HIGHWAY LOSS DATA INSTITUTE

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# Evaluation of motorcycle antilock braking systems

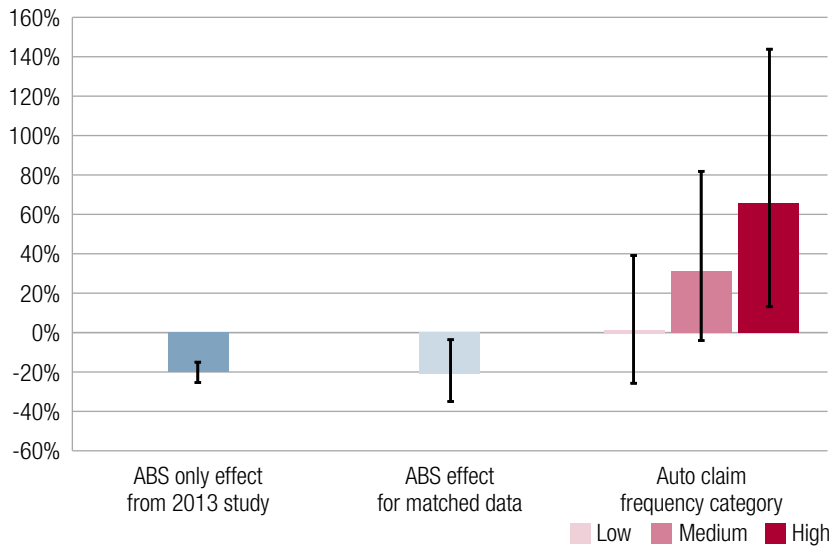
## Summary

Previous studies have shown that antilock braking systems (ABS) reduce insurance claim rates and fatal crash rates for motorcycles. An unresolved question about the prior research was whether the ABS effect was influenced by self-selection. People who place a greater value on safety may be more likely to purchase an optional safety feature and to ride in a manner that makes them less likely to crash. Previous Highway Loss Data Institute (HLDI) research controlled for rated driver age, gender, marital status, insurance risk profile, and insurance policy deductible. These variables have been shown to be highly correlated with insurance losses, but may not fully control for differences between safety conscious and more risky drivers. The purpose of this study is to evaluate ABS on motorcycles using a motorcycle rider's auto claim frequency as an indicator of the riders' penchant for risk in addition to these other predictive variables. The table below shows the breakdown of motorcycle exposure with and without ABS by auto claim frequency category for motorcycles with optional ABS. Although the amount of the exposure is small, the percentage of exposure with optional ABS increases with auto claim frequency. The figure below shows that after controlling for a rider's auto claim frequency, motorcycles with ABS are associated with a 21 percent reduction in motorcycle collision claim frequency compared with motorcycles without ABS, which is consistent with previous findings.

**Distribution of exposure by auto claim frequency category for April 2013 study vehicles**

| Auto claim frequency category | Exposure | Percent ABS | Percent no ABS |
|---|---|---|---|
| Zero | 33,279 | 26% | 74% |
| Low | 2,590 | 28% | 72% |
| Medium | 1,949 | 29% | 71% |
| High | 1,021 | 32% | 68% |

**Effect of optional ABS and auto collision claim frequency on motorcycle collision claim frequency, April 2013 study vehicles**



## Introduction

According to the National Highway Traffic Safety Administration (NHTSA), motorcycle registrations more than doubled between 1997 and 2010 (NHTSA, 2012). Analysis by the Insurance Institute for Highway Safety of data from the Fatality Analysis Reporting System shows that, during the same time period, fatalities in motorcycle crashes increased by 110 percent. Motorcyclist deaths began to increase in 1998 and continued to increase and peaked in 2008. Motorcyclist deaths decreased by 16 percent in 2009 compared with 2008 and increased only slightly in 2010 and in 2011. It is not known to what extent the overall decrease from 2008 is related to improvements in highway safety or due to the significant drop in new motorcycle sales from more than 1.1 million in 2008 to only 560,000 in 2010 (Motorcycle Industry Council, 2011). Compared with automobiles, motorcycles offer much less occupant protection in the event of a crash. Only 20 percent of automobile crashes result in injury or death, whereas 80 percent of motorcycle crashes do (NHTSA, 2005). Therefore, any countermeasure aimed at reducing the likelihood of motorcycle crashes should significantly reduce the risk of injury or death.

The purpose of this study is to examine the relationship between ABS and insurance losses under collision coverage while controlling for self-selection. People who place a greater value on safety may be more likely to purchase an optional safety feature and to ride in a manner that makes them less likely to crash. If primarily safer riders are the ones purchasing ABS-equipped motorcycles, then it is possible that a portion of the ABS effect observed in prior research was attributable to safer crash risk. This study controls for the safer rider effect by using a motorcycle rider's available auto claim history as a measure of their crash risk. Doing so separates the effect on motorcycle collision claim frequency due to the ABS technology from that attributable to crash risk.

## Methods

### Insurance data

Automobile insurance covers damage to vehicles and property as well as injuries to people involved in 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 coverage. Collision coverage insures against vehicle damage to an at-fault driver's vehicle sustained in a crash with an object or other vehicle; this coverage is common to all 50 states. Data are supplied to HLDI by its member companies.

### Motorcycle and auto loss data

In general, insurance companies who provide HLDI with loss data do not use the same policy ID numbers for a person's auto and motorcycle insurance. Therefore, in order to match motorcycle and auto loss data by rated driver, the following multi-step process was used:

1. Rated rider/driver demographic data was used to create a mapping of a rated motorcycle rider's policy ID with their corresponding auto policy ID. An individual rated rider/driver was identified by their insurance company, gender, marital status, year of birth, date of birth, zip code, and state. Full date of birth data for some companies first became available to HLDI beginning in 2011.

2. In total, 505,864 unique combinations of insurance company, gender, marital status, year of birth, date of birth, zip code and state existed in both auto and motorcycle databases concurrently. Approximately 13 percent of these combinations were associated with multiple auto or multiple motorcycle policy IDs or both and were therefore excluded from the analysis. The remaining 87 percent had a one-to-one mapping of motorcycle and auto policy IDs.

3. Once the mapping of policy IDs was established, the motorcycle and auto loss data associated with the rated rider/driver were linked. Although a rider/driver's full date of birth was initially used to create the policy ID mappings, full date of birth data were only available beginning in 2011. Therefore, after motorcycle and auto policy IDs were mapped, year of birth was used as a substitute to track a rated rider/driver's motorcycle and auto loss data through years preceding 2011.

This procedure resulted in 949,551 years of motorcycle collision exposure and 16,605 motorcycle claims for model years 2003 to 2014, and calendar years 2006 to 2013. This was matched to 1,204,271 years of auto collision exposure and 62,742 auto claims.

The observed auto claim frequency for each rider, based on their total available matched auto history, was calculated as the total number of auto claims divided by the total years insured times 100. For example, a rider with one auto claim over 5 years with auto insurance would have an observed auto claim frequency of 1/5 * 100 = 20. The total years insured is the number of years the rider/driver had auto insurance. For riders with multiple autos, the years insured was limited to at most one auto over any given time period. The observed auto claim frequencies were then categorized, as shown in **Table 1**.

**Table 1: Categorization of auto claim frequencies**

| Category | Auto Claim Frequency | Description |
|---|---|---|
| Zero | 0 | No auto claims |
| Low | 0 – 20 | An average of between 0 and 1 claims per 5 years insured |
| Medium | 20 – 40 | An average of between 1 and 2 claims per 5 years insured |
| High | 40 + | An average of more than 2 claims per 5 years insured |

## Analysis Methods

Regression analysis was used to quantify the effect of ABS and/or auto claim frequency on motorcycle collision claim frequency and severity while controlling for other covariates. Covariates included calendar year, vehicle age, garaging state, vehicle density (number of registered vehicles per square mile), rated driver age group, rated driver gender, rated driver marital status, deductible range, and risk. For analysis including only optional ABS vehicles, make and series was included as a covariate. For analysis including vehicles where ABS is standard or not available, motorcycle class and engine displacement were included as covariates.

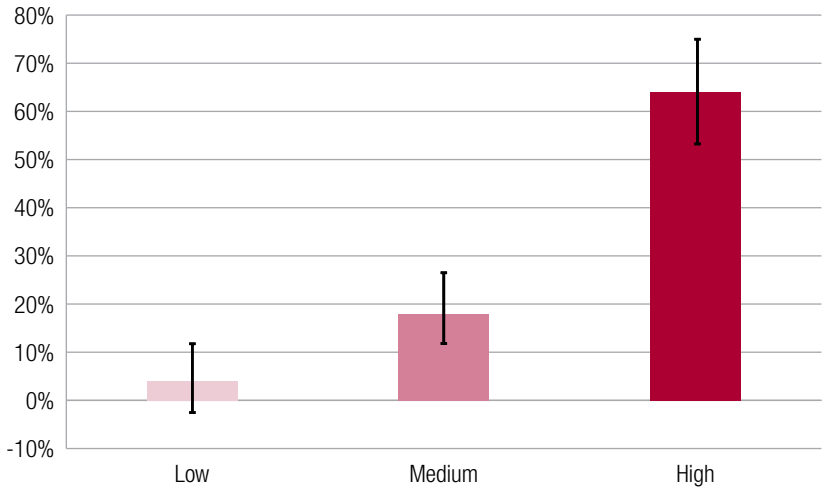
Claim frequency was modeled using a Poisson distribution, whereas claim severity (average loss payment per claim) was modeled using a Gamma distribution. Both models used a logarithmic link function.

For space reasons, full regression results are limited to the **Appendix**. 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 feature on that loss measure. For example, the estimate of the effect for ABS on motorcycle collision claim frequency was (-0.3268); thus, collision claim frequency for motorcycles with optional ABS is expected to be 28 percent lower than for motorcycles without ABS ((exp(-0.3268) -1)*100 = -28).

## Results

Before analyzing the effect of ABS, the relationship between auto claim frequency category and motorcycle claim frequency was examined. Figure 1 shows that riders with higher auto claim frequencies are associated with higher motorcycle claim frequency. The black bars correspond to the 95 percent confidence intervals. Riders categorized with a high auto claim frequency (an average of more than two auto claims per 5 years insured) are associated with a statistically significant 64 percent increase in motorcycle collision claim frequency compared with riders with no history of auto claims. Riders categorized with a medium auto claim frequency were associated with a statistically significant 18 percent increase, while those categorized with a low auto claim frequency were associated with a 4 percent increase.

**Figure 1: Motorcycle collision claim frequency by auto claim frequency category relative to rider/drivers with no auto claims**




The next step of the analysis was to examine whether auto claim frequencies could explain part of the ABS effect that was observed in prior studies. The most recent HLDI study was in April 2013 (HLDI, 2013). For a motorcycle to be included in that study, their vehicle identification numbers (VINs) had to have an ABS indicator. Only motorcycles with optional ABS and with loss data for both ABS and non-ABS versions were included. It should be noted that some motorcycles in this study population were also equipped with combined control braking systems (CCBS). However, both the ABS and non-ABS motorcycles had CCBS. Since CCBS was present in both the control and study group for those motorcycles the estimated effect was for ABS only.

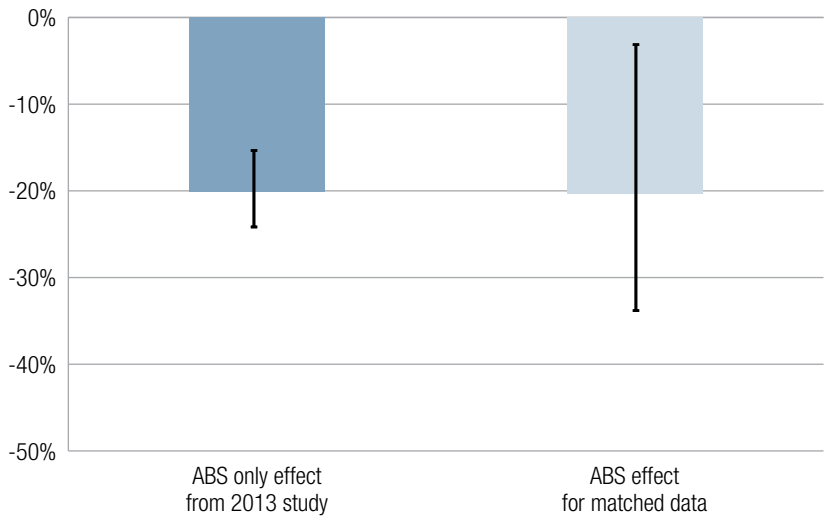
For comparative purposes, the same study vehicles from the 2013 ABS only study were used in this analysis. The motorcycles from the 2013 ABS/CCBS study were not included. Additionally, only motorcycles with at least one claim for both the ABS version and non-ABS version were included. This resulted in 38,838 years of motorcycle exposure and 622 motorcycle claims, matched with 56,707 years of auto insurance with 2,638 auto claims.

Table 2 shows the exposure for these vehicles after the matching procedure. In order to determine if the previously observed ABS effect is present in this new data set, the same regression model from the April 2013 study was used. Auto claim frequency category was not controlled for in this model so that the only differences between these models are the underlying data sets. Figure 2 compares the results from the April 2013 study with the results using the matched data. Despite a smaller dataset, motorcycle claim frequency declined by 20 percent, almost identical to the ABS only result from the 2013 study.

**Table 2: Distribution of exposure of antilock braking systems for April 2013 study vehicles**

| Make/Series | Exposure | Percent ABS | Percent no ABS |
|---|---|---|---|
| Aprilia Scarabeo 500 | 174 | 32% | 68% |
| Honda Gold Wing | 25,581 | 23% | 77% |
| Honda Interceptor 800 | 1,005 | 29% | 71% |
| Honda Reflex | 856 | 16% | 84% |
| Honda Silver Wing | 1,221 | 20% | 80% |
| Honda ST1300 | 2,448 | 31% | 69% |
| Kawasaki Ninja 650 | 90 | 36% | 64% |
| Kawasaki Ninja ZX-10R | 119 | 40% | 60% |
| Suzuki Bandit 1250 | 503 | 27% | 73% |
| Suzuki Burgman 400 | 181 | 42% | 58% |
| Suzuki Burgman 650 | 1,447 | 20% | 80% |
| Suzuki V-Strom 650 | 1,672 | 30% | 70% |
| Triumph Sprint ST | 587 | 41% | 59% |
| Triumph Thunderbird | 477 | 58% | 42% |
| Triumph Tiger | 672 | 34% | 66% |
| Triumph Tiger 800 | 310 | 89% | 11% |
| Yamaha FJR1300 | 1,496 | 48% | 52% |
| **Total** | **38,838** | **26%** | **74%** |

**Figure 2: Effect of optional ABS on motorcycle collision claim frequency without regard to auto claim frequency, April 2013 study vehicles**



Given that the ABS effect is present in the matched data set, the effect of additionally controlling for auto claim frequency was then analyzed. Table 3 shows the breakdown of motorcycle exposure with and without ABS by auto claim frequency category. Although the amount of the exposure is small, the percentage of exposure with ABS increases with auto claim frequency. 26 percent of the motorcycle exposure with zero auto claim frequency was for motorcycles with ABS compared to 32 percent of the exposure with high auto claim frequency.

**Table 3: Distribution of exposure by auto claim frequency category for April 2013 study vehicles**

| Auto claim frequency category | Exposure | Percent ABS | Percent no ABS |
|---|---|---|---|
| Zero | 33,279 | 26% | 74% |
| Low | 2,590 | 28% | 72% |
| Medium | 1,949 | 29% | 71% |
| High | 1,021 | 32% | 68% |

Figure 3 shows the results when both ABS status and the auto claim frequency categories are added as variables in the regression model. After controlling for auto claim frequency, the reduction in motorcycle collision claim frequency for ABS-equipped motorcycles increases slightly from 20 to 21 percent. The results for auto claim frequency are consistent with Figure 1, although the confidence bounds are larger due to the reduced size of the dataset.

**Figure 3: Effect of optional ABS and auto collision claim frequency on motorcycle collision claim frequency, April 2013 study vehicles**

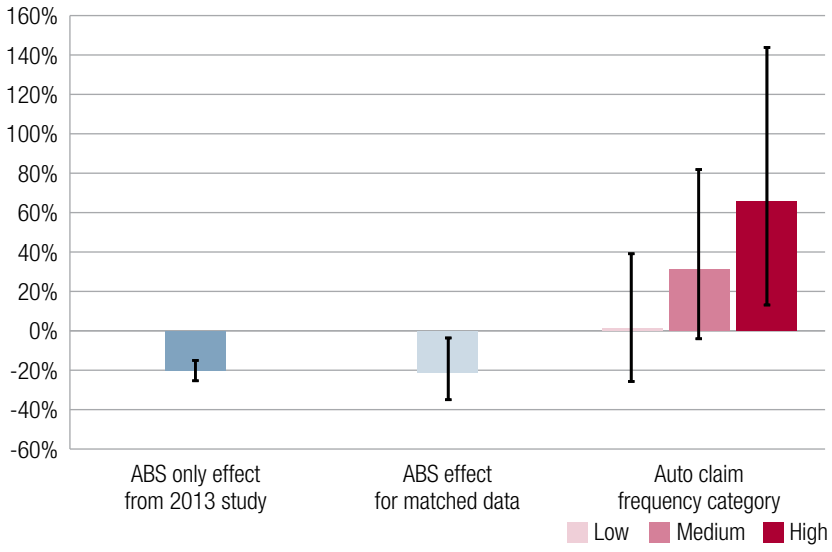


Figure 4 shows that the effects of ABS and auto claim frequency on motorcycle collision severity were not statistically significant. Figure 5 shows that overall losses declined by 17 percent for motorcycles with ABS, although the result was not statistically significant.

**Figure 4: Effect of optional ABS and auto collision claim frequency on motorcycle collision severity, April 2013 study vehicles**

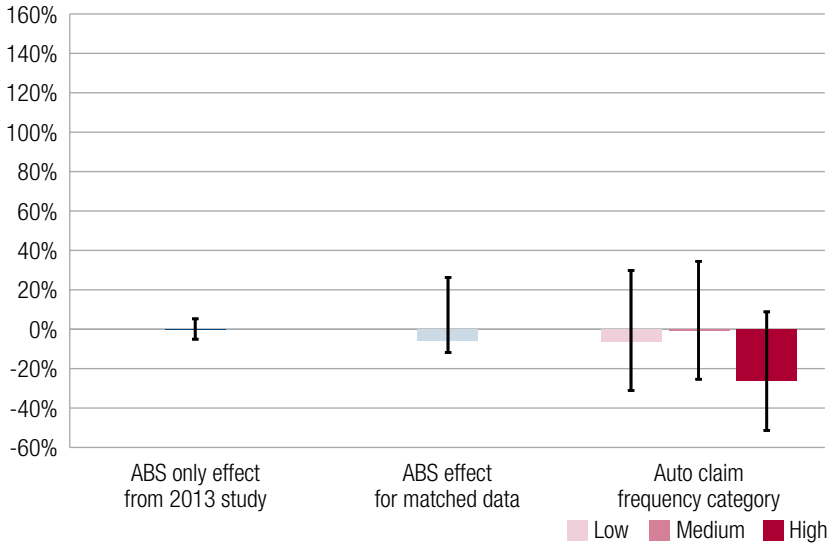
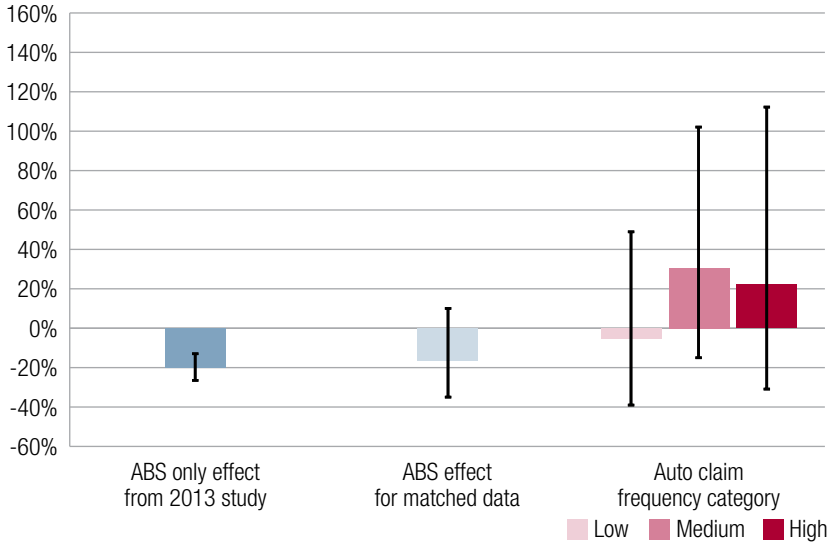



**Figure 5: Effect of optional ABS and auto collision claim frequency on motorcycle collision overall losses, April 2013 study vehicles**



The above analysis includes only the motorcycle series used in the April 2013 HLDI ABS study. Although these new results are consistent with the prior study, the amount of data available for these motorcycles after the rider/driver matching is limited. In order to further explore the effect of self-selection a supplemental analysis using a larger population of motorcycles was conducted. Both optional ABS motorcycles as well as those with ABS as standard or not available were analyzed. For some motorcycles ABS is available for purchase but the presence of ABS is not included in the VIN. These motorcycles were excluded.

The addition of motorcycles with standard and not available ABS resulted in 842,487 years of motorcycle exposure and 14,311 motorcycle claims matched with 1,093,225 years of auto exposure and 57,193 auto claims. This was an increase of over 21 times the motorcycle exposure of the optional ABS analysis. Since some make/series are only available with ABS standard, or do not have ABS available at all, make/series was removed as a covariate in the regression model due to confounding. Instead, the motorcycle class and engine displacement were used to control for the differences in motorcycle types.

While only motorcycles with known ABS status are included in this analysis, the CCBS status is not always known. For the April 2013 ABS/CCBS study, an extensive review of publically available documentation was conducted on all motorcycles included in the analysis. However, information about the presence of CCBS for some motorcycles is not always available from public sources. This analysis includes over 630 different motorcycle series over 12 model years. As a result, the effect of ABS in this study may be confounded with CCBS since some of the study motorcycles have ABS only while others may have both ABS and CCBS. The purpose of the following analysis is to examine the effect of motorcycles with ABS or ABS/CCBS compared to motorcycles without ABS. The effect of "ABS and ABS/CCBS" is analyzed with and without controlling for auto claim frequency. It should be noted that some of the motorcycles without ABS may have CCBS. However, this analysis assumes that CCBS in non-ABS motorcycles is a small part of the overall exposure.

As with the earlier analysis, the effect of ABS and ABS/CCBS was first examined without controlling for auto claim frequency. Figure 6 shows that the effect of ABS and ABS/CCBS, without controlling for auto claim frequency, was a statistically significant 28 percent. For comparative purposes the 2013 study results for ABS only and ABS/CCBS are shown. The observed effect of 28 percent for ABS and ABS/CCBS falls between the 2013 studies results of 20 percent for ABS only and 31 percent for ABS/CCBS.

**Figure 6: Effect of ABS and ABS/CCBS on motorcycle collision claim frequency, no auto claim frequency**

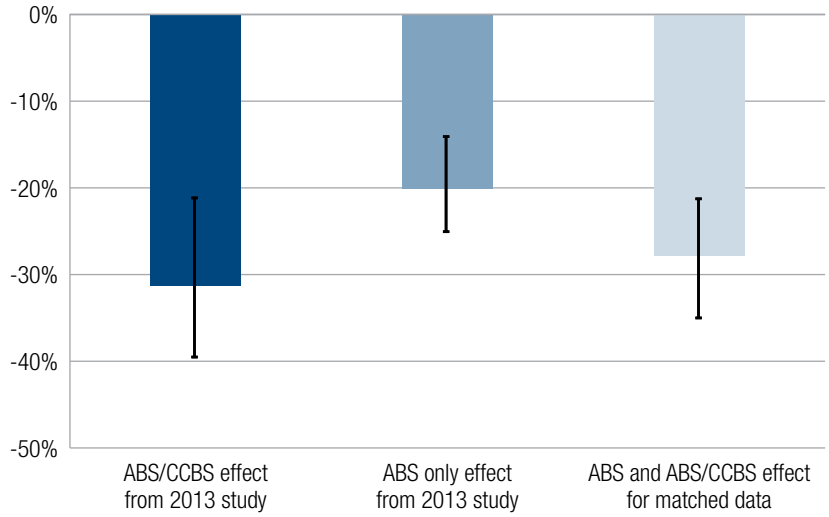
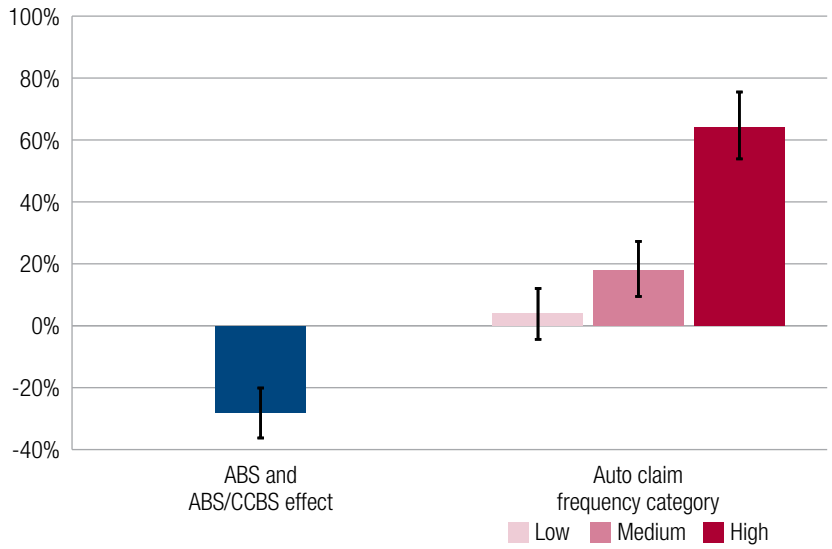


Figure 7 shows that after controlling for auto claim frequency, the effect of ABS and ABS/CCBS was also a statistically significant 28 percent. This affirms the results of the optional ABS analysis that additionally controlling for auto claim frequency does not substantively affect the observed ABS effect.

**Figure 7: Effect of ABS and ABS/CCBS and auto collision claim frequency on motorcycle collision claim frequency**




The effects of ABS and ABS/CCBS by auto claim frequency on motorcycle collision severity were not statistically significant, as shown in Figure 8. Figure 9 shows that overall losses for motorcycles with ABS and ABS/CCBS declined by a statistically significant 25 percent while controlling for auto claim frequency.

**Figure 8: Effect of ABS and ABS/CCBS and auto collision claim frequency on motorcycle collision severity**

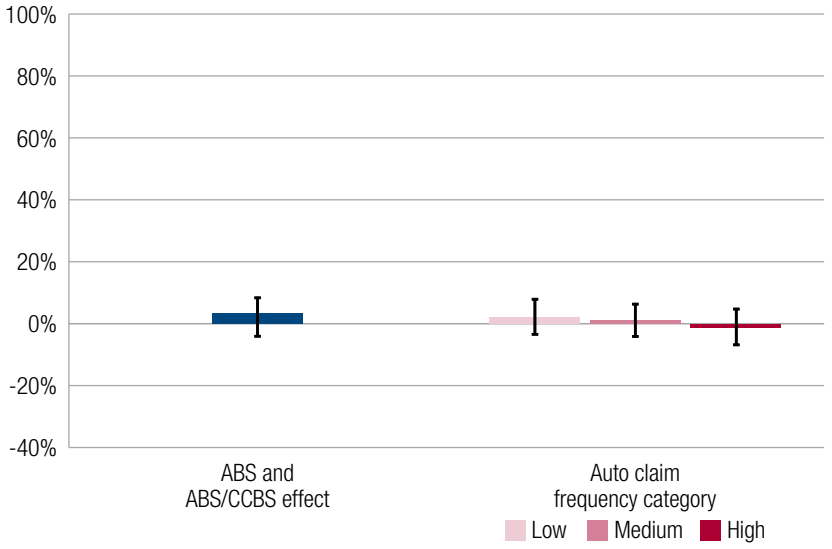


**Figure 9: Effect of ABS and ABS/CCBS and auto collision claim frequency on motorcycle collision overall losses**

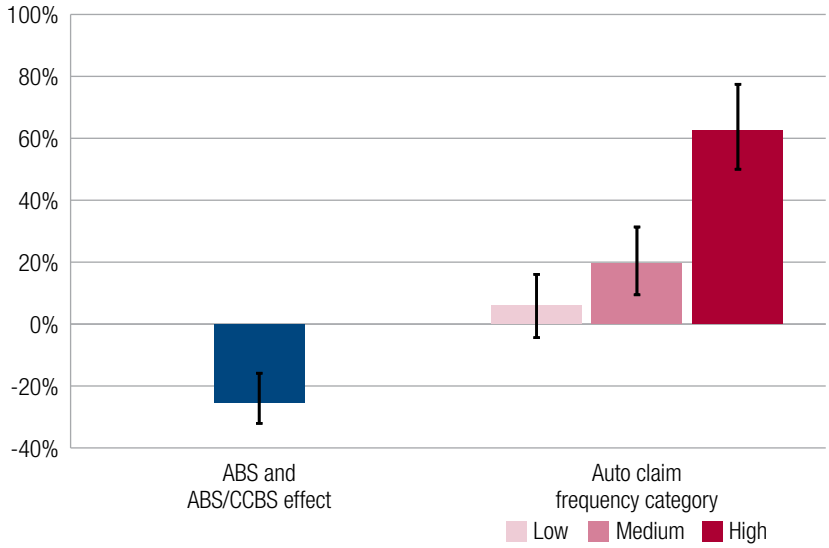
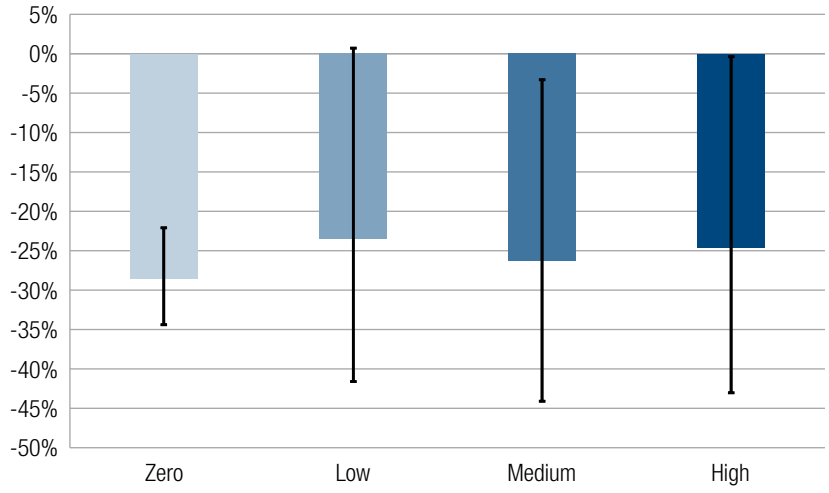



Figure 10 shows the effect of ABS and ABS/CCBS by auto claim frequency category. The effect by auto claim frequency category is fairly consistent. Motorcycles with ABS and ABS/CCBS are associated with a 29 percent reduction in motorcycle claim frequency compared with motorcycles without ABS for riders with no history of auto claims. ABS and ABS/CCBS for riders categorized with a low auto claim frequency was associated with a 24 percent reduction. ABS and ABS/CCBS for riders categorized with medium or high auto claim frequencies was associated with 26 and 25 percent reductions, respectively. The differences between the effects of ABS and ABS/CCBS by rider auto claim frequency was not statistically significant.

**Figure 10: Effect of ABS and ABS/CCBS by auto claim frequency category**



## Discussion

Prior HLDI studies have shown that ABS on motorcycles is effective in reducing collision losses. This study confirms those results while further addressing the issue of self-selection. A rider's auto claim frequency was used as a measure of their crash risk. Regression analysis showed that riders with higher auto claim frequencies were associated with higher motorcycle collision claim frequencies.

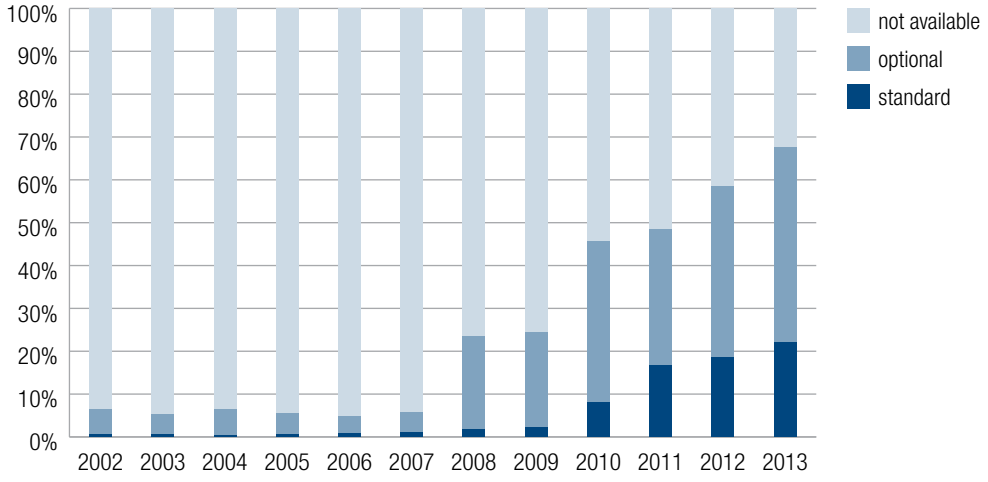
Before controlling for a rider's auto claim frequency, motorcycles with optional ABS were associated with a statistically significant 20 percent reduction in motorcycle collision claim frequency. After controlling for auto claim frequency, the reduction in motorcycle collision claim frequency for ABS equipped motorcycles increased slightly from 20 percent to 21 percent. Controlling for a rider's auto claim frequency did not substantively inform the observed ABS effect.

Supplemental analysis on a larger motorcycle population confirmed these results. The estimated ABS and ABS/CCBS effect with and without a control for auto claim frequency was 28 percent. As expected, this falls between the earlier estimate for ABS only (20 percent) and ABS/CCBS (31 percent) (HLDI, 2013). As before, controlling for a rider's auto claim frequency did not impact the observed effect. This benefit also did not vary significantly depending on the auto claim frequency category of the rider. These results indicate that all riders may benefit from ABS technology on their motorcycles.

Although previous studies have shown the benefit of antilock brakes for motorcycles, ABS is not currently required in the United States. Beginning in 2016 in the European Union, it will be mandatory for motorcycles that have an engine displacement greater than 125 cc to be fit with ABS. Manufacturers have taken the initiative to increase the availability of ABS on new motorcycles in the United States over the past few years.

Figure 11 shows the increase in ABS availability by model year. For this figure, the motorcycle series are weighted using HLDI's database of almost 5 million unique motorcycle VINs. This is not the HLDI loss database but rather an accumulation of every VIN in the HLDI loss database and VINs that HLDI has been asked to decode. More than 90 percent of 2002 model year bikes did not have ABS available. This is in stark contrast to the 2013 model year, in which more than two-thirds of new bikes either have standard (22 percent) or optional (46 percent) ABS.

**Figure 11: Motorcycle ABS availability by model year**



## Limitations

There are limitations on the data used in this analysis. Using auto claim frequency as a covariate in the regression required matching data from two separate databases using demographic data. Although there is no way to be absolutely certain that a matched rider/driver is the same person, using the full date of birth, zip code, gender and marital status limits the likelihood of erroneous matches. It is also possible that a particular person would have their auto and motorcycle policy with different companies. These individuals would be excluded from the analysis. In addition, motorcycle riders who do not have an auto policy would also be excluded from this analysis. It is unknown whether there are significant differences between riders who also have an auto policy and those with just a motorcycle.

## References

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Motorcycle Industry Council. 2011. Statistical annual. Irvine, CA.

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National Highway Traffic Safety Administration. 2012. Traffic Safety Facts, 2010. Report no. DOT HS-811-659. Washington, DC: US Department of Transportation.

## Appendix: Illustrative regression results - collision claim frequency for motorcycles with and without ABS or ABS/CCBS

| Parameter | | Degrees of freedom | Estimate | Effect | Standard Error | Wald 95% Confidence Limits | | Chi-Square | P-value |
|---|---|---|---|---|---|---|---|---|---|
| Intercept | | 1 | -9.2916 | | 0.4588 | -10.1908 | -8.3925 | 410.22 | <0.0001 |
| Calendar Year | 2006 | 1 | -0.3742 | -31.2% | 0.0961 | -0.5626 | -0.1857 | 15.15 | <0.0001 |
| | 2007 | 1 | -0.4147 | -33.9% | 0.0571 | -0.5266 | -0.3029 | 52.83 | <0.0001 |
| | 2008 | 1 | -0.4572 | -36.7% | 0.0428 | -0.5412 | -0.3732 | 113.87 | <0.0001 |
| | 2009 | 1 | -0.5816 | -44.1% | 0.0389 | -0.6578 | -0.5053 | 223.49 | <0.0001 |
| | 2010 | 1 | -0.5634 | -43.1% | 0.0332 | -0.6285 | -0.4982 | 287.54 | <0.0001 |
| | 2011 | 1 | -0.3190 | -27.3% | 0.0249 | -0.3679 | -0.2701 | 163.45 | <0.0001 |
| | 2012 | 1 | -0.2549 | -22.5% | 0.0230 | -0.3001 | -0.2098 | 122.37 | <0.0001 |
| | 2013 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Vehicle age | | 1 | -0.1087 | -10.3% | 0.0038 | -0.1161 | -0.1013 | 825.01 | <0.0001 |
| Rated driver age | 14–24 | 1 | 0.9486 | 158.2% | 0.0545 | 0.8417 | 1.0554 | 302.84 | <0.0001 |
| | 25–39 | 1 | 0.3173 | 37.3% | 0.0383 | 0.2422 | 0.3923 | 68.65 | <0.0001 |
| | 40–64 | 1 | 0.0105 | 1.1% | 0.0347 | -0.0575 | 0.0784 | 0.09 | 0.7629 |
| | 65+ | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Gender | Female | 1 | -0.1211 | -11.4% | 0.0266 | -0.1732 | -0.0691 | 20.79 | <0.0001 |
| | Male | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Marital status | Married | 1 | -0.1211 | -11.4% | 0.0978 | -0.3128 | 0.0706 | 1.53 | 0.2158 |
| | Single | 1 | 0.0231 | 2.3% | 0.0988 | -0.1706 | 0.2168 | 0.05 | 0.8152 |
| | Unknown | 0 | 0 | 0 | 0 | 0 | 0 | | |
| State | Alabama | 1 | 0.3570 | 42.9% | 0.1816 | 0.0011 | 0.7130 | 3.86 | 0.0493 |
| | Arizona | 1 | 0.4653 | 59.2% | 0.1771 | 0.1182 | 0.8125 | 6.90 | 0.0086 |
| | Arkansas | 1 | 0.2089 | 23.2% | 0.1995 | -0.1820 | 0.5999 | 1.10 | 0.2949 |
| | California | 1 | 0.4862 | 62.6% | 0.1724 | 0.1484 | 0.8240 | 7.96 | 0.0048 |
| | Colorado | 1 | 0.2029 | 22.5% | 0.1782 | -0.1463 | 0.5521 | 1.30 | 0.2548 |
| | Connecticut | 1 | 0.2198 | 24.6% | 0.1846 | -0.1420 | 0.5817 | 1.42 | 0.2337 |
| | Delaware | 1 | 0.8593 | 136.2% | 0.3354 | 0.2018 | 1.5167 | 6.56 | 0.0104 |
| | Dist of Columbia | 1 | 0.6508 | 91.7% | 0.2285 | 0.2031 | 1.0986 | 8.12 | 0.0044 |
| | Florida | 1 | 0.1984 | 21.9% | 0.1726 | -0.1398 | 0.5366 | 1.32 | 0.2502 |
| | Georgia | 1 | 0.3296 | 39.0% | 0.1762 | -0.0157 | 0.6748 | 3.50 | 0.0614 |
| | Hawaii | 1 | 0.2810 | 32.4% | 0.2000 | -0.1111 | 0.6730 | 1.97 | 0.1601 |
| | Idaho | 1 | 0.1199 | 12.7% | 0.2018 | -0.2757 | 0.5155 | 0.35 | 0.5525 |
| | Illinois | 1 | 0.0813 | 8.5% | 0.1768 | -0.2653 | 0.4279 | 0.21 | 0.6457 |
| | Indiana | 1 | 0.2783 | 32.1% | 0.1842 | -0.0829 | 0.6394 | 2.28 | 0.1310 |
| | Iowa | 1 | -0.0066 | -0.7% | 0.1868 | -0.3727 | 0.3594 | 0.00 | 0.9717 |
| | Kansas | 1 | 0.1217 | 12.9% | 0.1895 | -0.2498 | 0.4931 | 0.41 | 0.5209 |
| | Kentucky | 1 | 0.3797 | 46.2% | 0.1978 | -0.0080 | 0.7674 | 3.68 | 0.0549 |
| | Louisiana | 1 | 0.4134 | 51.2% | 0.1817 | 0.0573 | 0.7695 | 5.18 | 0.0229 |
| | Maine | 1 | 0.3473 | 41.5% | 0.2226 | -0.0890 | 0.7836 | 2.43 | 0.1187 |
| | Maryland | 1 | 0.3205 | 37.8% | 0.1769 | -0.0262 | 0.6673 | 3.28 | 0.0700 |
| | Michigan | 1 | 0.3058 | 35.8% | 0.1845 | -0.0558 | 0.6674 | 2.75 | 0.0974 |
| | Minnesota | 1 | 0.0431 | 4.4% | 0.1875 | -0.3243 | 0.4105 | 0.05 | 0.8181 |
| | Mississippi | 1 | 0.2709 | 31.1% | 0.2041 | -0.1292 | 0.6710 | 1.76 | 0.1845 |
| | Missouri | 1 | 0.2400 | 27.1% | 0.1890 | -0.1304 | 0.6105 | 1.61 | 0.2040 |
| | Montana | 1 | -0.1582 | -14.6% | 0.3089 | -0.7637 | 0.4472 | 0.26 | 0.6085 |

| Appendix: Illustrative regression results - collision claim frequency for motorcycles with and without ABS or ABS/CCBS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | Degrees of freedom | Estimate | Effect | Standard Error | Wald 95% Confidence Limits | | Chi-Square | P-value |
| | Nebraska | 1 | 0.0666 | 6.9% | 0.1946 | -0.3147 | 0.4479 | 0.12 | 0.7322 |
| | Nevada | 1 | 0.6364 | 89.0% | 0.1901 | 0.2639 | 1.0090 | 11.21 | 0.0008 |
| | New Hampshire | 1 | 0.2025 | 22.4% | 0.2255 | -0.2395 | 0.6446 | 0.81 | 0.3691 |
| | New Jersey | 1 | 0.1643 | 17.9% | 0.1879 | -0.2039 | 0.5325 | 0.76 | 0.3818 |
| | New Mexico | 1 | 0.2884 | 33.4% | 0.1846 | -0.0735 | 0.6502 | 2.44 | 0.1183 |
| | New York | 1 | 0.3641 | 43.9% | 0.1733 | 0.0243 | 0.7038 | 4.41 | 0.0357 |
| | North Carolina | 1 | 0.2203 | 24.6% | 0.1785 | -0.1295 | 0.5701 | 1.52 | 0.2171 |
| | North Dakota | 1 | 0.1481 | 16.0% | 0.3090 | -0.4575 | 0.7536 | 0.23 | 0.6318 |
| | Ohio | 1 | 0.0211 | 2.1% | 0.1763 | -0.3245 | 0.3667 | 0.01 | 0.9046 |
| | Oklahoma | 1 | 0.2389 | 27.0% | 0.1851 | -0.1238 | 0.6016 | 1.67 | 0.1968 |
| | Oregon | 1 | 0.3714 | 45.0% | 0.1877 | 0.0035 | 0.7394 | 3.92 | 0.0478 |
| | Pennsylvania | 1 | 0.2132 | 23.8% | 0.1760 | -0.1318 | 0.5582 | 1.47 | 0.2258 |
| | Rhode Island | 1 | 0.1529 | 16.5% | 0.2267 | -0.2914 | 0.5973 | 0.46 | 0.4999 |
| | South Carolina | 1 | 0.2064 | 22.9% | 0.1838 | -0.1538 | 0.5667 | 1.26 | 0.2614 |
| | South Dakota | 1 | 0.0033 | 0.3% | 0.2620 | -0.5102 | 0.5169 | 0.00 | 0.9898 |
| | Tennessee | 1 | 0.3529 | 42.3% | 0.1738 | 0.0122 | 0.6935 | 4.12 | 0.0423 |
| | Texas | 1 | 0.3324 | 39.4% | 0.1729 | -0.0064 | 0.6713 | 3.70 | 0.0545 |
| | Utah | 1 | -0.0321 | -3.2% | 0.1852 | -0.3951 | 0.3309 | 0.03 | 0.8623 |
| | Vermont | 1 | -0.0052 | -0.5% | 0.2690 | -0.5324 | 0.5220 | 0.00 | 0.9845 |
| | Virginia | 1 | 0.2582 | 29.5% | 0.1750 | -0.0847 | 0.6012 | 2.18 | 0.1400 |
| | Washington | 1 | 0.3058 | 35.8% | 0.1786 | -0.0443 | 0.6558 | 2.93 | 0.0869 |
| | West Virginia | 1 | -0.0597 | -5.8% | 0.2119 | -0.4749 | 0.3556 | 0.08 | 0.7781 |
| | Wisconsin | 1 | 0.0623 | 6.4% | 0.1917 | -0.3135 | 0.4380 | 0.11 | 0.7453 |
| | Wyoming | 1 | 0.2364 | 26.7% | 0.2433 | -0.2404 | 0.7132 | 0.94 | 0.3313 |
| | Alaska | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Density | < 50 | 1 | -0.4348 | -35.3% | 0.0380 | -0.5092 | -0.3603 | 130.95 | <0.0001 |
| | 50–99 | 1 | -0.3254 | -27.8% | 0.0322 | -0.3884 | -0.2624 | 102.39 | <0.0001 |
| | 100–249 | 1 | -0.2349 | -20.9% | 0.0277 | -0.2892 | -0.1806 | 71.87 | <0.0001 |
| | 250–499 | 1 | -0.2269 | -20.3% | 0.0274 | -0.2806 | -0.1732 | 68.59 | <0.0001 |
| | 599–999 | 1 | -0.1463 | -13.6% | 0.0277 | -0.2006 | -0.0920 | 27.86 | <0.0001 |
| | > 999 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Risk | Nonstandard | 1 | 0.0509 | 5.2% | 0.0202 | 0.0112 | 0.0905 | 6.32 | 0.0119 |
| | Standard | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Deductible range | 0 | 1 | -0.2403 | -21.4% | 0.4516 | -1.1254 | 0.6447 | 0.28 | 0.5946 |
| | 1–50 | 1 | 0.6109 | 84.2% | 0.4142 | -0.2009 | 1.4228 | 2.18 | 0.1402 |
| | 51–100 | 1 | -0.2555 | -22.5% | 0.4096 | -1.0583 | 0.5472 | 0.39 | 0.5327 |
| | 101–200 | 1 | -0.1534 | -14.2% | 0.4106 | -0.9581 | 0.6513 | 0.14 | 0.7087 |
| | 201–250 | 1 | -0.0151 | -1.5% | 0.4090 | -0.8167 | 0.7865 | 0.00 | 0.9706 |
| | 251–500 | 1 | -0.1875 | -17.1% | 0.4087 | -0.9884 | 0.6135 | 0.21 | 0.6464 |
| | 501–1000 | 1 | -0.5987 | -45.0% | 0.4102 | -1.4028 | 0.2053 | 2.13 | 0.1444 |
| | > 1000 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Motorcycle class | Chopper | 1 | -0.8309 | -56.4% | 0.1007 | -1.0283 | -0.6335 | 68.07 | <0.0001 |
| | Cruiser | 1 | -0.5776 | -43.9% | 0.0505 | -0.6765 | -0.4786 | 130.85 | <0.0001 |
| | Dual Purpose | 1 | -1.0269 | -64.2% | 0.0777 | -1.1792 | -0.8747 | 174.73 | <0.0001 |

| Appendix: Illustrative regression results - collision claim frequency for motorcycles with and without ABS or ABS/CCBS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | | Degrees of freedom | Estimate | Effect | Standard Error | Wald 95% Confidence Limits | | Chi-Square | P-value |
| | Scooter | 1 | -0.2698 | -23.6% | 0.0674 | -0.4018 | -0.1377 | 16.03 | <0.0001 |
| | Sport | 1 | 0.2885 | 33.4% | 0.0584 | 0.1740 | 0.4030 | 24.39 | <0.0001 |
| | Sport Touring | 1 | -0.1931 | -17.6% | 0.0759 | -0.3419 | -0.0442 | 6.46 | 0.0110 |
| | Standard | 1 | -0.2881 | -25.0% | 0.0841 | -0.4529 | -0.1233 | 11.74 | 0.0006 |
| | Super Sport | 1 | 0.5819 | 78.9% | 0.0535 | 0.4771 | 0.6868 | 118.31 | <0.0001 |
| | Touring | 1 | -0.4736 | -37.7% | 0.0553 | -0.5820 | -0.3651 | 73.27 | <0.0001 |
| | Unclad Sport | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Engine displacement | | 1 | 0.0004 | 0.0% | 0.0000 | 0.0004 | 0.0005 | 235.58 | <0.0001 |
| Auto claim frequency category | Low | 1 | 0.0358 | 3.6% | 0.0377 | -0.0381 | 0.1098 | 0.90 | 0.3422 |
| | Medium | 1 | 0.1661 | 18.1% | 0.0349 | 0.0976 | 0.2345 | 22.63 | <0.0001 |
| | High | 1 | 0.4975 | 64.5% | 0.0358 | 0.4272 | 0.5677 | 192.65 | <0.0001 |
| | Zero | 0 | 0 | 0 | 0 | 0 | 0 | | |
| ABS and ABS/CCBS | Equipped | 1 | -0.3268 | -27.9% | 0.0421 | -0.4092 | -0.2444 | 60.38 | <0.0001 |
| | Not Equipped | 0 | 0 | 0 | 0 | 0 | 0 | | |

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The Highway Loss Data Institute is a nonprofit public service organization that gathers, processes, and publishes insurance data on the human and economic losses associated with owning and operating motor vehicles.