52%	1.95%	1.17%
F14_30	3.46%	4.70%	3.53%	4.72%	3.61%	4.85%	0.75%	-0.20%	0.62%	-0.44%	1.24%	0.03%
F30_50	-0.05%	0.06%	0.03%	-0.11%	0.00%	-0.04%	-0.43%	-0.67%	-0.12%	-0.14%	-0.18%	-0.23%
F50_70	0.70%	1.13%	0.91%	0.93%	1.09%	1.34%	1.08%	0.86%	1.32%	1.39%	2.08%	1.86%
F70_96	4.33%	5.21%	3.31%	3.42%	3.36%	4.18%	1.86%	1.23%	-0.16%	-0.03%	0.58%	-0.18%
NITE	32.4%	41.1%	37.2%	47.3%	25.2%	30.5%	43.1%	33.7%	40.9%	29.2%	32.0%	29.7%
RURAL	20.9%	23.8%	19.3%	22.1%	15.2%	19.1%	48.4%	44.1%	41.4%	37.5%	43.3%	42.9%
SPDLIM55	60.4%	98.0%	41.7%	79.6%	33.4%	68.5%	82.9%	60.6%	88.2%	62.3%	88.3%	71.7%
VEHAGE	0.43%	1.32%	-0.04%	0.45%	1.57%	2.69%	1.87%	1.24%	2.35%	2.34%	0.88%	-0.56%
BRANDNEW	6.44%	7.66%	1.20%	0.89%	0.87%	0.11%	3.17%	4.17%	2.76%	5.23%	2.90%	1.94%
CY2002	-7.77%	-13.6%	-9.20%	-15.5%	-9.12%	-15.9%	4.34%	3.94%	9.91%	11.3%	11.9%	8.29%
CY2003	-5.66%	-15.3%	-2.49%	-12.0%	-3.84%	-14.9%	6.03%	7.31%	5.59%	8.52%	11.6%	11.0%
CY2004	-3.62%	-8.66%	-1.51%	-5.42%	-2.00%	-7.00%	1.75%	1.10%	1.63%	2.01%	-1.68%	-2.26%
CY2005	-1.42%	-4.68%	0.34%	-1.77%	0.71%	-4.53%	1.50%	2.18%	1.62%	2.10%	-0.08%	-2.62%
CY2007	3.98%	3.90%	2.86%	3.83%	3.66%	3.72%	-7.76%	-7.85%	-8.42%	-8.69%	-3.67%	-2.77%
CY2008	4.17%	4.24%	1.98%	3.48%	5.30%	4.70%	-10.2%	-10.4%	-12.3%	-12.8%	-6.89%	-6.21%
AL	144%	55.5%	92.4%	22.1%	130%	43.2%	-9.0%	57.2%	-23.8%	38.9%	-26.1%	38.7%
KS	63.3%	6.50%	40.9%	-7.5%	59.5%	5.84%	-85.7%	-75.9%	-87.4%	-78.0%	-88.1%	-79.1%
KY	158%	35.1%	138%	18.3%	199%	45.4%	-78.5%	-61.0%	-81.6%	-64.9%	-82.1%	-65.5%
MD	-1.96%	-11.8%	-13.3%	-22.8%	-4.69%	-10.5%	-60.4%	-65.1%	-54.4%	-58.4%	-51.1%	-55.6%
MI	97.6%	9.39%	64.8%	-9.66%	78.9%	2.47%	-89.2%	-78.8%	-91.0%	-81.2%	-89.5%	-78.9%
MO	98.8%	28.7%	63.0%	4.31%	90.8%	19.3%	-70.9%	-54.4%	-71.9%	-54.3%	-73.3%	-57.0%
NE	85.4%	-1.57%	58.7%	-13.0%	66.0%	-7.52%	-74.4%	-52.6%	-73.7%	-52.3%	-77.1%	-55.3%
NJ	84.7%	31.0%	69.1%	16.6%	79.4%	23.5%	-91.8%	-87.5%	-91.9%	-87.1%	-92.5%	-87.5%
PA	-28.2%	-27.0%	-23.9%	-22.4%	-24.9%	-21.5%	-75.6%	-79.0%	-75.4%	-77.9%	-76.5%	-79.9%
WA	—	—	—	—	—	—	—	—	—	—	—	—
WI	49.6%	7.61%	37.8%	-3.91%	37.4%	-3.15%	-74.5%	-64.5%	-76.6%	-66.6%	-76.8%	-66.1%
WY	138%	53.2%	36.6%	-13.7%	97.8%	23.5%	-75.0%	-56.6%	-77.6%	-65.2%	-75.5%	-57.1%

* Values in red are statistically significant at the 95% level.

Appendix B: Discussion of crash frequency and risk per crash results in Kahane 2012

Below is the discussion of DRI's estimates of crash frequency and risk per crash included in Kahane 2012.

> For passenger cars and truck-based LTVs, overall and for many of the individual crash types, these analyses tend to show that (1) mass reduction lowers F/A *[i.e. risk per crash]*, but (2) increases A/VMT *[i.e. crash frequency]*.
>
> The analyses appear to be computationally valid. The sum of the F/A and the A/VMT coefficients is usually close to the baseline coefficients in NHTSA's analysis.
>
> However, in most of their tables, Van Auken and Zellner label the column of F/A coefficients as the "effect of mass reduction on **crashworthiness** and crash compatibility" and the A/VMT coefficients as its "effect on **crash avoidance**." In other words, the tables say mass reduction benefits crashworthiness and harms crash avoidance. NHTSA believes these are not accurate characterizations of the coefficients and they lead, in turn, to misunderstandings. Specifically, the ICCT in their public comment argue that the observed benefit to crashworthiness and harm to crash avoidance is counterintuitive and may be evidence of a flaw in the baseline analysis, such as a need for additional or different control variables.
>
> NHTSA believes the metric of fatalities per reported crash (F/A) does not measure just crashworthiness but also certain important aspects of crash avoidance, namely the severity of a crash. In addition, it could be influenced by how often crashes are reported or not reported.
>
> Conceptually, crashworthiness is the likelihood that an occupant will survive, given an impact to a vehicle that in turn results in a particular physical insult to the occupant. It is quite appropriate for the regression analyses to control for driver age and gender, because it is known that, given the same physical insult, a person is more likely to die with each year that he or she gets older. Furthermore, from young adulthood up to middle age, a female is more likely to die from the same physical insult as a male of the same age. Crash-data analyses have shown increases in fatality risk of 2 to 4 percent for each year that a person gets older. Young adult females are 20 to 30 percent more vulnerable than males of the same age; that differences decreases over time and eventually reverses by late middle age, but averaging across all ages, females are still 5 to 20 percent more vulnerable than males of the same age.
>
> In other words, if these F/A regressions truly modeled crashworthiness, the analyses of the crash types where most fatalities are in the case vehicle (rollover, fixed-object, heavy-truck, and the various types of collisions where the other vehicle is heavier) should have coefficients like -0.03 for M14_30, F14_30, M30_50, and F30_50, each of which measure how many years the driver is younger than 30 or 50, respectively. They should have coefficients like +0.03 for M50_70, F50_70, M70_96, and F70_96, which measure how many years the driver is older than 50 or 70. They should have a coefficient like -

0.10 for DRVMALE, because a male is less vulnerable than a female. In crashes where the fatalities are uncommon in the case vehicle (hitting a pedestrian or a much lighter vehicle), the coefficients should all be close to zero, because the age or gender of the driver will not affect how the pedestrian reacts to a physical insult.
Instead, the regressions rather consistently estimate positive or near-zero coefficients for M14_30, F14_30, M30_50, and F30_50 and positive coefficients for DRVMALE. They say F/A decreases as the occupant ages up to age 50 and F/A is lower for females than males.

A more blatant example: on purely crashworthiness considerations, whether it is light or dark outside ought to have little effect on the risk of death from a given physical insult, except perhaps to the extent it affects EMS arrival. But NITE is consistently associated with an extraordinary increase in F/A.

Of course, it is obvious what is going on. These crash data have no measure of crash severity, such as delta v. M14_30, F14_30, M30_50, F30_50, DRVMALE, and NITE all act as surrogates for crash severity. They not only indicate crashworthiness (ability to survive a physical insult) but also, and in some cases primarily, crash avoidance – namely, the ability of age 30-50 drivers, females, and daytime drivers to stay out of situations that lead to fatal crashes, while having their share of fender-benders. Driving at night, on the other hand, is a way to avoid fender-benders characteristic of rush-hour traffic and thereby increases F/A.

Just as many of the control variables in the F/A regressions measure effects of crash avoidance in addition to (and sometimes in place of) crashworthiness, by the same token, there is no particular reason that the coefficients for UNDRWT00, OVERWT00, and FOOTPRNT measure the effects of crashworthiness exclusively and not also crash avoidance. Control variables such as M14_30, F14_30, M30_50, F30_50, DRVMALE, NITE, and also SPDLIM55 and RURAL may account for much of the effect of crash severity on risk per reported crash, but it is unknown exactly how much.

A salient feature of NHTSA's approach, where the numerator is fatalities and the denominator VMT, is to take crash-reporting rates out of the formula for calculating risk. A fatality is a fatality and a mile of travel is a mile of travel – unlike contact events that may or may not be police-reported, depending on the vehicle, the driver, the locality, or the circumstances of the moment. These analyses of F/A and A/VMT appear to be computationally valid, but NHTSA doubts they truly measure the "effect of mass reduction on crashworthiness" and "effect of mass reduction on crash avoidance."