A DIFFERENCE IN ROLLOVER FREQUENCY BETWEEN CHEVROLET AND GMC TRUCKS

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16. Abstract

The rollover experience in single vehicle accident data was compared for corporate twins: Chevrolet and the corresponding GMC pickup trucks. Chevrolet trucks showed higher rollover proportions than GMC trucks. A number of driver and environmental factors were examined; some showed statistically significant differences between the two makes. A statistical model was developed to control for such differences. Still, a statistically significant difference in rollover proportions remained. The magnitude of this difference is comparable to the effect of the difference between dry and wet pavement, the difference between skidding or not skidding, or a difference of 30 years in driver age. It is 10 percent of the difference in rollover proportion between urban and rural environments.

A secondary issue, the controlled size-specific rollover indicators were studied in relation to certain physical vehicle parameters. The rollover proportion was lower for vehicles with longer wheelbase. Contrary to expectations it was worse for vehicles with higher stability indicators, be they critical sliding velocity, Tilt Table Ratio, or static stability factor. Series with ABS showed significantly lower rollover indicators. Chevrolet, again, higher rollover indicators. The results of the second analysis should be interpreted with caution since only few of these series had physical parameters appreciably differing from their average.

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1 Introduction

In November 1993, NHTSA submitted to Docket 91-68 data on Tilt Table Ratio, Critical Sliding Velocity, and Michigan Rollover per single vehicle accident for many vehicle makes and series [1]. A review of the data showed a systematic difference between the rollover rates of Chevrolet pickup trucks and their "corporate twins," GMC pickup trucks (Table 1). In eight of ten cases the rollover proportions of Chevrolet trucks were higher than those of GMC trucks, in two cases the reverse held, though in one case both proportions were practically equal. If the expected rollover proportions of corporate twins were equal, and the actual proportions differed due only to chance, the probability that in eight (or more) cases out of ten the Chevrolet trucks had a higher rollover proportion would be only 0.054, nearly so low that statisticians would reject the null hypothesis of no difference in rollover proportions. The actual situation is even stronger: in one case, the proportions 21.56 and 21.68 are practically equal. In such a situation one would ignore this case and consider only the 8 (or more) out of 9 cases when Chevrolet trucks had the higher rollover rate. The probability that this is due to chance if both makes had the same rollover probability is only 0.020. This would be considered a significant deviation from the null hypothesis. Thus, there is a strong indication of a difference between Chevrolet and GMC pickup trucks.

Table 1. Rollover proportions in Michigan single vehicle accidents for "corporate twins," Chevrolet and GMC Pickup trucks.

CHEVROLET					GMC
NCSA Code	Model/Series	MI RO/SVA	MI RO/SVA	NCSA Code	Model/Series
0211	S-10 Pickup (4x2)	22.30	19.64	0213	S-15 Pickup (4x2)
0215	S-10 Pickup (4x2)w/ABS	22.90	16.39	0214	S-15 Pickup (4x2)w/ABS
1173	K-1500 Pickup (4x4)w/ABS w/ABS	17.37	12.41	1176	K-1500 Pickup (4x4)
0201	T-10 Pickup (4x4)	23.57	17.00	0203	T-15 Pickup (4x4)
0202	T-10 Pickup (4x4)w/ABS	25.49	8.33	0204	T-15 Pickup (4x4) w/ABS
1183	C-1500 Pickup w/ABS	8.52	11.11	1186	C-1500 Pickup w/ABS[1]
0191	C-20 Pickup (4x2)	21.56	21.68	0194	C-2500 Pickup (4x2)
0192	R-20/2500 Pickup (4x2)	27.78	13.33	0195	R-2500 Pickup (4x2)
0181	C-10 Pickup (4x2)	15.36	12.42	0184	C-1500 Pickup (4x2)
0182	R-10 Pickup (4x2)	16.77	9.80	0185	R-1500 Pickup (4x2)

[1] Average metric for long and short bed models.

Since NHTSA assigned vehicle parameters (tilt table ratio (TTR), critical sliding velocity (CSV), static stability factor (SSF) and wheelbase) measured on one make/series to all corporate twins, these parameters can not explain the observed differences. Therefore, we searched for user and use differences that might explain the differences in the observed rollover proportion. Beyond this question, we also took a look at some additional vehicle factors.

2 Data

To study this question further, NHTSA's detailed original data on single vehicle accidents in Michigan, contained in the data file MI86TO90, were studied. Cases involving the 20 vehicle make/series listed in Table 1 were selected. The accident factors shown in Table 2 were derived from the sometimes more detailed codes in the file. Information on drinking was not used, because it was coded only if drinking was involved; missing information can not be safely interpreted as indication of no alcohol involvement.

After excluding cases with missing data, 3269 urban, and 8003 rural accident involvements were available.

Table 2. Differences in prevalence of accident factors between corresponding Chevrolet and GMC pickup trucks. An asterisk indicates a difference significant at better than 0.1.

Accident factor	Significant	Chevrolet	GMC
Driver age (average)		31.2	31.3
Young (<25), %		37.1	38.4
Very young (<21), %		21.4	21.6
Male, %	*	81.6	83.1
Pursued, %		0.2	0.2
Passing, %		1.3	1.5
Turning, %	*	4.6	5.5
Avoiding, %		13.9	14.5
Skidding, %		9.5	8.9
Rural, %	*	70.8	67.5
Offroad, %		93.6	93.7
Curve, %	*	16.4	15.0
Dry, %	*	47.4	49.7
Bad weather, %		26.9	26.2

3 Comparison of Accident Factors

Table 2 shows the frequencies (in percent) with which the various accident factors were present for the Chevrolet and for GMC vehicles. Only four differed significantly (better than .1, some even better), but there was no pattern in the differences. Chevrolet had a higher adverse incidence in the factors rural, curve, and dry surface; GMC in the factors male and turning. Thus, a quantitative analysis is necessary to determine whether these differences explain the differences in rollover patterns.

4 First Stage Analysis

The analysis was performed in two stages: the first stage dealt with the driver and use factors, and separates their effort from vehicle factors. The second stage compares the remaining vehicle effects, primarily with regard to differences between Chevrolet and GMC, and incidentally also with regard to other vehicle factors.

Each accident involved vehicle was considered one observation. The dependent variable y was 0 if no, 1 if a rollover occurred. For each of these factors in Table 2 a dependent variable x_i was used, continuous for driver age, categorized for the other factors. In addition, for each of the 20 make/series an indicator variable was introduced: being 1 if the vehicle was of that make/series, 0 otherwise. The coefficient of this variable combines a variety of effects. They include differences in the driver population and driving environments that are not captured by the variables such as age, male, rural, offroad, etc.; they also include effects of differences in the physical characteristics of the various makes/series. A logistic model for the probability that y = 1 was used

$$p(y=1) = \exp(f)/(1+\exp(f))$$

where

$$f = a_0 + a_1 x_1 + a_2 x_2 + \ldots$$

The model was fitted to the data by stepwise logistic regression, using the SAS routine LOGISTIC. Variables were included if their significance level was 0.1 or better. In only a few cases were variables selected with significance levels larger than 0.05; however, the choice of 0.1 as inclusion criterion had the effect that there was always a large gap in significance between the included and not included variables.

Because the strong effect of the factor urban/rural is well established, models were developed not only for all accidents together, but also separately for urban and rural accidents. Table 3 shows the coefficients of the three statistical models. The coefficients for the driver and use factors are in the lower part of the table. The selection of coefficients differs among the three data sets. The fact that a certain coefficient does not appear in one data set does not necessarily mean that that factor has no effect: its standard error may just be too large to let it be recognized as significant. The factor age appears in the overall model, and in the urban data set, but not in the rural data set. There, however, the factor "very young" appears which also reflects an effect of age, though a very nonlinear one (being under 21 years has the same effect in the rural environment as being 6 years younger in the urban environment).

Some coefficients have the expected sign: a higher age is related to a lower probability of rollover, as is a dry pavement. A rural environment, passing, skidding, and being in a curve are related to higher rates. Puzzling is that turning has a lower risk, as do an avoidance maneuver, and being off-road.

Table 3. Coefficients and their standard errors of the first stage models for all, urban and rural accidents. Coefficients for series code C0211 are by definition zero. "#" indicates series that had to be excluded from the urban model because of no rollovers in urban accidents. "*" indicates that a variable was not selected by the stepwise procedure. "-" indicates that no entry is applicable.

	all		urban		rural	
variable	coeff	stderr	coeff	stderr	coeff	stderr
INTERCPT	-2.2723	0.1435	-1.2843	0.3196	-0.9783	0.0536
C0211	0	-	0	-	0	-
C0213	-0.1094	0.0906	-0.1675	0.2876	-0.0976	0.0955
C0214	-0.3952	0.2549	0.3125	0.6278	-0.5027	0.2752
C0215	0.0165	0.1080	-0.3231	0.4190	0.0489	0.1122
C1176	-0.6330	0.2763	-0.6150	1.0313	-0.6099	0.2873
C1173	-0.2645	0.1415	-0.0428	0.4508	-0.2626	0.1488
C0203	-0.3533	0.1834	-0.7451	0.7374	-0.3006	0.1902
C0201	0.0506	0.0928	0.1650	0.3225	0.0741	0.0967
C0204	-1.0021	1.0718	#	#	-0.8598	1.0876
C0202	0.0660	0.3341	1.2488	1.1447	0.0688	0.3470
C1186	-0.7086	0.2676	#	#	-0.6102	0.2716
C1183	-1.0333	0.1782	-0.9710	0.6047	-1.0346	0.1861
C0191	0.1563	0.1281	0.1488	0.3757	0.1703	0.1364
C0194	0.1439	0.2170	-0.1004	0.7441	0.1749	0.2293
C0192	0.4818	0.3982	0.8475	1.0941	0.4178	0.4251
C0195	-0.2719	0.7880	#	#	0.0567	0.8399
C0185	-0.9240	0.4815	#	#	-0.8817	0.4847
C0184	-0.5719	0.1328	-0.5811	0.4405	-0.5833	0.1390
C0181	-0.3532	0.0744	-0.3702	0.2558	-0.3525	0.0771
C0182	-0.2097	0.2313	-0.3080	0.7417	-0.1857	0.2445
AGE	-0.00624	0.00205	-0.0237	0.0077	*	*
VYOUNG	*	*	*	*	0.1444	0.0608
PASSING	0.5849	0.1944	*	*	0.6260	0.2082
TURNING	-0.6390	0.1581	-1.2986	0.5154	-0.5778	0.1682
AVOID	*	*	*	*	-0.1366	0.0747
SKID	0.2631	0.0833	0.4976	0.2348	0.2070	0.0893
RURAL	1.8005	0.0855	-	-	-	-
OFFROAD	-0.3255	0.0987	-1.1916	0.2296*	*	
CURVE	0.4124	0.0618	1.2852	0.1843	0.2999	0.0650
DRY	-0.1496	0.0516	*	*	-0.1014	0.0544

The coefficients for the make/series codes show how, after controlling for the other factors, the rollover probability for a make/series differs from that of C0211, the most numerous make/series in this data set. C0213, e.g., has a lower rollover probability. In a few cases, the coefficients in the urban and rural environments differ in their sign, e.g., C0214, C0215, C0194. In all of these cases, the standard error of at least one coefficient is so large that the discrepancy in signs can well be due to chance.

5 Differences Chevrolet Versus GMC Trucks

For each matching pair of Chevrolet and GMC trucks, the difference of the coefficients in Table 3 was calculated, and its standard error (the calculation of the standard error included the effect of the correlations between the coefficients; however, this effect was always less than 10 percent). The differences Chevrolet minus GMC ranged from -.32 to 1.07. Their mean, weighted according to the standard error, is 0.18 with a standard error of 0.06, clearly significantly different from zero.

For rural environments, the weighted average of the differences is 0.15 (.07), and for urban environments 0.18 (.21). Though the latter would not be statistically different from zero, it is neither from the rural value. Thus, it is acceptable and also plausible to assume a value of 0.18 also for urban environments.

Since effects of the available driver and use factors were controlled for by the first stage of the analysis, and in the second stage effects of the available vehicle parameters were controlled by matching, the observed difference must be due to other driver and use factors, which are not in the data base.

To put this difference in perspective: it compares to one tenth of the urban/rural difference, or to a difference of 30 years of age. It is more than the difference between a dry and wet surface, but less than the difference between skidding and not skidding.

6 Second Stage Analysis: Vehicle Factors

In the first stage, driver and use factors were modelled, and all effects resulting from or related to vehicle characteristics were expressed by the coefficients of the indicator variables. In the second stage, these coefficients are studied in relation to physical characteristics of the vehicles. This gives not exactly the same estimates as if all factors, vehicle, user, and use, had been incorporated into one model. However, the differences should be small since the absolute correlation between the user and use variables, and the vehicle indicator are less than 0.06, with the exception of driver age, when it can reach 0.17. The advantage of the two- stage procedure is that it allows a better understanding of the effects and interactions of vehicle factors.

Table 4 shows the vehicle parameters used for the second stage analyses. They are taken from references [1], [2], and [3].

Table 4. Vehicle parameters: Wheelbase, critical sliding velocity, tilt table ratio, static stability factor, antilock brakes, and four-wheel drive. CHV indicates Chevrolet make, and IDF an identifying letter used in the graphs.

CODE	IDF	WB	CSV	TTR	SSF	ABS	4WD	CHV
0213	m	117.72	15.49	1.11	1.236	0	0	0
0211	x	117.72	15.49	1.11	1.236	0	0	1
0214	n	117.72	15.49	1.11	1.236	1	0	0
0215	o	117.72	15.49	1.11	1.236	1	0	1
1176	q	118.30	15.65	1.10	1.144	1	1	0
1173	p	118.30	15.65	1.10	1.144	1	1	1
0203	k	123.16	14.97	.	1.200	0	1	0
0201	i	123.16	14.97	.	1.200	0	1	1
0204	l	123.16	14.97	.	1.200	1	1	0
0202	j	123.16	14.97	.	1.200	1	1	1
1186	s	124.50	15.78	1.07	1.165	1	0	0
1183	r	124.50	15.78	1.07	1.165	1	0	1
0191	e	131.00	16.72	1.15	1.221	0	0	1
0194	g	131.00	16.72	1.15	1.221	0	0	0
0192	f	131.00	16.72	1.15	1.221	0	0	1
0195	h	131.00	16.72	1.15	1.221	0	0	0
0185	d	131.84	15.55	1.12	1.148	0	0	0
0184	c	131.84	15.55	1.12	1.148	0	0	0
0181	a	131.84	15.55	1.12	1.148	0	0	1
0182	b	131.84	15.55	1.12	1.148	0	0	1

7 Other Vehicle Factors

The data in Table 3 allow a similar analysis of matched pairs with and without ABS, but for only four pairs. The mean difference is -.03, with a standard error of 0.10, indicating a small, not significant reduction. For urban environments the difference is 0.00 (.34), and for rural environments -.01 (.10). Because of the large errors, even a practically important effect would not have been detectable.

Figures 1 through 3 show the vehicle coefficient, which is an indicator of rollover proportion, adjusted for nonvehicle factors in relation to three stability measures, CSV, TTR, and SSF. Fig. 1 shows no strong pattern; the points for the 20/2500 series (e-h) suggest an increasing trend, whereas one would expect a declining trend. In Fig. 2, the data points more clearly suggest an increase of rollover frequency with increasing TTR. This time, the pattern depends not only on the 20/2500 family, but is supported by the C-1500 data. Again, the apparent trend contravenes the expectation.

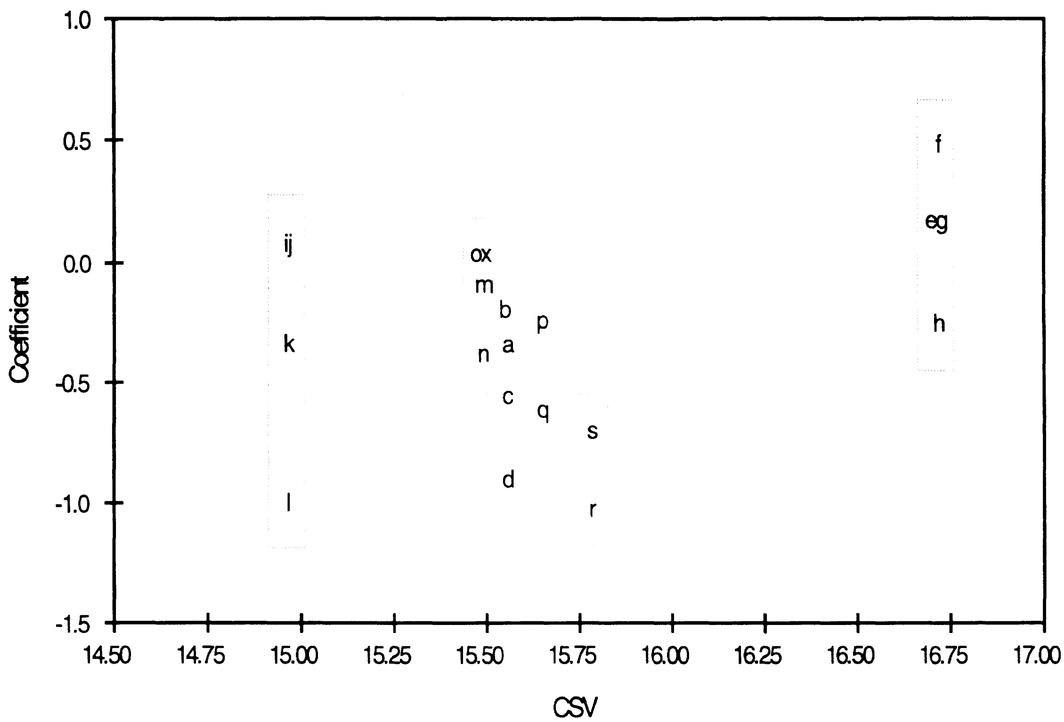

Figure 1. The coefficient of the first stage model as indicator of controlled rollover proportion, versus Critical Sliding Velocity. Letters indicate which make/series (Table 4), make/series with the same wheelbase and stability measures are "boxed."

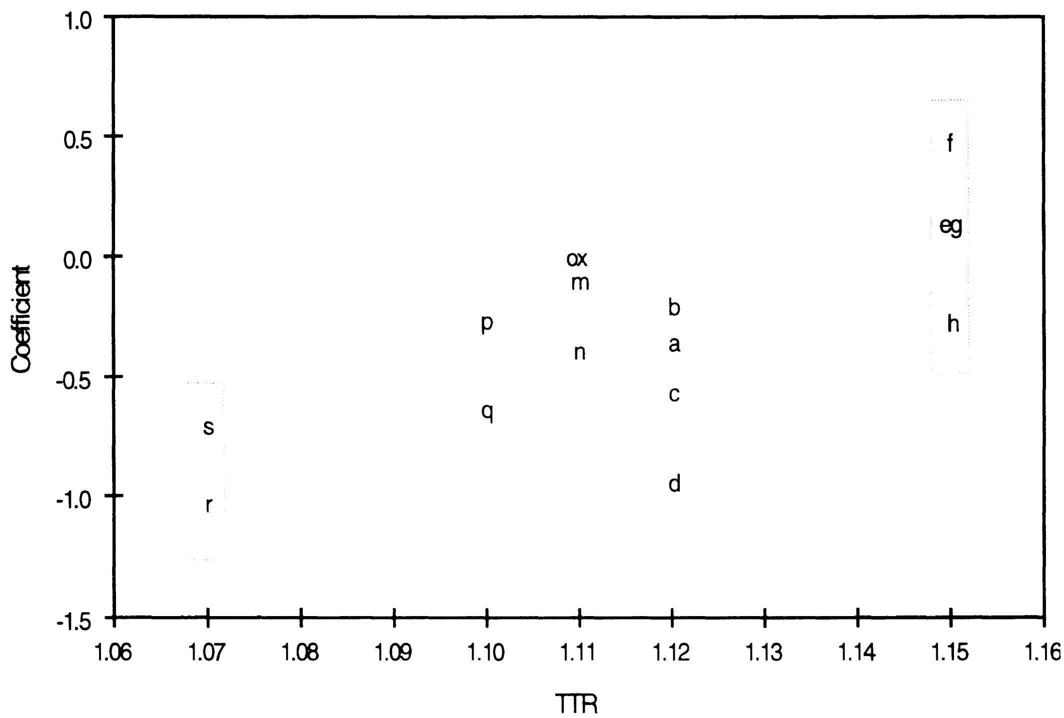

Figure 2. The coefficient of the first stage model as indicator of controlled rollover proportion, versus Tilt Table Ratio. Letters indicate vehicle make/series (Table 4), make/series with the same wheelbase and stability measures, are "boxed."

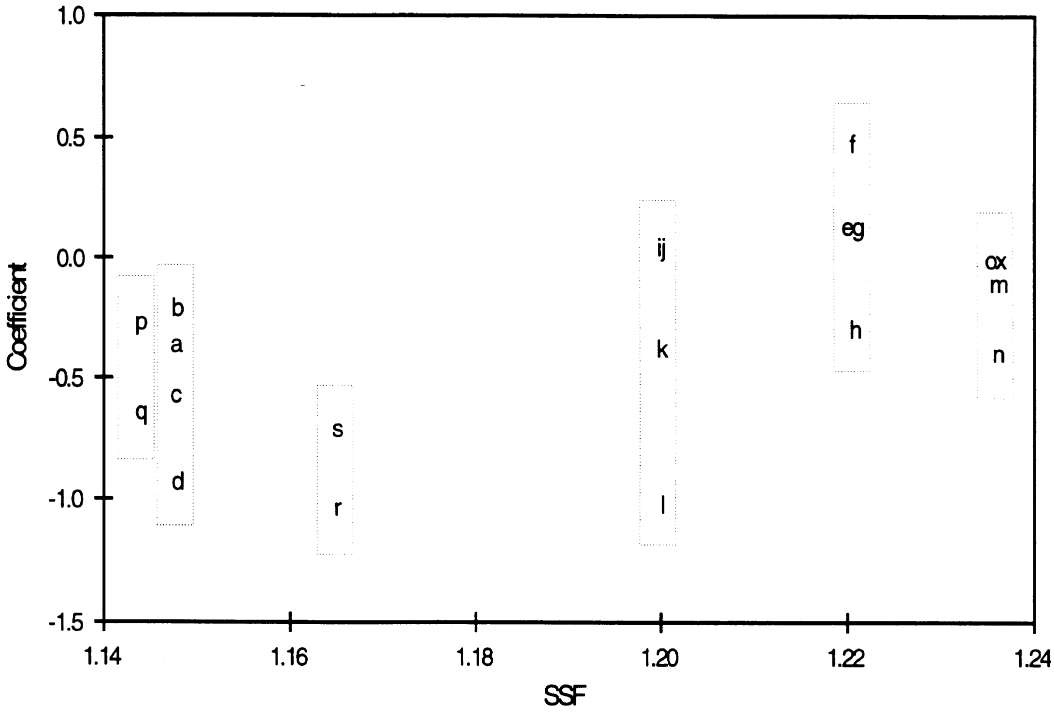

Figure 3. The coefficient of the first stage model as indicator of controlled rollover proportion, versus Static-Stability Factor. Letters indicate which make/series (Table 4), make/series with the same wheelbase and stability measures are "boxed."

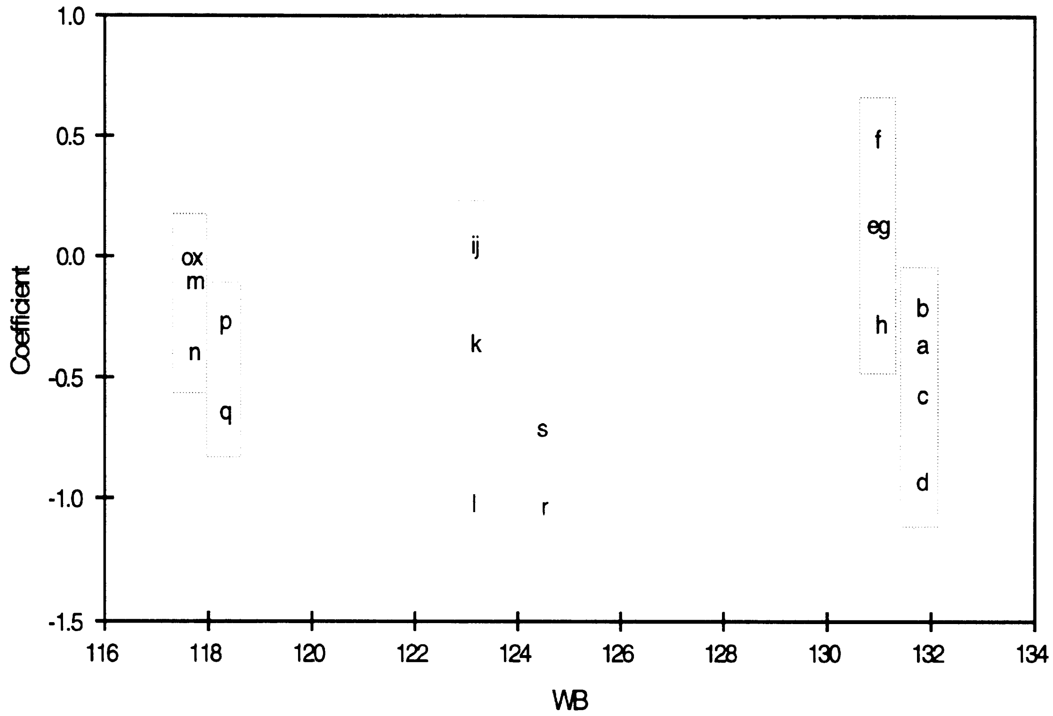

Figure 4. The coefficient of the first stage model as indicator of controlled rollover proportion, versus wheelbase. Letters indicate vehicle make/series, make/series with the same wheelbase are "boxed."

Fig. 3 shows the relation with SSF; there is a slight suggestion of an increase with increasing SSF, but it is not pronounced. Wheelbase (Fig. 4) shows no apparent relation with rollover.

To explore potentially more complex effects of vehicle factors, stepwise regression models were developed with the series coefficient as dependent variable, and the vehicle factors wheelbase (WB), CSV, TTR, SSF, antilock brakes (ABS), four-wheel-drive (4WD), and Chevrolet (Chevy) as independent variables. Because the stability measures are correlated, only one of the three measures was admitted in each model. As selection criterion, c_p was used [4]; though more complicated, it is considered to give better fitting models, though it may include coefficients appearing not significant to the simple t-test when using a stepwise regression. Table 5 shows the result. In some models, WB is a very significant variable, if joined with CSV or TTR. Its sign is as expected. In these cases, CSV or TTR are also very significant, but have a sign opposite to the expected, as suggested by Figs. 1 and 2. When TTR is allowed, it is very significant, but has also the "wrong" sign, and WB does not enter the model. When ABS appears, its coefficient is very significant, and it has the expected sign. This contrasts with the result from the simple matched comparison reported above. One reason for the discrepancy may be that the matched comparison is based on the smaller number of series, which could be matched. Another reason is that the coefficient of ABS in the regression model is also influenced by other vehicle factors series with ABS tend to have shorter wheelbases, and lower values of the stability measures. Therefore, it is not clear which of the two findings is more realistic.

Four-wheeldrive appears only in urban environments, and its coefficient is not, or is barely, significant.

For all accidents, and for urban accidents, the coefficient of Chevy is very significant. It varies between .14 and .36, far more than the uncertainty reflected by the standard error. The estimate obtained by a matched comparison falls into this range. In urban accidents, this term does not appear. If it is forced into the model, its value ranges from .07 to .21, with standard errors of the same order of magnitude. Again, the value found by matched comparison falls into this range.

The regression models did not modify the pattern clearly present in Figs. 1 and 2, and less strongly indicated in Fig. 3. In all models, the stability measure, if included by the selection process, had the "wrong" sign, and was also highly significant. Wheelbase, when entered into the model, always had the "right" sign, and was very significant, whereas in Fig. 4 no relation was apparent.

Table 5 also shows the root mean square error of the model. From the first stage analysis, one also obtains the standard errors of the coefficients, which are the dependent variables in the second stage models. For the model of all accidents their root mean square error is 0.37, for the model of rural accidents it is 0.39, well below the errors of the model described in Table 5. For the urban data, however, the root mean square error of the dependent variable was 0.68, which is more than the root mean square error of the urban models (2). While this suggests "overfitting" inclusion of terms in the model that represent only random fluctuations the very close agreements of the coefficients with those of the rural model (2) reject this concern.

Table 5. Coefficients of second level regression models. Model (1) allows CSV, model (2) TTR, and model (3) SSF to enter as stability measure. "*" indicates parameters that were not allowed to enter the model, "-" parameters that were not selected by the modelling process. RMSE is the root mean square error of the model.

	all			rural			urban		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
RMSE	1.48	0.83	1.19	1.45	0.90	1.15	0.79	0.46	0.71
intercept	1.1	-14.7	-7.7	1.1	-14.7	-7.8	-.24	-14.4	-5.5
	(1.8)	(1.9)	(1.3)	(1.8)	(2.2)	(1.3)	(.10)	(3.8)	(2.3)
WB	-.049	-.036	-	-.049	-.037	-	-	-.032	-
	(.012)	(.006)		(.012)	(.006)			(.010)	
CSV	.30	*	*	.30	*	*	-	*	*
	(.12)			(.12)					
TTR	*	16.0	*	*	17.0	*	*	16.3	*
		(2.0)			(2.2)			(3.9)	
SSF	*	*	6.2	*	*	6.2	*	*	4.4
			(1.1)			(1.1)			(2.2)
ABS	-.56	-	-.24	-.57	-	-.23	-	-	-
	(.15)		(.09)	(.15)		(.09)			
4WD	-	-		-	-		.26	-	.32
							(.21)		(.19)
CHEVY	.36	.14	.27	.36	.14	.26	-	-	-
	(.12	(.07)	(.09)	(.12)	(.07)	(.09)			

8 Discussion

We did find some differences in driver and environmental factors between corresponding GMC and Chevrolet pickup trucks. These differences, however, do not explain the clear difference in their rollover experience. After controlling for such factors, a difference remains that is larger than that resulting from the difference between a dry and a wet road, less than the difference between skidding and not skidding, equal to 10 percent of the difference between urban and rural environment, or a difference of 30 years in driver age.

Thus, there must be differences between the drivers or driving environments of these two vehicle makes, or there might be differences in optional equipment selected by the buyers of these two vehicle makes that make them physically not identical.

As a secondary issue, the effect of several vehicle factors combined was studied. Wheelbase showed a plausible effect: longer wheelbase was correlated with a lower rollover proportion. None of the three rollover stability measures showed an effect in the expected direction. In all cases, greater stability was correlated with a higher rollover proportion, and the coefficients were highly significant (between 2.5 and 8 times their standard errors). About the reasons one can only speculate: all stability measures for a certain vehicle (or possibly two vehicles) might be erroneous, or there are important factors that are not available in the database and therefore not included in the model, which have a strong relation to rollover probability.

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