



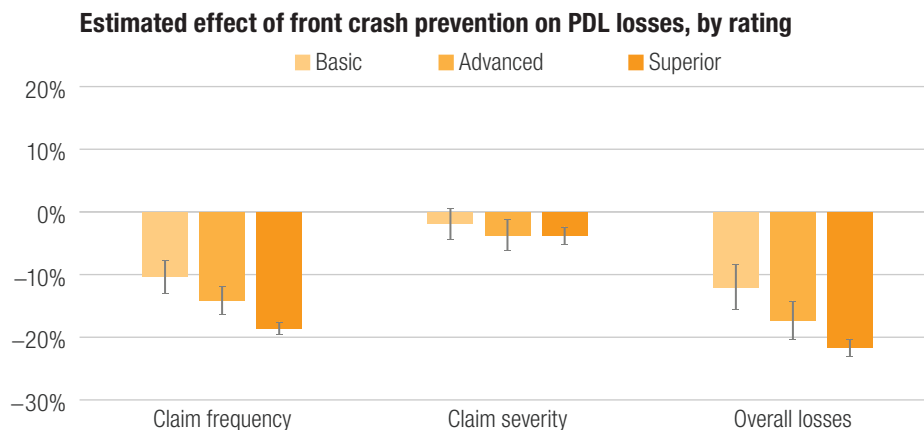
IIHS front crash prevention ratings and insurance losses

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The Insurance Institute for Highway Safety launched a rating program for front crash prevention (FCP) systems in 2013. The program evaluated front automatic emergency braking, forward collision warning, or the combination of the two. The original evaluation, which sunsetted at the end of 2022, assessed the performance of FCP systems in front-to-rear vehicle-to-vehicle crash scenarios at 12 and 25 mph. Vehicles could earn ratings of basic, advanced, or superior.

This study examines the relationship between FCP ratings and insurance losses for 2018–19 model year vehicles under collision, property damage liability (PDL), and bodily injury liability coverages. It focuses on vehicle series that offered FCP as optional equipment, enabling comparisons between rated vehicles equipped with FCP and those without.

Claim frequency reductions were associated with all ratings. Larger benefits were observed for systems with higher ratings. Under PDL, claim severity benefits were also observed, with the largest benefits for the advanced-and superior-rated systems.



► Introduction

Front crash prevention (FCP) systems are designed to prevent or mitigate crashes. The technology detects when the vehicle is getting too close to a potential crash partner. The systems often issue a warning and apply the brakes if the driver doesn't respond. In 2009, the Highway Loss Data Institute (HLDI) was the first to document the effects of a collision avoidance technology on motor vehicle crashes when it evaluated the Mercedes-Benz Distronic system (HLDI, 2009). Since then, HLDI has published more than 100 research reports documenting the efficacy of various collision avoidance technologies for reducing insurance losses. Other studies by the Insurance Institute for Highway Safety (IIHS) examining police reports have found reductions in front-to-rear crashes associated with front crash prevention systems. (e.g., Cicchino, 2017).

Early HLDI findings on the benefits of FCP — the combination of front automatic emergency braking (AEB) and forward collision warning (FCW) — led IIHS to begin evaluating FCP performance in 2013, using a stationary target designed to resemble the rear of a vehicle. The tests assessed the ability of vehicles to avoid or mitigate crashes at speeds of 12 and 25 mph (20 and 40 km/h) (IIHS, 2013). Based on performance in these tests, vehicles were assigned one of three ratings—basic, advanced, or superior.

Figure 1 illustrates the distribution of IIHS FCP ratings from model years 2013 to 2023. The figure is not a representation of the vehicle fleet, but rather of the vehicles evaluated in any of the IIHS testing programs. Of the more than 60 2013 model year vehicles that received an FCP rating, two-thirds received a basic rating, and only 16% received the highest rating of superior. By model year 2023, all rated vehicles were equipped with FCP, with 91% rated superior.

Figure 1: Front crash prevention ratings, 2013–23 model years

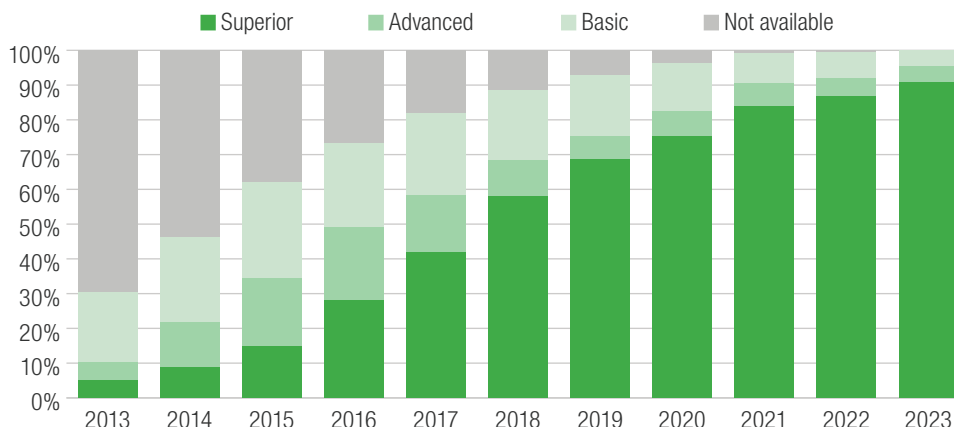
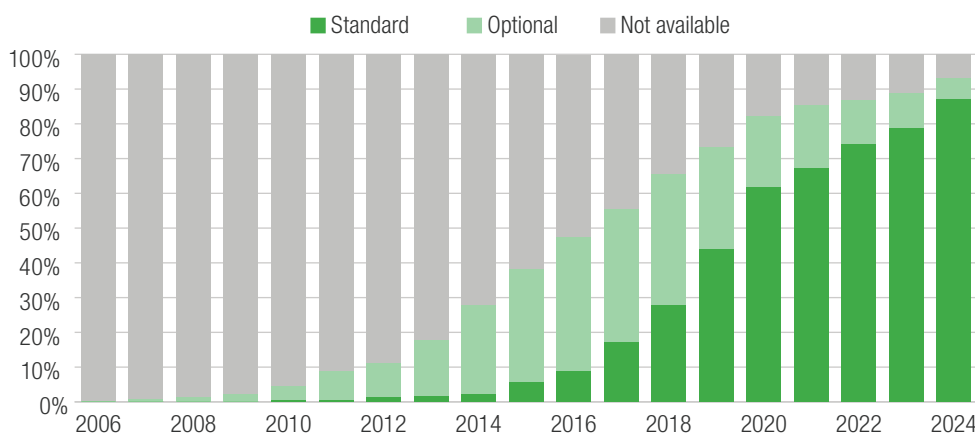


Figure 2 shows front AEB availability for new vehicles sold in the U.S. from model year 2006 to 2024. Prior to 2019, front AEB was predominantly optional or not available; however, at that time, 20 automakers entered a commitment with IIHS, the National Highway Traffic Safety Administration, and Consumer Reports to equip at least 95% of new light vehicles with standard AEB by the production year ending August 31, 2023. By 2024, over 90% of all new vehicle series featured standard front AEB.

Figure 2: New vehicle series with front automatic emergency braking by model year



The purpose of this report is to determine if there are differences in insurance losses associated with different FCP ratings.

► Method

Feature data

HLDI collects and maintains a detailed vehicle information database spanning more than 40 model years. The data collected include information on vehicle features and specifications such as base price and curb weight. Information is also collected on the presence of advanced driver assistance systems (ADAS), including front crash prevention, side-assist systems, night-assist systems, and parking-assist technologies. Historically, data were collected at the vehicle series level, which aggregates model year, vehicle make, and series (e.g., “2018 Hyundai Kona four-door”).

Beginning with the 2018 model year, HLDI began collecting this information at the more granular level of model and engine type. Since then, this more granular level has been expanded to cover vehicles from model year 2017 forward. Within HLDI, the term “model” refers to the name a manufacturer applies to a subdivision of a vehicle series, generally for marketing purposes, such as SE or Limited. Outside of HLDI, this is more commonly referred to as “trim.” Within a vehicle series, a HLDI model typically includes a bundle of vehicle options such as interior material; engine type; and comfort, convenience, and safety features. For example, for the 2018 Hyundai Kona four-door, information is now collected about the SE, Limited, SEL, SEL with Tech Package, and Ultimate models. If multiple engine options are available for a given model, information is collected separately.

Collecting data at the model and engine levels allows for a more precise understanding of the features that a given vehicle is equipped with (HLDI, 2019). These data enable HLDI to analyze the effect of specific features on vehicle claims without having to rely on manufacturers to provide Vehicle Identification Numbers (VIN) of individual vehicles equipped with the features.

At the series level, HLDI records feature availability in three general categories: standard, optional, and not available. A feature is considered standard if all vehicles of that model year, make, and series have the feature. A feature is optional if some vehicles have it but some do not.

At the more granular engine level, if all vehicles of that model year, make, series, model, and engine have the feature, it is marked as “equipped” with the feature. “Unknown equipped” is indicated for a feature if some vehicles have it but some do not. Observations are coded “not equipped” if either no vehicles of that model year, make, series, model, and engine could have the feature or if an individual observation is known not to be equipped. HLDI determines these values by reviewing publicly available information.

This study focuses on two features:

Forward collision warning (FCW): Alerts drivers to potential frontal collisions using visual, audible, or haptic signals; some systems also detect pedestrians.

Front automatic emergency braking (AEB): Uses sensors like radar or forward-facing cameras to alert drivers of emergency situations and automatically applies the vehicle’s brakes if the driver does not respond to a warning or imminent crash. The system may or may not detect pedestrians.

Additional ADAS features were grouped into functional bundles—parking (rear AEB, front and rear parking sensors), side (blind spot warning, rear cross-traffic alert), and night (automatic high beams, adaptive headlights). These bundles were controlled for in statistical models that produced the results for this report.

Vehicles

The vehicles in this study were constrained to model years 2018 and 2019. The study population was constrained for a few reasons. In model years 2018 and 2019 there was a sufficient mix of FCP ratings. Additionally, in 2018 and 2019 there were a sufficient number of vehicles sold with optional FCP systems. In contrast, the technology was standard in later years. Finally, during the initial phases of testing, which began with the 2013 model year, evaluations focused on specific vehicle segments that were not representative of the vehicle fleet. However, by model year 2018, IIHS testing expanded to include multiple vehicle segments.

Vehicles included in this study were constrained to those with optional FCP systems. A vehicle was included if its FCP system was optional at the series level and it was known to be equipped or not equipped at the engine level. A list of the 84 vehicle series included in this study is provided in **Table A1** in the **Appendix**.

Vehicle ratings

Manufacturers sometimes offered multiple system configurations. In many instances, those configurations are not associated with specific models or engine types. When this occurred, IIHS evaluated all available systems. For example, the 2018 Cadillac XT5 four-door could have been equipped with the Driver Assist Package (earning a superior rating) or the Luxury Driver Awareness Package or Premium Luxury Trim (earning an advanced rating).

For this study, when a vehicle series had multiple ratings, the minimum (lowest) rating was used. This approach ensures that effectiveness estimates reflect the least favorable configuration, thereby representing a worst-case scenario for FCP performance. These lower-rated systems are also generally offered as part of less expensive, more commonly selected packages than higher-rated ones.

Insurance data

Automobile insurance covers damage to vehicles and property as well as injuries to people that result from crashes. Different insurance coverages pay for vehicle damage versus injuries, and different coverages may apply depending on who is at fault. The current study is based on collision, property damage liability (PDL), and bodily injury liability (BIL).

Collision coverage insures against vehicle damage to an at-fault driver's vehicle that is sustained in a crash with an object or another vehicle; this coverage is common to all 50 states.

PDL coverage insures against vehicle damage that at-fault drivers cause to other people's vehicles and property in crashes. This coverage exists in all states except Michigan, where vehicle damage is covered on a no-fault basis (each insured vehicle pays for its own damage in a crash, regardless of who is at fault).

BIL coverage insures against medical, hospital, and other expenses for injuries that at-fault drivers inflict on occupants of other vehicles or others on the road. Although motorists in most states may have BIL coverage, this information is analyzed only in states where the at-fault driver has first obligation to pay for injuries (33 states with traditional tort insurance systems).

Table 1 summarizes PDL exposure and claims by minimum rating, along with the number of vehicle series per rating. Most vehicles were rated superior, followed by basic and advanced.

Table 1: Exposure, claims, and rated vehicles by minimum rating					
	Exposure		Claims		
Rating	FCP equipped	FCP not equipped	FCP equipped	FCP not equipped	Rated vehicle series
Basic	682,184	589,976	18,708	18,339	13
Advanced	749,343	877,954	14,365	25,063	9
Superior	7,698,875	9,198,458	158,284	270,529	62
Total	9,130,402	10,666,388	191,357	313,931	84

Statistical methods

Regression analysis was used to quantify the effect of FCP ratings on insurance losses while controlling for several covariates. The covariates were model year, make, and series; calendar year; garaging state; vehicle density (number of registered vehicles per square mile); rated driver age group, gender, marital status; deductible range (for collision coverage); risk; and availability of other ADAS functional feature bundles (parking, side, and night).

Vehicles equipped with FCP were compared with not equipped vehicles within the same series. In all statistical models, not equipped vehicles served as the comparison group. For other ADAS bundles, availability was coded into four tiers. Tier A was defined as all features standard, tier B had at least one feature but not all standard, tier C had at least one feature optional and none standard, and tier D had none of the features available and served as the baseline.

Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Results are presented for collision and PDL coverages (frequency, severity, and overall losses), while BIL includes only frequency estimates for all claims (those that have already been paid and those for which money has been set aside for possible payment in the future).

For space reasons, illustrative full regression results for PDL claim frequency are shown in **Appendix Table A2**. To further simplify the presentation here, the exponent of the parameter estimate was calculated, 1 was subtracted, and the result multiplied by 100. The resulting number corresponds to the effect of the covariate on that loss measure. For example, the estimate of the effect of a basic rating on PDL claim frequency was -0.1095 ; thus, vehicles with a basic rating had 10.4% lower PDL claim frequency compared with vehicles not equipped with FCP ($[\exp(-0.1095) - 1] \times 100 = -10.4$).

► Results

Figure 3 presents the estimated differences in collision losses for 2018–19 tested vehicles equipped with FCP versus those without. Basic-rated vehicles were associated with a statistically significant 2% increase in claim frequency. In contrast, advanced-rated vehicles were associated with a nominal decrease in claim frequency, while claim frequency declined a statistically significant 7% for superior-rated vehicles. Effects on claim severity were minimal and not statistically significant. Collision overall losses mirrored the pattern observed for claim frequency.

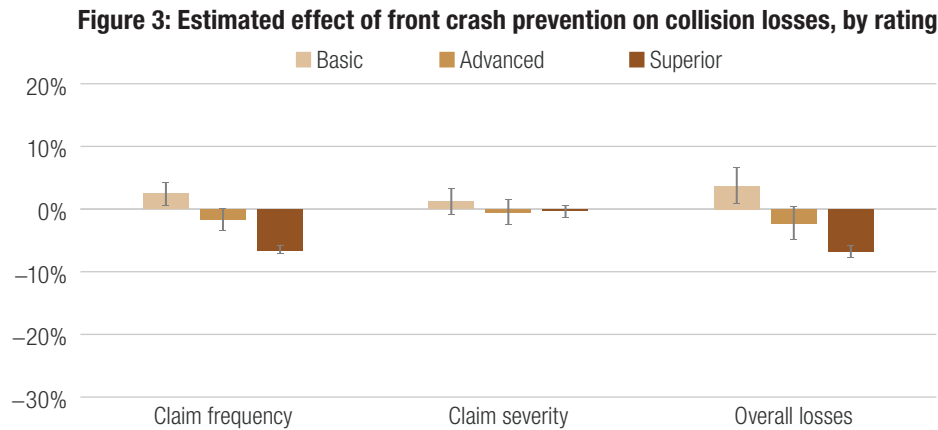


Figure 4 shows the estimated effects on PDL losses. Compared with not equipped vehicles, claim frequency was 10% lower for basic-rated vehicles, 14% lower for advanced-rated vehicles, and 19% lower for superior-rated vehicles. These reductions were statistically significant. Claim severity was 4% lower for both advanced and superior ratings, and the reductions were statistically significant. The 2% reduction for basic rated vehicles was not statistically significant. Overall losses followed the same trend as claim frequency, with superior-rated vehicles achieving the largest reduction (22%), followed by advanced (17%) and basic (12%).

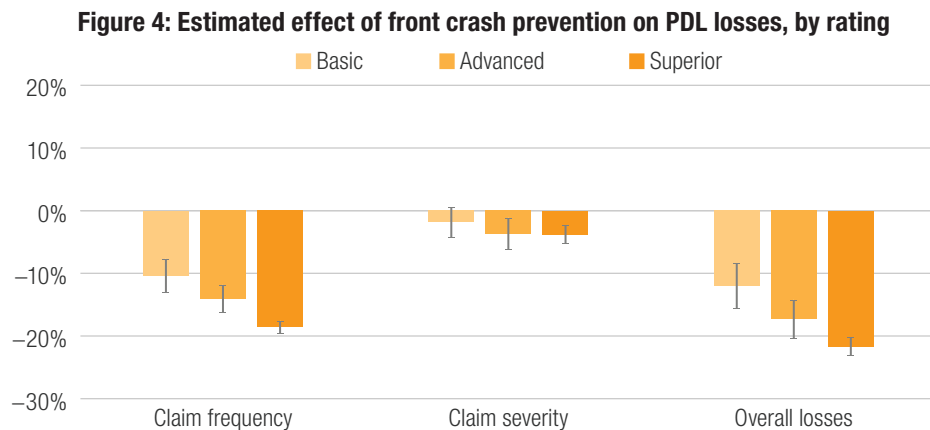
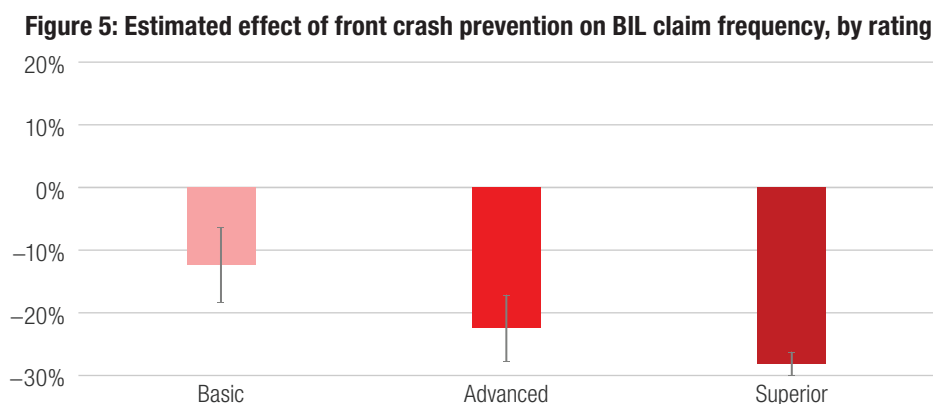


Figure 5 shows the estimated effect of FCP on BIL claim frequency. Superior-rated vehicles showed the greatest reduction of 28%, followed by advanced (22%) and basic (12%).



► Discussion

The results demonstrate that front crash prevention systems provide measurable benefits in reducing insurance losses, and these benefits increase with the IIHS rating level. The largest reductions in claim frequency were for PDL and BIL coverages. PDL overall losses for superior-rated vehicles were 22% lower than for vehicles without FCP. Under BIL, the reduction in claim frequency was 28%. These results suggest that FCP significantly reduces third-party property damage and injury risk. In contrast, collision coverage showed only modest benefits, with superior-rated vehicles reducing claim frequency by 7% and no significant change in severity. This difference may reflect the nature of collision claims, which often involve single-vehicle crashes or other scenarios in which FCP is not relevant, such as backing crashes. Although reductions in claim severity were modest, particularly for collision coverage, the consistent downward trend for PDL suggests that FCP systems not only prevent crashes but may also help to reduce impact forces when crashes occur.

Two additional scenarios were analyzed to assess the impact of the rating assignment methodology. One scenario included evaluating only vehicle series with a single rating, while the other included all series but adopted the maximum rating for those with multiple ratings. Results for both scenarios showed similar claim frequency estimates for superior-rated vehicles, whereas the estimates for advanced and basic ratings became statistically indistinguishable due to the reduced sample size for these categories. Since the superior rating estimate remained stable across all approaches, the minimum rating methodology was adopted in order to produce more reliable estimates for the advanced- and basic-rated vehicles, given their limited representation.

The strong correlation between IIHS ratings and real-world insurance outcomes is encouraging. IIHS has since adopted a more demanding test, conducted at speeds of 31, 37 and 43 mph (50, 60 and 70 km/h). In addition to a passenger car target, it examines performance with a motorcycle target and a semitrailer. As data are collected, HLDI will examine the correlation between the new ratings and insurance losses.

► Limitations

This study has several limitations. First, vehicles within the same series are sometimes equipped with different versions of front crash prevention systems. HLDI cannot always determine from the VIN which system was equipped on an individual vehicle. To address this, HLDI used the minimum rating for each series. While this increased the exposure in the basic and advanced rating categories, the estimated effects for basic and advanced ratings may be overestimated. The minimum rating was also selected as consumers may opt for less expensive systems when multiple options are available. Future research that can link FCP configurations to model or engine-level data would enable a more granular analysis of system effectiveness.

Additionally, at the time of a crash, the status of a feature is not known. Often, features can be deactivated by the driver, and there is no way to know how many were turned off by drivers before the crash. However, surveys conducted by IIHS indicate that large majorities of drivers of vehicles with these types of systems leave them on (Reagan et al., 2018). If a significant number of drivers do turn these features off, any reported reductions may actually underestimate the true effectiveness of these systems.

► References

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► Appendix

Table A1: 2018–19 study vehicles

Model year	Make	Series	Minimum rating	Maximum rating	Exposure with FCP	Exposure without FCP	PDL Claims with FCP	PDL Claims without FCP
2018	Buick	Enclave 4dr	Superior	Superior	50,111	59,475	1,064	1,577
2018	Buick	Enclave 4dr 4WD	Superior	Superior	67,527	36,590	1,392	922
2018	Volkswagen	Jetta 4dr	Advanced	Advanced	3,615	158,772	110	6,417
2018	Volkswagen	Golf station wagon	Superior	Superior	3,269	2,256	59	49
2018	Volkswagen	Atlas 4dr	Superior	Superior	82,796	32,386	2,005	1,120
2018	Volkswagen	Atlas 4dr 4WD	Superior	Superior	199,757	22,223	4,276	723
2018	Cadillac	CTS 4dr	Basic	Superior	372	16,743	6	416
2018	Cadillac	XTS 4dr	Basic	Superior	2,509	1,869	52	44
2018	Cadillac	XT5 4dr	Advanced	Superior	144,655	50,660	2,864	1,274
2018	Cadillac	XT5 4dr 4WD	Advanced	Superior	118,772	14,794	2,117	327
2018	Lincoln	MKX 4dr 4WD	Superior	Superior	9,457	3,262	198	81
2018	Honda	Civic 4dr hatchback	Superior	Superior	65,779	328,605	1,511	10,807
2018	Honda	Civic 4dr	Superior	Superior	94,192	1,053,303	2,656	39,618
2018	Honda	Civic 2dr	Superior	Superior	4,377	87,230	105	3,134
2018	Honda	CR-V 4dr 4WD	Superior	Superior	1,440,866	215,080	28,301	6,076
2018	Honda	CR-V 4dr	Superior	Superior	615,324	163,105	12,811	4,734
2018	Honda	Odyssey	Superior	Superior	647,507	17,233	13,732	475
2018	Honda	Pilot 4dr 4WD	Superior	Superior	158,978	265,548	3,031	6,750
2018	Honda	Ridgeline crew cab pickup 4WD	Superior	Superior	63,013	42,559	1,267	991
2018	Honda	Pilot 4dr	Superior	Superior	40,835	140,007	843	3,567
2018	Honda	Fit station wagon	Superior	Superior	116,958	91,752	2,606	2,466
2018	Chevrolet	Traverse 4dr 4WD	Superior	Superior	49,041	19,685	1,074	673
2018	Chevrolet	Equinox 4dr	Superior	Superior	158,456	929,356	3,338	23,981
2018	Chevrolet	Equinox 4dr 4WD	Superior	Superior	168,167	517,583	3,041	12,594
2018	Chevrolet	Silverado 1500 crew cab pickup	Basic	Basic	5,909	89,001	174	3,075
2018	Chevrolet	Silverado 1500 crew cab pickup 4WD	Basic	Basic	56,588	265,161	1,255	6,698
2018	GMC	Acadia 4dr	Advanced	Superior	37,802	135,095	866	4,075
2018	GMC	Acadia 4dr 4WD	Advanced	Superior	68,488	115,501	1,306	2,782
2018	GMC	Sierra 1500 crew cab pickup	Basic	Basic	11,210	8,884	318	274
2018	GMC	Sierra 1500 crew cab pickup 4WD	Basic	Basic	154,001	33,860	3,287	868
2018	Chrysler	Pacifica plug-in hybrid	Superior	Superior	50,852	18,299	1,065	512
2018	Jeep	Grand Cherokee 4dr	Superior	Superior	4,658	130,854	89	4,118
2018	Jeep	Grand Cherokee 4dr 4WD	Superior	Superior	47,964	417,295	884	11,693
2018	Hyundai	Accent 4dr	Superior	Superior	4,641	71,205	109	2,848
2018	Hyundai	Ioniq hybrid 4dr	Superior	Superior	5,708	15,613	111	490
2018	Hyundai	Santa Fe Sport 4dr	Superior	Superior	32,718	260,178	739	8,497
2018	Hyundai	Santa Fe Sport 4dr 4WD	Superior	Superior	40,133	199,780	863	5,753
2018	Hyundai	Kona 4dr	Superior	Superior	29,937	74,589	628	2,004
2018	Hyundai	Kona 4dr 4WD	Superior	Superior	22,297	70,011	440	1,818
2018	Kia	Sportage 4dr 4WD	Superior	Superior	17,012	123,866	271	3,494
2018	Kia	Sportage 4dr	Superior	Superior	11,798	117,318	204	3,551
2018	Kia	Sedona	Superior	Superior	12,190	3,692	243	144
2019	Buick	Enclave 4dr	Superior	Superior	29,646	75,568	602	1,845

Table A1: 2018–19 study vehicles

Model year	Make	Series	Minimum rating	Maximum rating	Exposure with FCP	Exposure without FCP	PDL Claims with FCP	PDL Claims without FCP
2019	Buick	Enclave 4dr 4WD	Superior	Superior	48,895	51,007	998	1,146
2019	Cadillac	Escalade 4dr 4WD	Basic	Basic	64,003	913	1,407	34
2019	Cadillac	Escalade 4dr	Basic	Basic	20,646	2,150	513	76
2019	Cadillac	Escalade ESV 4dr 4WD	Basic	Basic	43,626	489	1,074	10
2019	Cadillac	CTS 4dr	Basic	Superior	339	11,365	6	259
2019	Cadillac	Escalade ESV 4dr	Basic	Basic	11,906	735	347	41
2019	Cadillac	XTS 4dr	Basic	Superior	2,528	1,667	46	52
2019	Cadillac	XT5 4dr	Advanced	Superior	118,196	34,767	2,338	795
2019	Cadillac	XT5 4dr 4WD	Advanced	Superior	116,208	8,672	1,985	200
2019	Mazda	3 4dr	Superior	Superior	60,305	5,236	1,536	211
2019	Honda	CR-V 4dr 4WD	Superior	Superior	1,111,092	196,239	21,668	5,498
2019	Honda	CR-V 4dr	Superior	Superior	514,630	119,440	10,422	3,415
2019	Honda	Odyssey	Superior	Superior	657,474	26,663	13,544	700
2019	Honda	Ridgeline crew cab pickup 4WD	Superior	Superior	116,579	123,771	2,230	2,957
2019	Honda	Fit station wagon	Superior	Superior	88,046	146,544	1,829	3,877
2019	Honda	HR-V 4dr	Superior	Superior	88,535	112,860	2,205	3,576
2019	Honda	HR-V 4dr 4WD	Superior	Superior	182,147	209,364	4,264	6,465
2019	Chevrolet	Traverse 4dr	Superior	Superior	477	315,271	9	9,009
2019	Chevrolet	Traverse 4dr 4WD	Superior	Superior	64,401	22,974	1,361	790
2019	Chevrolet	Silverado 1500 crew cab pickup	Superior	Superior	4,621	164,950	114	5,397
2019	Chevrolet	Silverado 1500 crew cab pickup 4WD	Superior	Superior	71,555	602,144	1,516	15,304
2019	GMC	Acadia 4dr	Advanced	Superior	55,481	192,429	1,204	5,316
2019	GMC	Acadia 4dr 4WD	Advanced	Superior	86,128	167,263	1,575	3,877
2019	Jeep	Grand Cherokee 4dr	Superior	Superior	1,224	97,786	29	2,772
2019	Jeep	Grand Cherokee 4dr 4WD	Superior	Superior	23,743	273,316	403	6,851
2019	Mitsubishi	Outlander Sport 4dr 4WD	Superior	Superior	2,533	46,856	58	1,591
2019	Hyundai	Sonata 4dr	Superior	Superior	16,382	171,453	328	6,276
2019	Hyundai	Elantra 4dr	Basic	Superior	308,548	157,139	10,223	6,492
2019	Hyundai	Accent 4dr	Superior	Superior	4,162	97,556	106	3,905
2019	Hyundai	Ioniq hybrid 4dr	Superior	Superior	35,612	20,190	709	787
2019	Hyundai	Sonata hybrid 4dr	Superior	Superior	6,108	5,956	146	206
2019	Hyundai	Ioniq plug-in hybrid 4dr	Superior	Superior	9,872	10,326	211	309
2019	Hyundai	Santa Fe XL 4dr	Superior	Superior	13,291	17,063	328	473
2019	Hyundai	Santa Fe XL 4dr 4WD	Superior	Superior	11,186	12,431	242	344
2019	Kia	Sportage 4dr 4WD	Superior	Superior	11,888	109,472	208	2,919
2019	Kia	Sportage 4dr	Superior	Superior	7,437	105,937	124	3,075
2019	Kia	Sedona	Superior	Superior	39	3,795	-	105
2019	Kia	Sorento 4dr	Superior	Superior	69,162	310,049	1,534	9,586
2019	Kia	Sorento 4dr 4WD	Superior	Superior	89,437	197,157	1,841	5,388
2019	Kia	Cadenza 4dr	Superior	Superior	5,531	2,672	104	67
2019	Kia	Stinger 4dr 2WD/4WD	Superior	Superior	36,549	14,475	659	425

Table A2: Illustrative regression results—PDL claim frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
Intercept		1	−9.4112		0.0157	−9.4420	−9.3805	359861.00	<0.0001
Rating	Basic	1	−0.1095	−10.4%	0.0142	−0.1372	−0.0817	59.78	<0.0001
	Advanced	1	−0.1517	−14.1%	0.0144	−0.1800	−0.1235	110.88	<0.0001
	Superior	1	−0.2057	−18.6%	0.0072	−0.2198	−0.1916	818.26	<0.0001
	Not equipped	0	0	0	0	0	0		
Night feature availability	Tier A	1	−0.1463	−13.6%	0.0251	−0.1955	−0.0971	34.03	<0.0001
	Tier B	1	−0.0296	−2.9%	0.0112	−0.0516	−0.0076	6.95	0.0084
	Tier C	1	−0.0047	−0.5%	0.0092	−0.0226	0.0132	0.26	0.6084
	Tier D	0	0	0	0	0	0		
Parking feature availability	Tier A	1	−0.4157	−34.0%	0.0304	−0.4752	−0.3562	187.44	<0.0001
	Tier B	1	−0.0985	−9.4%	0.0089	−0.1160	−0.0810	121.48	<0.0001
	Tier C	1	−0.0281	−2.8%	0.0120	−0.0517	−0.0045	5.44	0.0197
	Tier D	0	0	0	0	0	0		
Side feature availability	Tier A	1	−0.0922	−8.8%	0.0097	−0.1113	−0.0731	89.68	<0.0001
	Tier B	1	−0.2342	−20.9%	0.3338	−0.8885	0.4202	0.49	0.4831
	Tier C	1	−0.1406	−13.1%	0.0129	−0.1659	−0.1153	118.50	<0.0001
	Tier D	0	0	0	0	0	0		
Vehicle series	2018 Buick Enclave 4dr	1	0.2085	23.2%	0.0240	0.1614	0.2556	75.31	<0.0001
	2018 Buick Enclave 4dr 4WD	1	0.2523	28.7%	0.0248	0.2037	0.3009	103.38	<0.0001
	2018 Cadillac CTS 4dr	1	0.0891	9.3%	0.0542	−0.0172	0.1953	2.70	0.1004
	2018 Cadillac XT5 4dr	1	−0.0036	−0.4%	0.0222	−0.0471	0.0400	0.03	0.8730
	2018 Cadillac XT5 4dr 4WD	1	−0.0119	−1.2%	0.0265	−0.0639	0.0401	0.20	0.6544
	2018 Cadillac XTS 4dr	1	−0.0076	−0.8%	0.1030	−0.2095	0.1944	0.01	0.9415
	2018 Chevrolet Equinox 4dr	1	0.1153	12.2%	0.0150	0.0859	0.1446	59.15	<0.0001
	2018 Chevrolet Equinox 4dr 4WD	1	−0.0338	−3.3%	0.0156	−0.0644	−0.0033	4.71	0.0301
	2018 Chevrolet Silverado 1500 crew cab	1	0.1682	18.3%	0.0225	0.1242	0.2123	56.11	<0.0001
	2018 Chevrolet Silverado 1500 crew cab 4WD	1	0.0086	0.9%	0.0175	−0.0258	0.0430	0.24	0.6233
	2018 Chevrolet Traverse 4dr 4WD	1	0.2577	29.4%	0.0264	0.2059	0.3095	94.97	<0.0001
	2018 Chrysler Pacifica plug-in hybrid	1	0.1431	15.4%	0.0287	0.0868	0.1994	24.83	<0.0001
	2018 GMC Acadia 4dr	1	0.2605	29.8%	0.0201	0.2212	0.2999	168.43	<0.0001
	2018 GMC Acadia 4dr 4WD	1	0.1336	14.3%	0.0215	0.0915	0.1757	38.73	<0.0001
	2018 GMC Sierra 1500 crew cab	1	0.1506	16.3%	0.0435	0.0653	0.2358	11.98	0.0005
	2018 GMC Sierra 1500 crew cab 4WD	1	0.0408	4.2%	0.0230	−0.0043	0.0858	3.14	0.0762
	2018 Honda CR-V 4dr	1	−0.0149	−1.5%	0.0097	−0.0339	0.0040	2.38	0.1229
	2018 Honda Civic 2dr	1	0.0895	9.4%	0.0224	0.0456	0.1334	15.98	<0.0001
	2018 Honda Civic 4dr	1	0.1296	13.8%	0.0147	0.1009	0.1584	77.96	<0.0001
	2018 Honda Civic 4dr hatchback	1	−0.0024	−0.2%	0.0165	−0.0347	0.0299	0.02	0.8831
	2018 Honda Fit station wagon	1	−0.1468	−13.7%	0.0197	−0.1853	−0.1083	55.80	<0.0001

Table A2: Illustrative regression results—PDL claim frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
2018 Honda Odyssey	1	0.0885	9.3%	0.0147	0.0596	0.1173	36.12	<0.0001
2018 Honda Pilot 4dr	1	−0.0907	−8.7%	0.0172	−0.1244	−0.0570	27.80	<0.0001
2018 Honda Pilot 4dr 4WD	1	−0.0442	−4.3%	0.0127	−0.0691	−0.0192	12.01	0.0005
2018 Honda Ridgeline crew cab 4WD	1	0.0126	1.3%	0.0236	−0.0337	0.0589	0.28	0.5941
2018 Hyundai Accent 4dr	1	0.2081	23.1%	0.0230	0.1630	0.2533	81.63	<0.0001
2018 Hyundai Ioniq hybrid 4dr	1	0.0585	6.0%	0.0419	−0.0237	0.1407	1.94	0.1632
2018 Hyundai Kona 4dr	1	−0.0750	−7.2%	0.0252	−0.1244	−0.0257	8.87	0.0029
2018 Hyundai Kona 4dr 4WD	1	−0.0825	−7.9%	0.0261	−0.1337	−0.0312	9.95	0.0016
2018 Hyundai Santa Fe Sport 4dr	1	0.2023	22.4%	0.0174	0.1682	0.2365	134.92	<0.0001
2018 Hyundai Santa Fe Sport 4dr 4WD	1	0.1355	14.5%	0.0183	0.0997	0.1714	54.91	<0.0001
2018 Jeep Grand Cherokee 4dr	1	0.1105	11.7%	0.0202	0.0709	0.1502	29.82	<0.0001
2018 Jeep Grand Cherokee 4dr 4WD	1	0.1038	10.9%	0.0155	0.0735	0.1342	44.92	<0.0001
2018 Kia Sedona	1	0.2894	33.6%	0.0551	0.1815	0.3973	27.61	<0.0001
2018 Kia Sportage 4dr	1	0.1601	17.4%	0.0291	0.1031	0.2171	30.32	<0.0001
2018 Kia Sportage 4dr 4WD	1	0.1393	14.9%	0.0289	0.0827	0.1959	23.25	<0.0001
2018 Lincoln MKX 4dr 4WD	1	0.1991	22.0%	0.0625	0.0765	0.3216	10.13	0.0015
2018 Volkswagen Atlas 4dr	1	0.1837	20.2%	0.0205	0.1436	0.2239	80.39	<0.0001
2018 Volkswagen Atlas 4dr 4WD	1	0.1306	14.0%	0.0172	0.0969	0.1643	57.81	<0.0001
2018 Volkswagen Golf station wagon	1	−0.1932	−17.6%	0.0966	−0.3826	−0.0038	4.00	0.0455
2018 Volkswagen Jetta 4dr	1	0.3190	37.6%	0.0184	0.2829	0.3551	299.78	<0.0001
2019 Buick Enclave 4dr	1	0.1833	20.1%	0.0245	0.1352	0.2313	55.80	<0.0001
2019 Buick Enclave 4dr 4WD	1	0.2286	25.7%	0.0251	0.1793	0.2779	82.64	<0.0001
2019 Cadillac CTS 4dr	1	0.1210	12.9%	0.0682	−0.0128	0.2547	3.14	0.0763
2019 Cadillac Escalade 4dr	1	0.3157	37.1%	0.0453	0.2268	0.4045	48.46	<0.0001
2019 Cadillac Escalade 4dr 4WD	1	0.3189	37.6%	0.0343	0.2516	0.3862	86.25	<0.0001
2019 Cadillac Escalade ESV 4dr	1	0.5107	66.6%	0.0545	0.4038	0.6175	87.74	<0.0001
2019 Cadillac Escalade ESV 4dr 4WD	1	0.4318	54.0%	0.0384	0.3566	0.5070	126.62	<0.0001
2019 Cadillac XT5 4dr	1	0.0187	1.9%	0.0238	−0.0278	0.0653	0.62	0.4306
2019 Cadillac XT5 4dr 4WD	1	0.0366	3.7%	0.0275	−0.0173	0.0906	1.77	0.1830
2019 Cadillac XTS 4dr	1	0.0637	6.6%	0.1020	−0.1362	0.2637	0.39	0.5323
2019 Chevrolet Silverado 1500 crew cab pickup	1	0.2787	32.1%	0.0197	0.2400	0.3173	199.52	<0.0001
2019 Chevrolet Silverado 1500 crew cab 4WD	1	0.1758	19.2%	0.0159	0.1446	0.2071	121.70	<0.0001
2019 Chevrolet Traverse 4dr	1	0.2198	24.6%	0.0176	0.1853	0.2543	156.18	<0.0001

Table A2: Illustrative regression results—PDL claim frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
	2019 Chevrolet Tra- verse 4dr 4WD	1	0.2716	31.2%	0.0252	0.2223	0.3210	116.58	<0.0001
	2019 GMC Acadia 4dr	1	0.2261	25.4%	0.0184	0.1900	0.2622	150.44	<0.0001
	2019 GMC Acadia 4dr 4WD	1	0.1323	14.1%	0.0193	0.0945	0.1702	46.94	<0.0001
	2019 Honda CR-V 4dr	1	−0.0117	−1.2%	0.0105	−0.0321	0.0088	1.24	0.2647
	2019 Honda CR-V 4dr 4WD	1	0.0133	1.3%	0.0082	−0.0027	0.0293	2.66	0.1027
	2019 Honda Fit station wagon	1	−0.1487	−13.8%	0.0204	−0.1886	−0.1087	53.16	<0.0001
	2019 Honda HR-V 4dr	1	0.0218	2.2%	0.0156	−0.0089	0.0524	1.94	0.1640
	2019 Honda HR-V 4dr 4WD	1	0.0302	3.1%	0.0126	0.0055	0.0548	5.76	0.0164
	2019 Honda Odyssey	1	0.0888	9.3%	0.0103	0.0686	0.1089	74.37	<0.0001
	2019 Honda Ridgeline crew cab 4WD	1	0.0250	2.5%	0.0158	−0.0060	0.0559	2.50	0.1136
	2019 Hyundai Accent 4dr	1	0.2292	25.8%	0.0210	0.1879	0.2704	118.62	<0.0001
	2019 Hyundai Elantra 4dr	1	0.2669	30.6%	0.0182	0.2311	0.3026	213.86	<0.0001
	2019 Hyundai Ioniq hybrid 4dr	1	0.1492	16.1%	0.0271	0.0960	0.2023	30.25	<0.0001
	2019 Hyundai Ioniq plug-in hybrid 4dr	1	−0.0289	−2.8%	0.0449	−0.1168	0.0590	0.41	0.5195
	2019 Hyundai Santa Fe XL 4dr	1	0.2058	22.9%	0.0382	0.1310	0.2806	29.09	<0.0001
	2019 Hyundai Santa Fe XL 4dr 4WD	1	0.2111	23.5%	0.0439	0.1251	0.2971	23.15	<0.0001
	2019 Hyundai Sonata 4dr	1	0.2790	32.2%	0.0217	0.2364	0.3216	164.81	<0.0001
	2019 Hyundai Sonata hybrid 4dr	1	0.2926	34.0%	0.0561	0.1827	0.4026	27.19	<0.0001
	2019 Jeep Grand Cherokee 4dr	1	0.1397	15.0%	0.0244	0.0918	0.1876	32.67	<0.0001
	2019 Jeep Grand Cherokee 4dr 4WD	1	0.1100	11.6%	0.0190	0.0728	0.1472	33.57	<0.0001
	2019 Kia Cadenza 4dr	1	0.0523	5.4%	0.0774	−0.0994	0.2040	0.46	0.4992
	2019 Kia Sedona	1	0.0414	4.2%	0.0986	−0.1519	0.2346	0.18	0.6748
	2019 Kia Sorento 4dr	1	0.2242	25.1%	0.0148	0.1952	0.2533	228.82	<0.0001
	2019 Kia Sorento 4dr 4WD	1	0.1529	16.5%	0.0162	0.1212	0.1846	89.32	<0.0001
	2019 Kia Sportage 4dr	1	0.0123	1.2%	0.0224	−0.0316	0.0562	0.30	0.5839
	2019 Kia Sportage 4dr 4WD	1	−0.0282	−2.8%	0.0224	−0.0721	0.0157	1.59	0.2078
	2019 Kia Stinger 4dr 2WD/4WD	1	0.0656	6.8%	0.0337	−0.0004	0.1315	3.79	0.0515
	2019 Mazda 3 4dr	1	0.1255	13.4%	0.0282	0.0703	0.1807	19.86	<0.0001
	2019 Mitsubishi Out- lander Sport 4dr 4WD	1	0.3695	44.7%	0.0284	0.3139	0.4251	169.44	<0.0001
	2018 Honda CR-V 4dr 4WD	0	0	0	0	0	0		
State	Alabama	1	−0.1435	−13.4%	0.0140	−0.1710	−0.1160	104.38	<0.0001
	Alaska	1	−0.0485	−4.7%	0.0404	−0.1277	0.0308	1.44	0.2307
	Arizona	1	−0.0350	−3.4%	0.0109	−0.0563	−0.0137	10.36	0.0013
	Arkansas	1	0.0347	3.5%	0.0172	0.0010	0.0685	4.07	0.0436
	California	1	0.0366	3.7%	0.0064	0.0240	0.0492	32.21	<0.0001

Table A2: Illustrative regression results—PDL claim frequency

Parameter	Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
Colorado	1	−0.1561	−14.5%	0.0134	−0.1823	−0.1298	135.76	<0.0001
Connecticut	1	−0.1214	−11.4%	0.0139	−0.1486	−0.0942	76.76	<0.0001
Delaware	1	−0.1302	−12.2%	0.0224	−0.1742	−0.0862	33.65	<0.0001
District of Columbia	1	0.2072	23.0%	0.0315	0.1455	0.2690	43.23	<0.0001
Florida	1	−0.1523	−14.1%	0.0067	−0.1655	−0.1392	515.42	<0.0001
Georgia	1	−0.0058	−0.6%	0.0089	−0.0232	0.0117	0.42	0.5166
Hawaii	1	−0.2192	−19.7%	0.0231	−0.2644	−0.1740	90.30	<0.0001
Idaho	1	−0.2014	−18.2%	0.0261	−0.2526	−0.1503	59.59	<0.0001
Illinois	1	−0.1505	−14.0%	0.0085	−0.1671	−0.1339	316.24	<0.0001
Indiana	1	−0.2104	−19.0%	0.0119	−0.2338	−0.1871	312.85	<0.0001
Iowa	1	−0.1738	−16.0%	0.0170	−0.2071	−0.1406	105.04	<0.0001
Kansas	1	−0.2595	−22.9%	0.0185	−0.2957	−0.2233	197.81	<0.0001
Kentucky	1	−0.1883	−17.2%	0.0148	−0.2173	−0.1592	161.31	<0.0001
Louisiana	1	0.0920	9.6%	0.0122	0.0681	0.1160	56.91	<0.0001
Maine	1	−0.1863	−17.0%	0.0267	−0.2386	−0.1340	48.74	<0.0001
Maryland	1	0.0421	4.3%	0.0097	0.0230	0.0612	18.72	<0.0001
Massachusetts	1	0.1702	18.6%	0.0109	0.1487	0.1916	242.09	<0.0001
Michigan	1	−1.4961	−77.6%	0.0181	−1.5316	−1.4607	6832.05	<0.0001
Minnesota	1	−0.2663	−23.4%	0.0125	−0.2908	−0.2419	456.03	<0.0001
Mississippi	1	−0.0876	−8.4%	0.0193	−0.1254	−0.0497	20.57	<0.0001
Missouri	1	−0.1334	−12.5%	0.0120	−0.1570	−0.1098	122.61	<0.0001
Montana	1	−0.1062	−10.1%	0.0336	−0.1721	−0.0402	9.96	0.0016
Nebraska	1	−0.1143	−10.8%	0.0196	−0.1527	−0.0758	33.92	<0.0001
Nevada	1	0.0791	8.2%	0.0149	0.0498	0.1083	28.12	<0.0001
New Hampshire	1	−0.0977	−9.3%	0.0206	−0.1381	−0.0574	22.58	<0.0001
New Jersey	1	−0.1234	−11.6%	0.0084	−0.1399	−0.1069	215.44	<0.0001
New Mexico	1	−0.1057	−10.0%	0.0210	−0.1468	−0.0646	25.41	<0.0001
New York	1	0.0105	1.1%	0.0074	−0.0040	0.0250	2.02	0.1550
North Carolina	1	−0.1923	−17.5%	0.0098	−0.2115	−0.1731	385.29	<0.0001
North Dakota	1	−0.0249	−2.5%	0.0321	−0.0878	0.0379	0.61	0.4365
Ohio	1	−0.2710	−23.7%	0.0088	−0.2883	−0.2538	949.77	<0.0001
Oklahoma	1	−0.0787	−7.6%	0.0143	−0.1068	−0.0506	30.15	<0.0001
Oregon	1	−0.1458	−13.6%	0.0164	−0.1779	−0.1138	79.47	<0.0001
Pennsylvania	1	−0.1245	−11.7%	0.0083	−0.1407	−0.1083	226.23	<0.0001
Rhode Island	1	0.0922	9.7%	0.0217	0.0497	0.1347	18.09	<0.0001
South Carolina	1	−0.0255	−2.5%	0.0117	−0.0485	−0.0026	4.75	0.0293
South Dakota	1	−0.2460	−21.8%	0.0343	−0.3132	−0.1787	51.41	<0.0001
Tennessee	1	−0.2192	−19.7%	0.0117	−0.2422	−0.1961	348.23	<0.0001
Utah	1	−0.1149	−10.9%	0.0176	−0.1494	−0.0804	42.66	<0.0001
Vermont	1	−0.1140	−10.8%	0.0366	−0.1857	−0.0423	9.72	0.0018
Virginia	1	−0.1002	−9.5%	0.0094	−0.1187	−0.0817	112.41	<0.0001
Washington	1	−0.1310	−12.3%	0.0117	−0.1540	−0.1080	124.49	<0.0001
West Virginia	1	−0.1933	−17.6%	0.0212	−0.2348	−0.1518	83.33	<0.0001
Wisconsin	1	−0.4306	−35.0%	0.0135	−0.4570	−0.4042	1022.16	<0.0001

Table A2: Illustrative regression results—PDL claim frequency

Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	p value
Registered vehicle density	Wyoming	1	−0.2174	−19.5%	0.0466	−0.3088	−0.1260	21.75	<0.0001
	Texas	0	0	0	0	0.0000	0.0000		
	0–99	1	−0.3740	−31.2%	0.0051	−0.3839	−0.3641	5483.92	<0.0001
	100–499	1	−0.1856	−16.9%	0.0035	−0.1924	−0.1788	2850.89	<0.0001
	500+	0	0	0	0	0	0		
Rated driver age	14–24	1	0.3143	36.9%	0.0061	0.3023	0.3264	2615.75	<0.0001
	25–29	1	0.0882	9.2%	0.0060	0.0763	0.1000	212.45	<0.0001
	40–49	1	0.0022	0.2%	0.0049	−0.0074	0.0118	0.21	0.6504
	50–59	1	−0.0728	−7.0%	0.0051	−0.0829	−0.0628	202.57	<0.0001
	60–64	1	−0.1412	−13.2%	0.0065	−0.1540	−0.1284	466.03	<0.0001
	65–69	1	−0.1037	−9.9%	0.0067	−0.1168	−0.0906	240.71	<0.0001
	70+	1	0.1335	14.3%	0.0052	0.1233	0.1436	663.88	<0.0001
	Unknown	1	0.0157	1.6%	0.0128	−0.0094	0.0408	1.50	0.2208
	30–39	0	0	0	0	0	0		
Rated driver gender	Female	1	0.0049	0.5%	0.0031	−0.0012	0.0109	2.50	0.1139
	Unknown	1	−0.0969	−9.2%	0.0135	−0.1233	−0.0706	51.90	<0.0001
	Male	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2066	22.9%	0.0033	0.2000	0.2131	3808.90	<0.0001
	Unknown	1	0.0863	9.0%	0.0129	0.0611	0.1115	45.10	<0.0001
	Married	0	0	0	0	0	0		
Calendar year	2017	1	−0.0093	−0.9%	0.0271	−0.0624	0.0439	0.12	0.7325
	2018	1	0.1909	21.0%	0.0070	0.1772	0.2047	738.96	<0.0001
	2019	1	0.2006	22.2%	0.0053	0.1902	0.2110	1441.46	<0.0001
	2020	1	−0.1868	−17.0%	0.0054	−0.1974	−0.1761	1178.81	<0.0001
	2022	1	0.0689	7.1%	0.0051	0.0589	0.0789	183.37	<0.0001
	2023	1	0.0769	8.0%	0.0051	0.0669	0.0869	228.64	<0.0001
	2024	1	0.0707	7.3%	0.0051	0.0606	0.0807	189.46	<0.0001
	2025	1	−0.1230	−11.6%	0.0068	−0.1363	−0.1098	329.69	<0.0001
	2021	0	0	0	0	0	0		
Risk	Nonstandard	1	0.2581	29.4%	0.0056	0.2470	0.2691	2095.12	<0.0001
	Standard	0	0	0	0	0	0		