Auto Loss Cost Drivers: Liability

August 2018

CAS PCI SOCIETY OF ACTUARIES

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Examining the drivers of bodily injury, property damage, and personal injury protection frequency and severity.

In the latter half of 2013, personal auto insurance carriers began to notice an uptick in property damage liability and collision frequency. This marked the beginning of a new increasing frequency trend bucking over 25 years of falling crash rates. While the period of falling frequency preceding this increase was largely attributable to safety awareness, technology, and enforcement, explanations supporting increasing frequency required further investigation.

In response, industry partners banded together to analyze these trends. Using publicly available data from the Federal Highway Administration, Bureau of Labor Statistics, the Census Bureau, and other sources, an analysis group is searching for explanatory variables. This paper represents some of their findings in collision and comprehensive frequency and severity. The group's goal is to provide an analytical basis for discussing and understanding auto insurance loss cost drivers that ultimately affect premiums.

The key findings from this work are:

- Congestion (through drivers per lane mile or average commute times) is positively related to bodily injury frequency, PIP frequency, PIP severity (in verbal threshold states), and property damage frequency.
- Bodily injury severity increases as you have more very young (under 20) or very old (over 75) drivers or more lawyers and is negatively related to bodily injury frequency.
- In verbal threshold states, the number of lawyers is rather positively related to the PIP claim frequency, but that relationship does not hold in monetary threshold states.
- Michigan has an outsized impact in both bodily injury and PIP.

Data Description

We mainly focus on two sources of data, the auto claims data and the economic variables which we will try to relate to them. We have quarterly bodily injury, personal injury protection, and property damage frequency and severity data for each state (excluding DC and HI) from Q4 2011 through Q4 2015 from the FAST TRACK PLUS™ database. Additionally, we have the following state-level explanatory variables.

- UrbanVMTPercent: Percent of the vehicle miles traveled (VMT) in an urban area.
- LawyersPer1MillionCapita: Number of lawyers in the state per 1 million people.
- UrbanAvgCommuteTime: Average commute time in minutes for people in urban areas.
- RuralAvgCommuteTime: Average commute time in minutes for people in rural areas.
- MobileBroadbandPercent: Percent of population with access to mobile broadband
- InterstateGood: Percent of interstate miles rated as good
- DriversUnder20Percent: Percent of drivers under age 20
- DriversOver75Percent: Percent of drivers over age 75
- CommutePrivateVehiclePercent: Percent of people who commute by private vehicle
- AverageQuarterlyPrecipitation: Average quarterly precipitation in inches.
- BLSUnemployment: Unemployment rate from Bureau of Labor Statistics (BLS)
- UrbanVMTperLane: Urban vehicle miles traveled per urban lane mile.
- RuralVMTperLane: Rural vehicle miles traveled per rural lane mile.
- CapitalOutlayperVMT: Total transportation dollars spent on capital projects, per vehicle miles travelled.

- MaintenanceExpensesperVMT: Total transportation dollars spent on maintenance expenses, per VMT.
- PolicingExpensesperVMT: Total transportation dollars spent on policing expenses, per VMT.
- DUIs: Total DUIs per driver
- GasPricevsWage: Average gas price in dollars divided by average hourly wage in dollars.
- TortSystem: No-fault, optional no-fault, tort
- LicensedDrivers: Number of licensed drivers in the state.
- LaneMilesTotal: Total number of lane miles in the state.
- DriversperLaneMile: LicensedDrivers/LaneMilesTotal

Bodily Injury Liability Claim Frequency

Figures 1 and 2 show average bodily injury claim frequency and severity respectively from 4Q 2011 to 4Q 2015. We can see generally that the states with the highest frequency have some of the lowest severities, and vice versa. Later in the report we will explore this further. Rhode Island, Louisiana, Maryland, and Massachusetts have the highest bodily injury frequency, while Michigan, North Dakota, and Minnesota have the lowest. We fit a random forest model and used it to measure variable importance. Variables with higher importance in a random forest have better predictive ability. The relative importance of variables plotted in figure 3 helped us decide which explanatory variables to further examine. The top variable is rural average commute time, followed by rural vehicle miles travelled (VMT, as a percentage of total miles), tort system, drivers per lane mile, and urban VMT. We will further explore some of these variables as well as percentage of drivers over 75, percentage of drivers under 20, and urban average commute time.

Figure 1
Average bodily injury frequency (claims per car year), 4Q 2011 – 4Q 2015

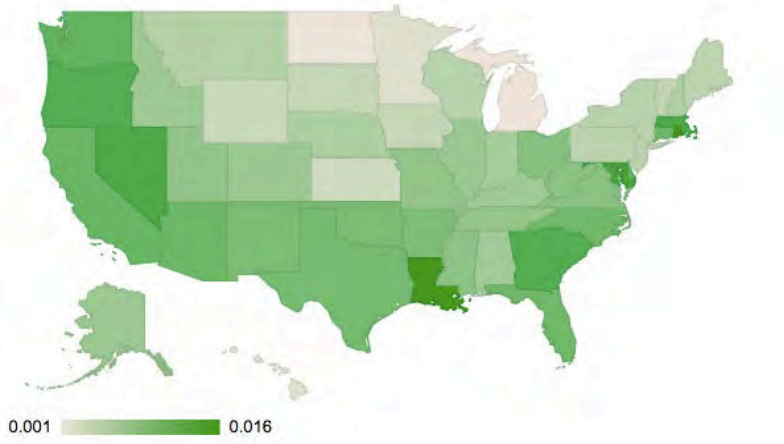
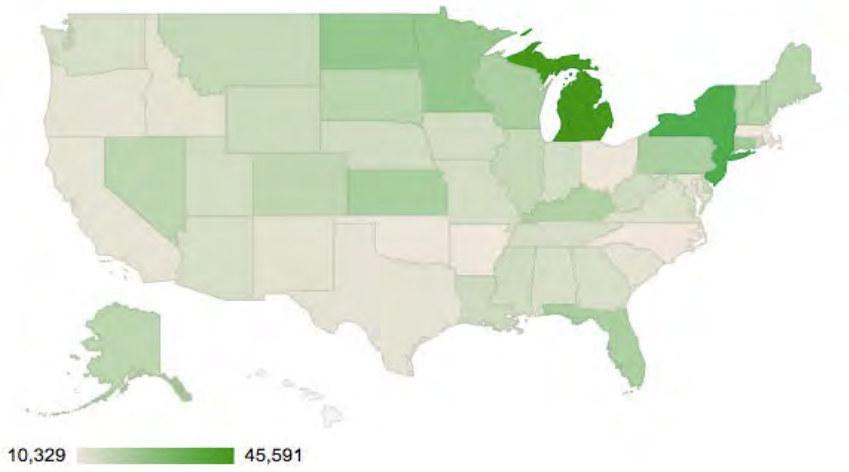


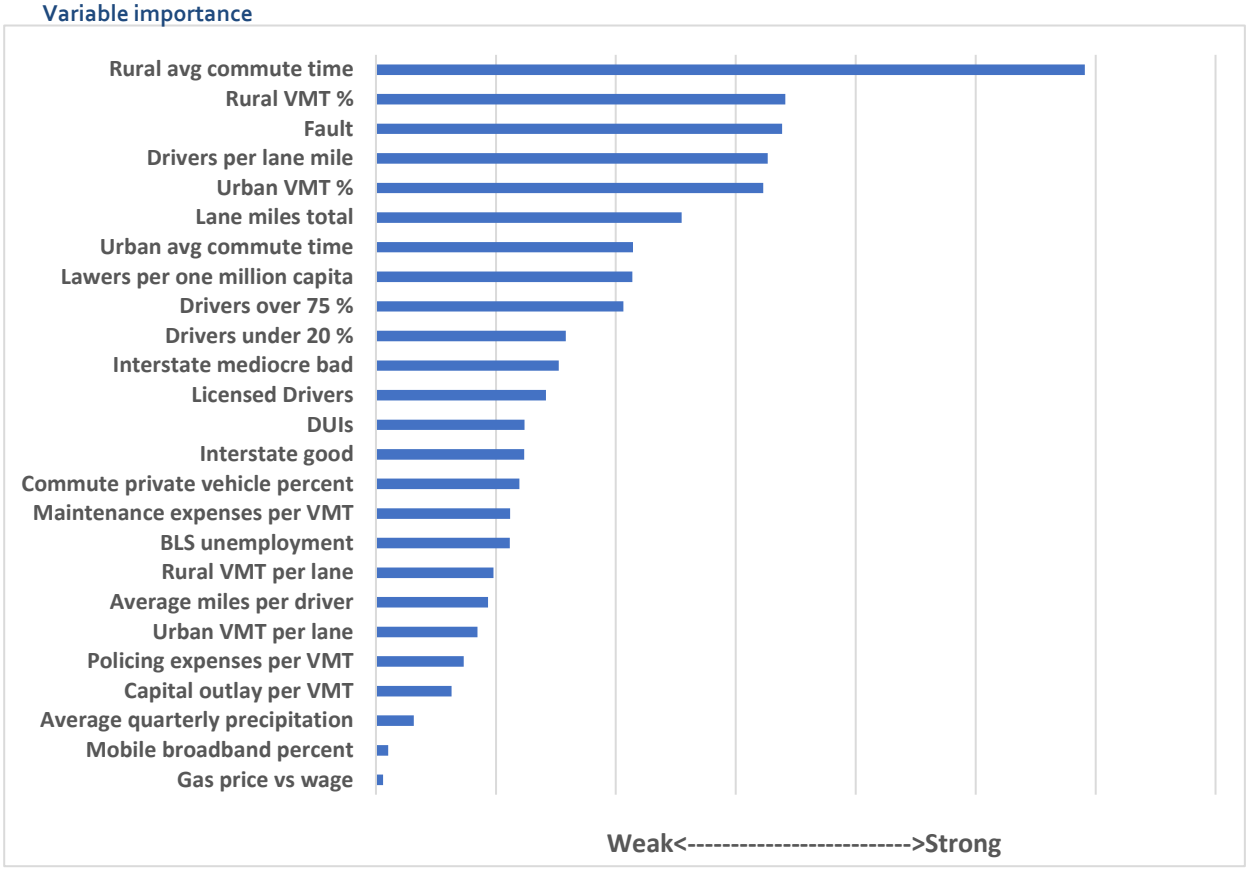
Figure 2
Average bodily injury severity (cost per claim), 4Q 2011 – 4Q 2015



Rural commute time

The average commute time in rural areas has a strong positive relationship with bodily injury frequency. Figure 4 is an added variable plot for rural average commute time. Added variable plots show the relationship between the response (in this case bodily injury frequency) and a single explanatory variable (rural average commute time) after accounting for all the other variables. These plots are really valuable when the explanatory variables are highly correlated.

Figure 3
Variable importance



This is the strongest positive relationship we have for bodily injury frequency. The factors we included in our model were rural average commute time, drivers per lane mile, urban average commute time, interstate mediocre/bad, lawyers per one million capita, percentage of drivers under 20, average miles per driver, and tort system.

We can also see in figure 5 that if you plot BI frequency by state from least to greatest, and plot rural average commute time against it, there is a clear positive trend between rural average commute time and BI frequency.

Figure 4
Rural average commute time added variable plot

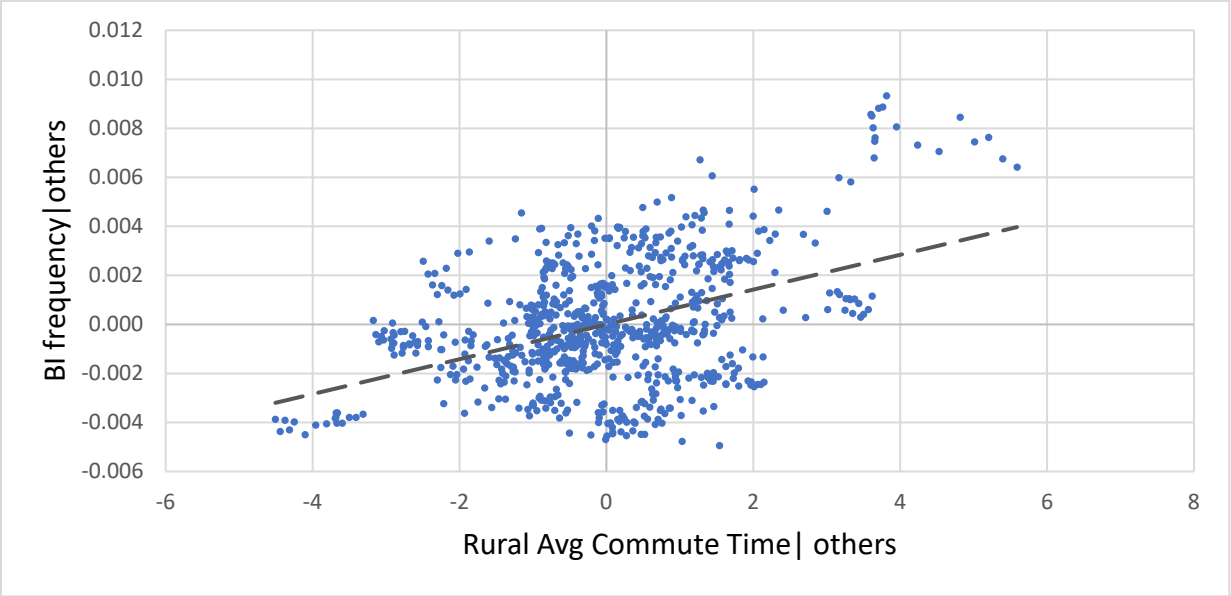
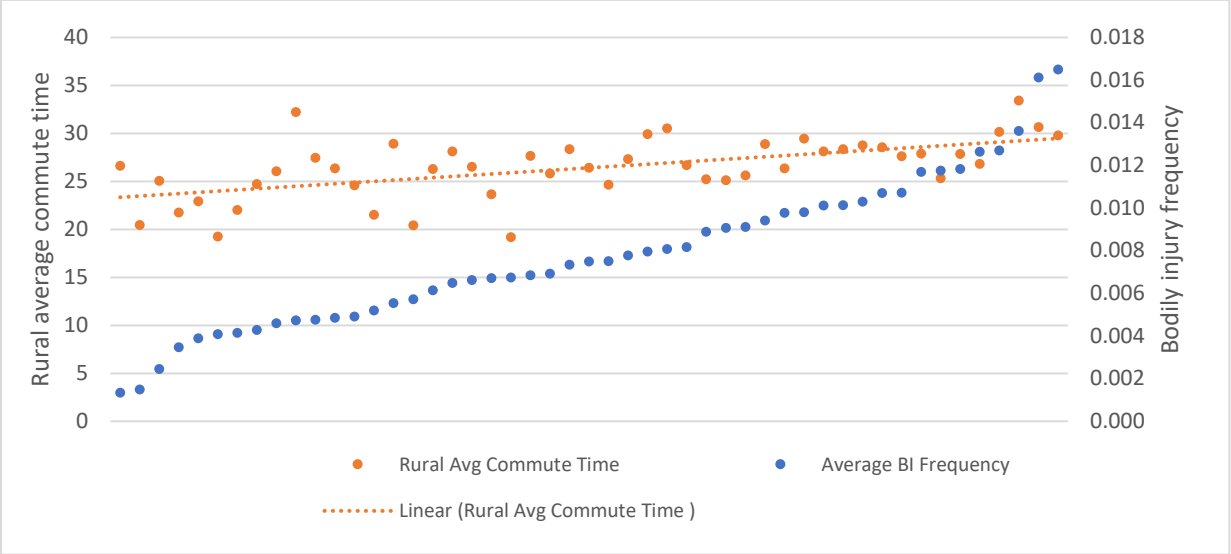


Figure 5
Rural average commute time vs. bodily injury frequency



Urban commute time

When we compare the added variable plots for urban and rural average commute time in figures 6 and 4 respectively, we see that in contrast to rural average commute time, urban commute time has a negative correlation with BI frequency.

If we again look at the trend between states in figure 7, we see a positive trend between urban average commute time and bodily injury frequency. The reason these two can be different is that the added variable plot shows what this variable adds after accounting for the effects of the other variables in the model, where the other plot just shows the general trend between the bodily injury frequency and urban average commute time, not accounting for anything else. It could be that other variables like drivers per lane mile explain the positive trend well if it is due to population density.

Figure 6
Urban average commute time added variable plot

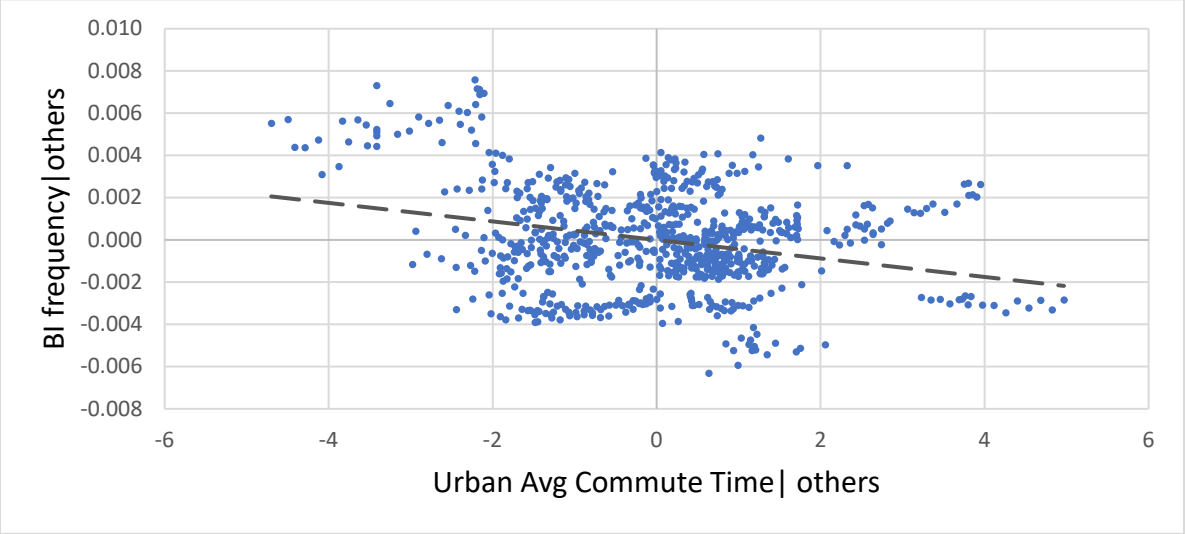
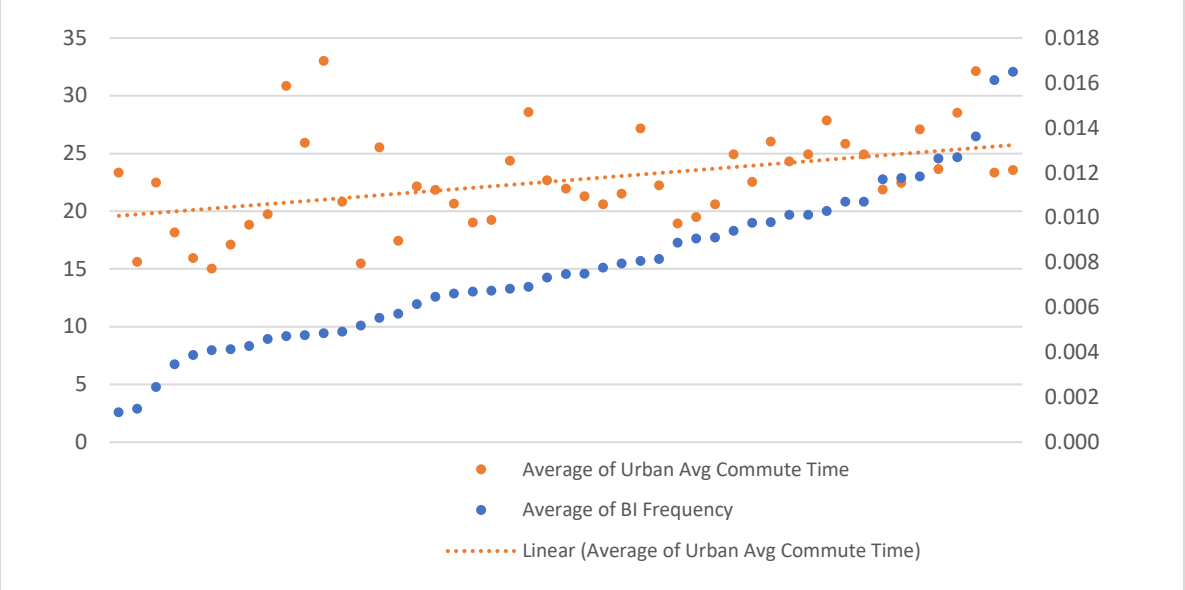


Figure 7
Urban average commute time vs. frequency



Drivers per lane mile

We also see a positive trend between drivers per lane mile and bodily injury frequency in the added variable plot in figure 8. Drivers per lane mile is our main road congestion variable, which suggests that more congested roads lead to higher bodily injury claim frequency. This trend is consistent from state to state as well, as seen in figure 9, except for a few notable exceptions. In particular, New Jersey, New York, Pennsylvania and Michigan. We would expect these states to have much higher BI frequency based upon their drivers per lane mile. These states are all no-fault states with a verbal threshold required to sue in a bodily injury case. This means that only in special circumstances can a person sue in a bodily injury case, which keeps bodily injury claim frequency low. These states also have high average bodily injury claim severity, since the injuries a person has to sustain to be allowed to sue are also likely to lead to expensive claims.

Figure 8

Drivers per lane mile added variable plot

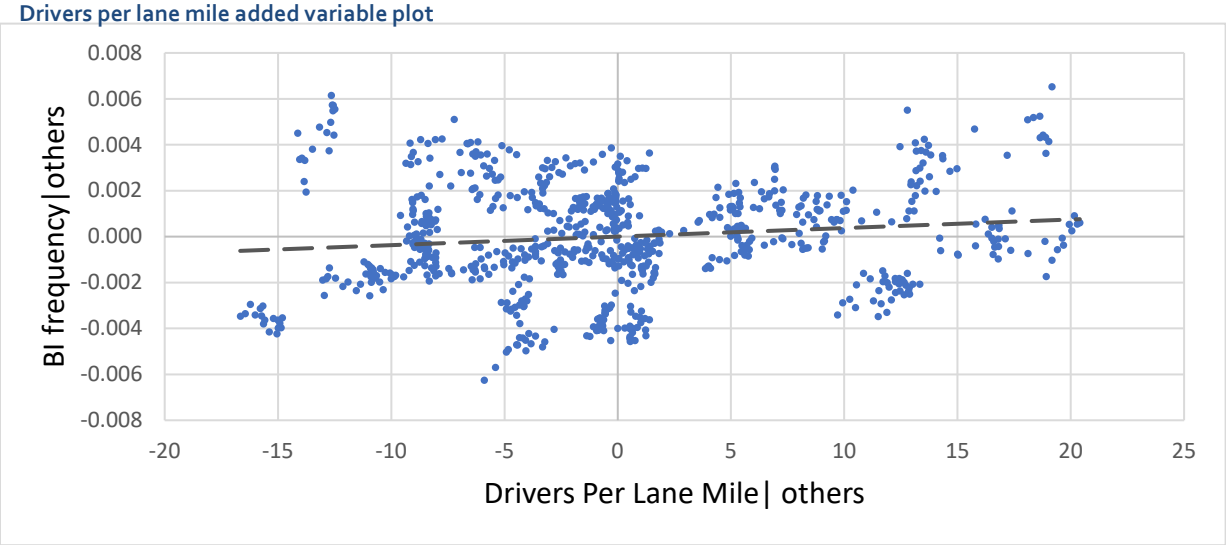
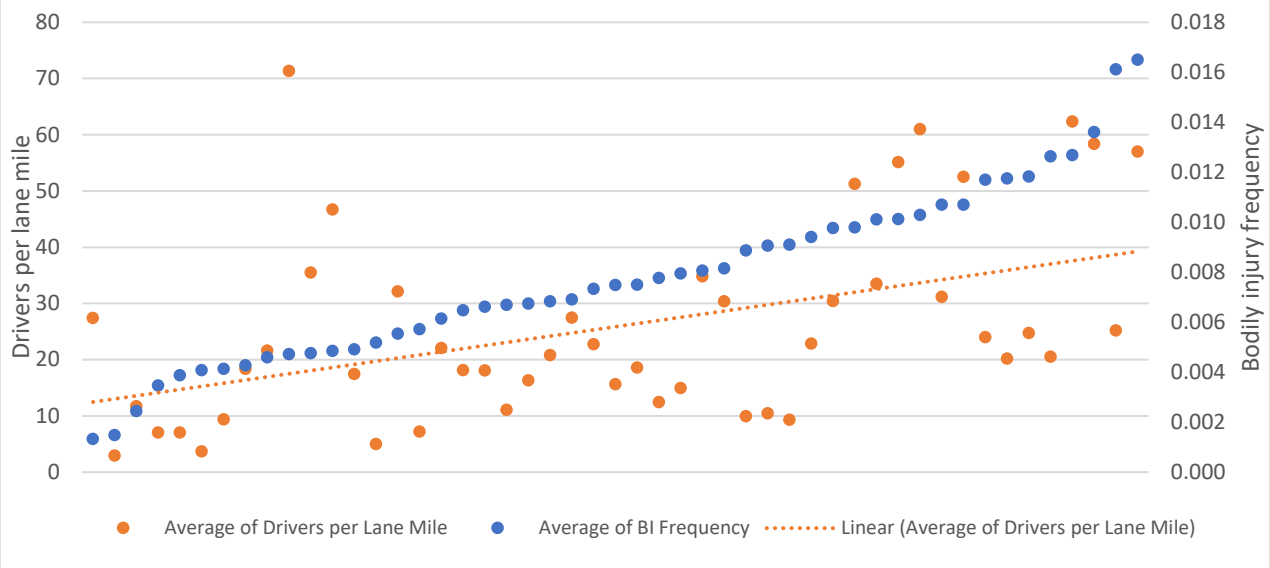


Figure 9

Drivers per lane mile vs. frequency (claims per car year)



Drivers over 75 and drivers under 20

The other interesting relationships for bodily injury frequency are percentage of drivers under 20, and percentage of drivers over 75. Added variable plots for these variables are found in figures 10 and 11 respectively. These trends are not just an anomaly in our model, these negative trends hold up in the state to state comparison as well, with the percentage of drivers under 20 in figure 12 and drivers over 75 in figure 13. States with higher bodily injury claim frequency tend to have a smaller percentage of drivers under 20 and over 75. One possible explanation is that these drivers are on the road less, or during less congested times, so even though they may have higher accident rates per mile driven, the total effect is fewer accidents.

Figure 10

Drivers under 20 added variable plot

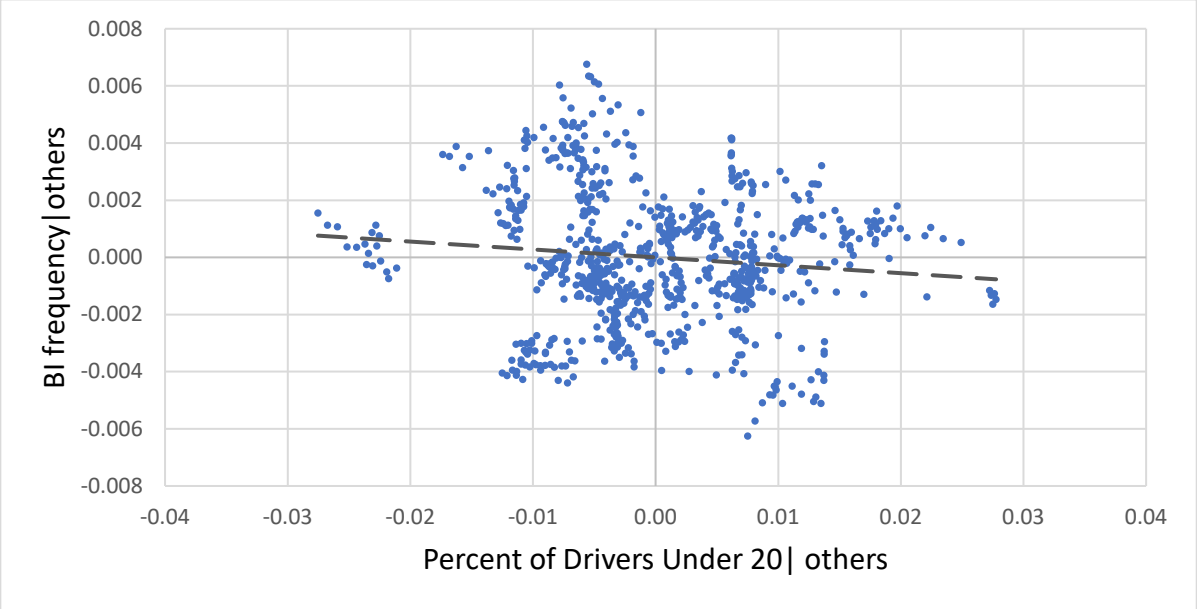


Figure 11

Drivers over 75 added variable plot

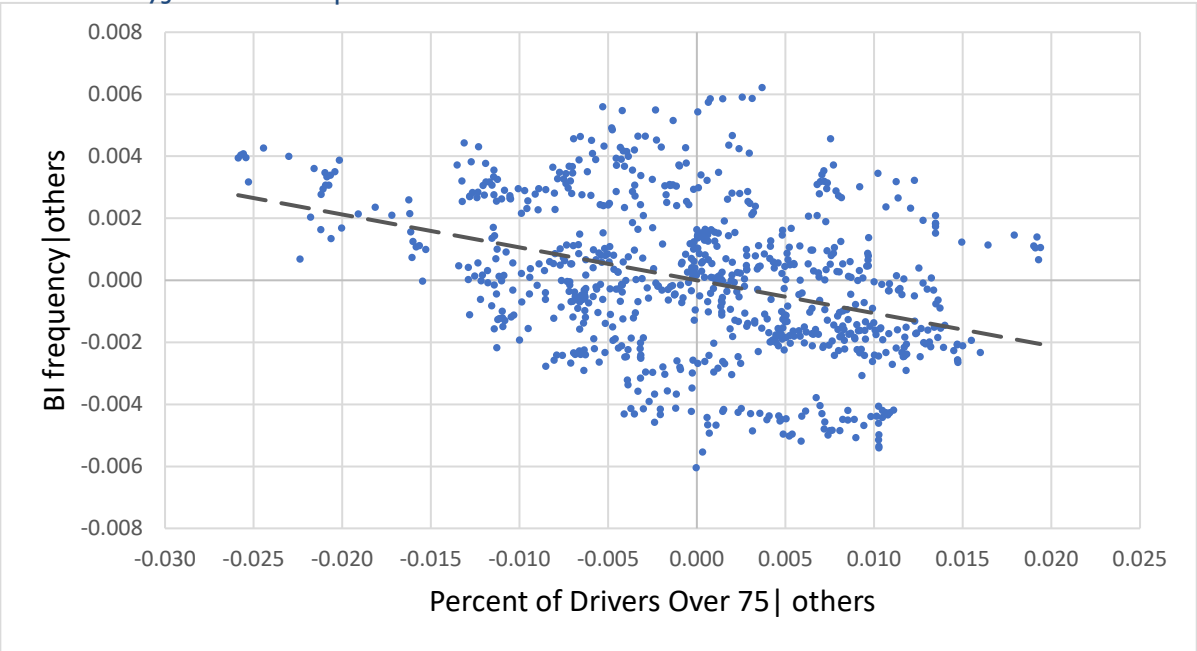


Figure 12
Drivers under 20 vs. frequency

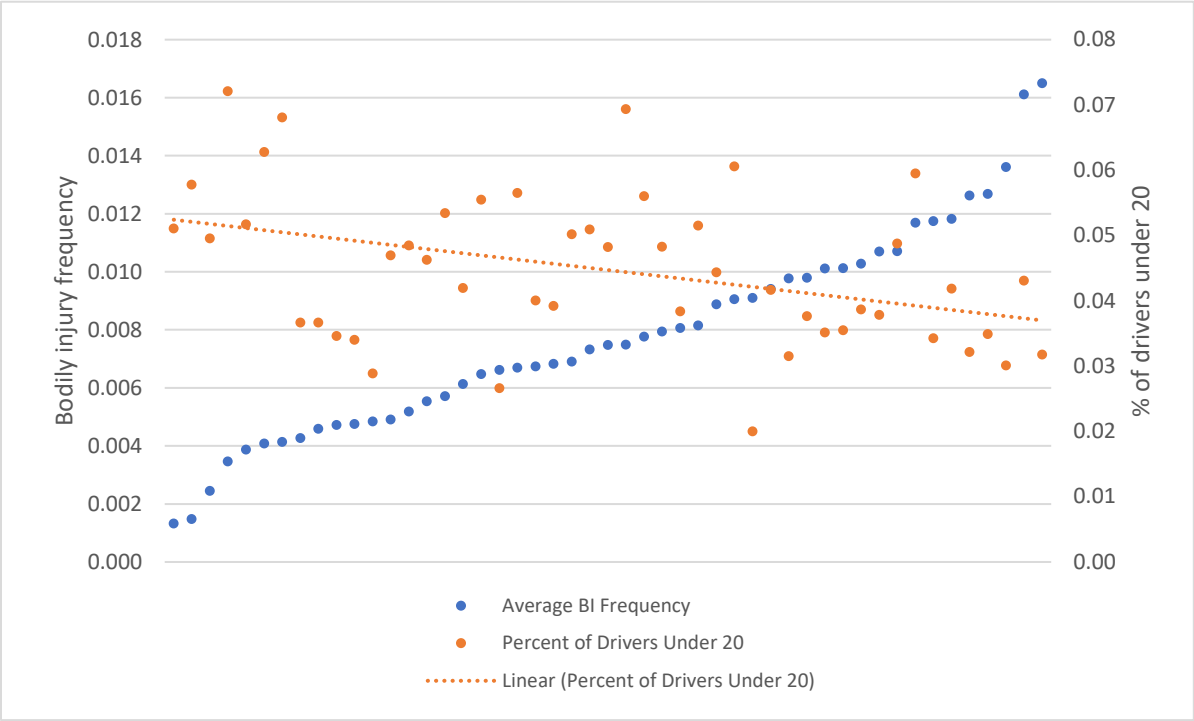
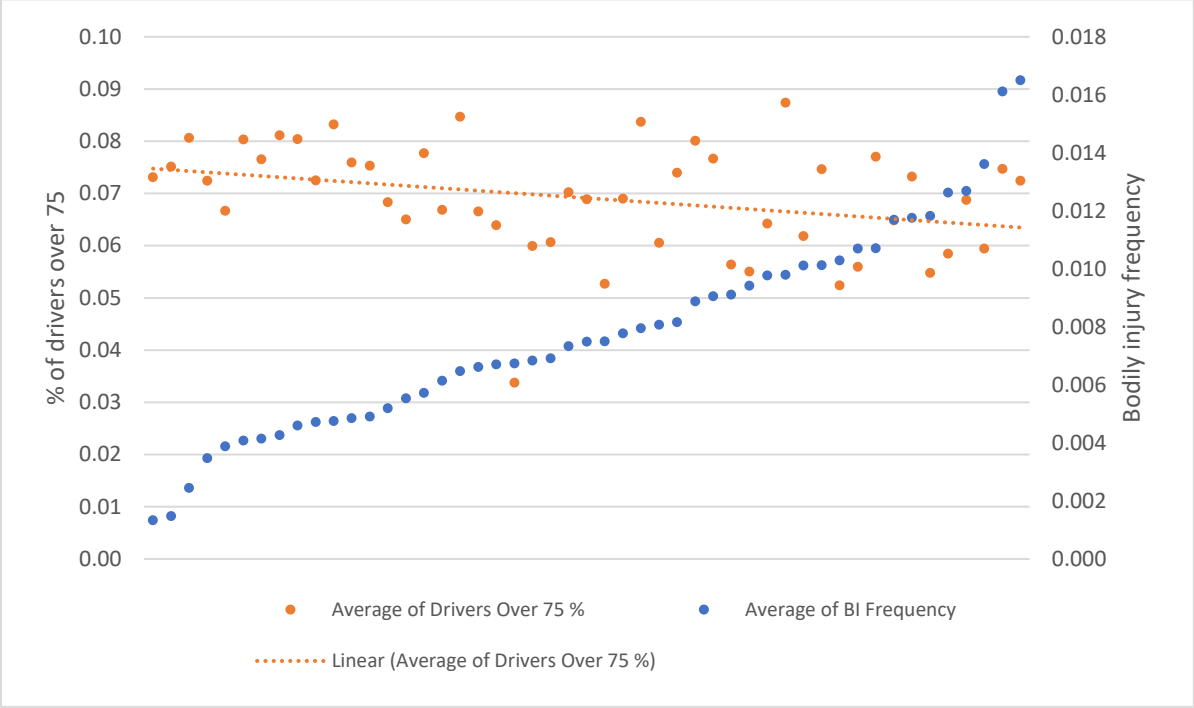


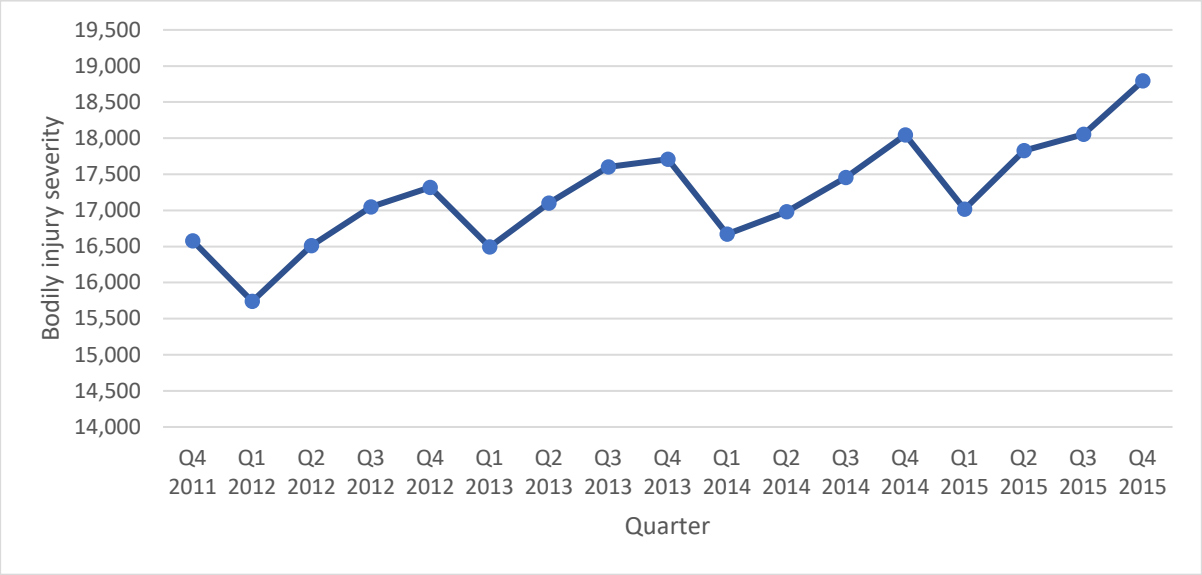
Figure 13
Drivers over 75 vs. frequency



Bodily Injury Liability Severity

Figure 14 shows the average bodily injury severity from 4Q 2011 to 4Q 2015. Two trends are readily apparent; there is a quarterly trend with the first quarter of each year having the lowest severity, then each quarter increases until the fourth. Surprisingly, this resets every year. The second trend is a clear inflationary trend from year to year. The average severity increases by 3.44 percent from 2012 to 2013, 0.36 percent from 2013 to 2014, and 3.67 percent from 2014 to 2015.

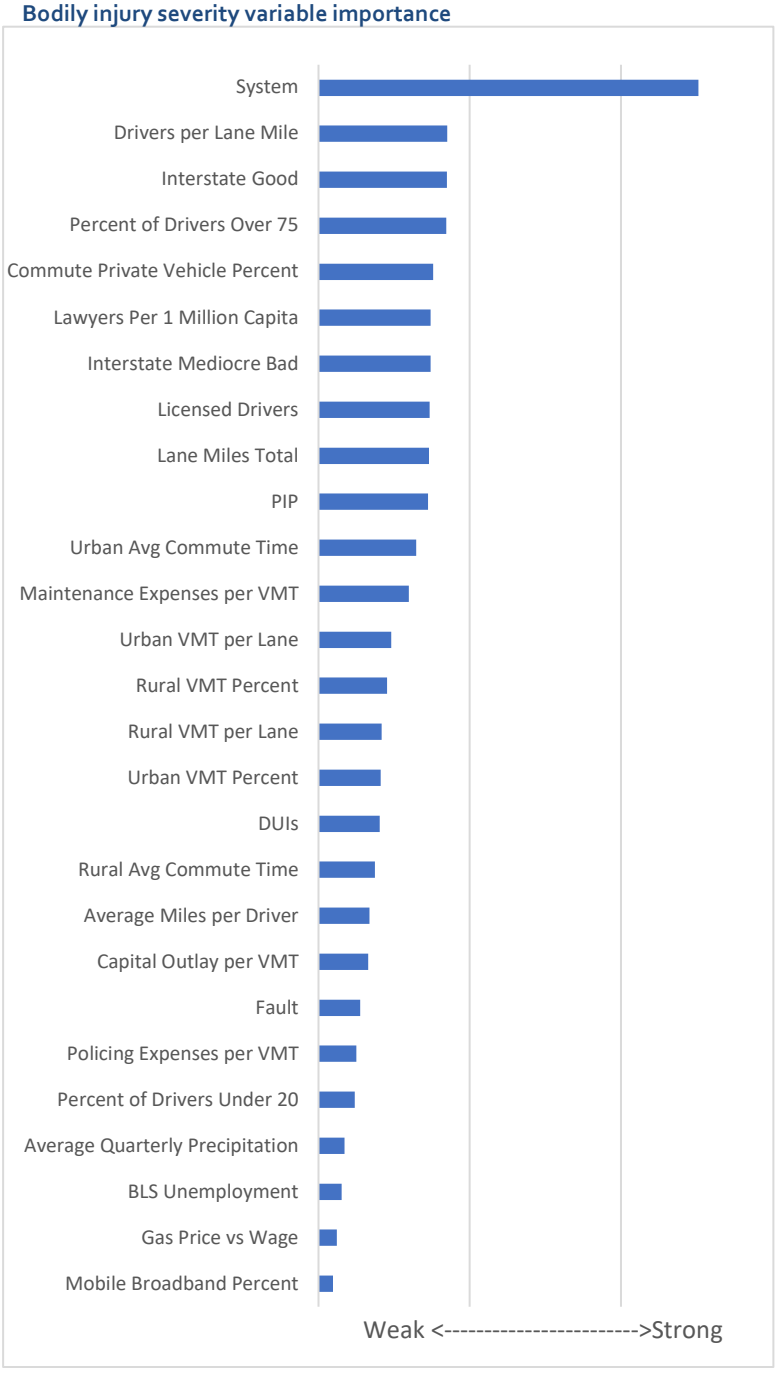
Figure 14
Average bodily injury severity



Fault system

When we fit a random forest model on the bodily injury severity data, the most important variable by far was fault system, as seen in figure 15. This is the variable that tells if a state has a tort system, an optional no-fault, a no-fault system with a monetary threshold, or a no-fault system with a verbal threshold. A monetary threshold allows a party injured in an accident to sue the person at fault if medical expenses arising from the accident exceed a certain threshold. A verbal threshold only allows the injured party to sue if damages fit a verbal description of a serious injury, for instance in New York no-fault law a serious injury is defined as "a personal injury which results in death; dismemberment; significant disfigurement; a fracture; loss of a fetus; permanent loss of use of a body organ, member, function or system; permanent consequential limitation of use of a body organ or member; significant limitation of use of a body function or system…" This makes bodily injury liability insurance act very differently in verbal threshold states than in all others. The overall average bodily injury severity for no-fault states with a verbal threshold is $31,557, the average for the other states is $15,604. Because of this disparity, making a model with all of the states gives leverage to any variables that differentiate between these types of states. The main analysis that follows will focus only on states without a verbal threshold.

Figure 15
Bodily injury severity variable importance



Urban areas

Drivers per lane mile and percentage of people commuting in a private vehicle both have negative relationships with bodily injury severity. Figure 16 has states ordered by increasing bodily injury severity with drivers per lane mile plotted in orange. Figure 17 is a histogram of drivers per lane mile with states grouped by quintiles. Added variable plots in figures 18 and 19 show the relationship with bodily injury severity after accounting for the impact of other variables. These variables are both related to road congestion, and it appears that more congested roads tend to create less severe accidents. The second variable could be proxy for rush hour traffic, the more people who commute to work in their own vehicle the more cars on the road during rush hour. The fact that this is negatively related with bodily injury severity and that similar congestion variables are positively related to bodily injury frequency tells us that more congested roads have more frequent accidents that are less severe. More sparsely populated areas have less collisions, but those collisions tend to be more severe.

Figure 16
Drivers per lane mile added variable plot

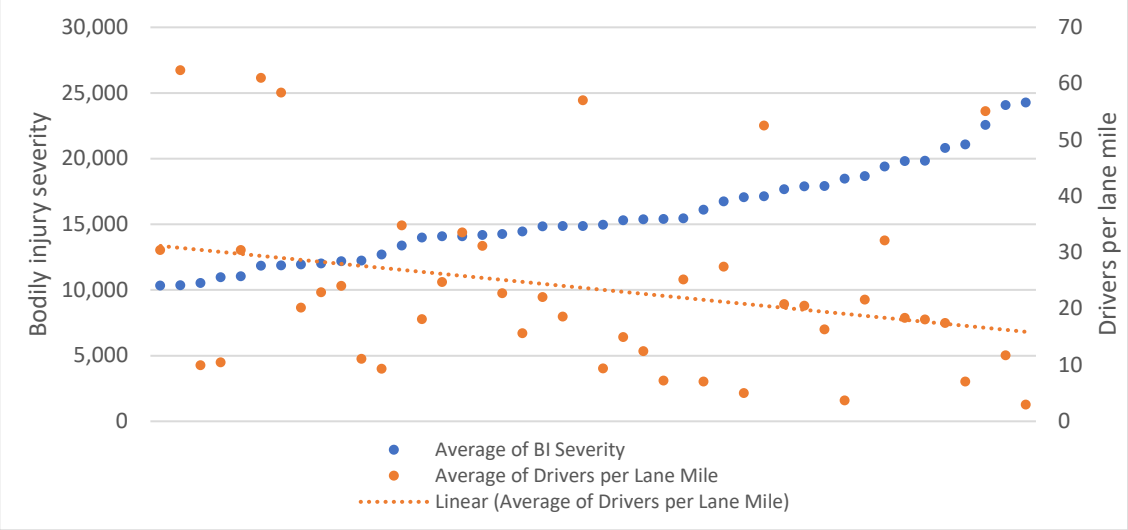


Figure 17
Drivers per lane mile sorted by bodily injury severity

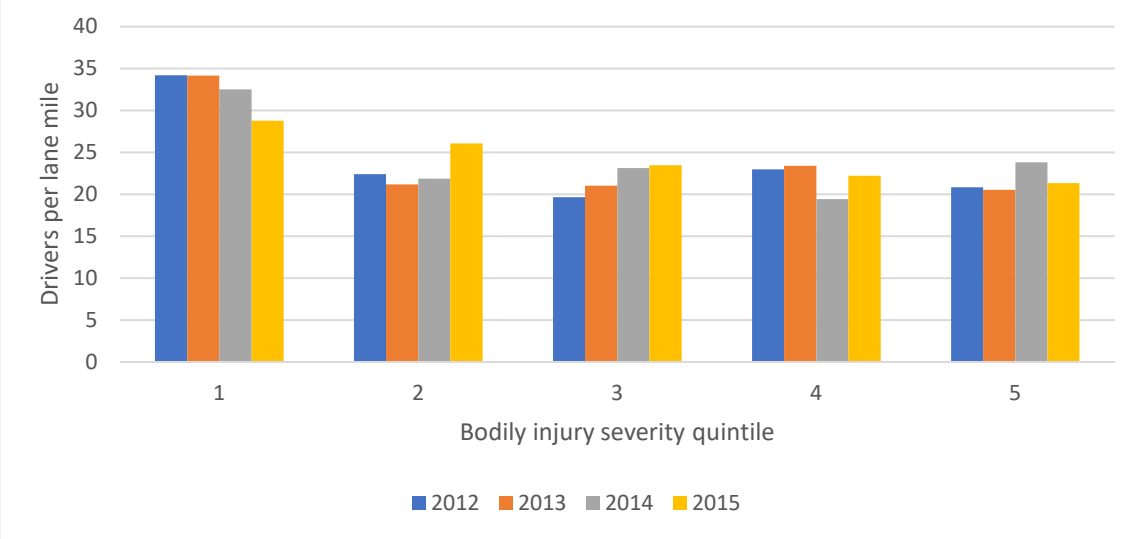


Figure 18
Drivers per lane mile added variable plot

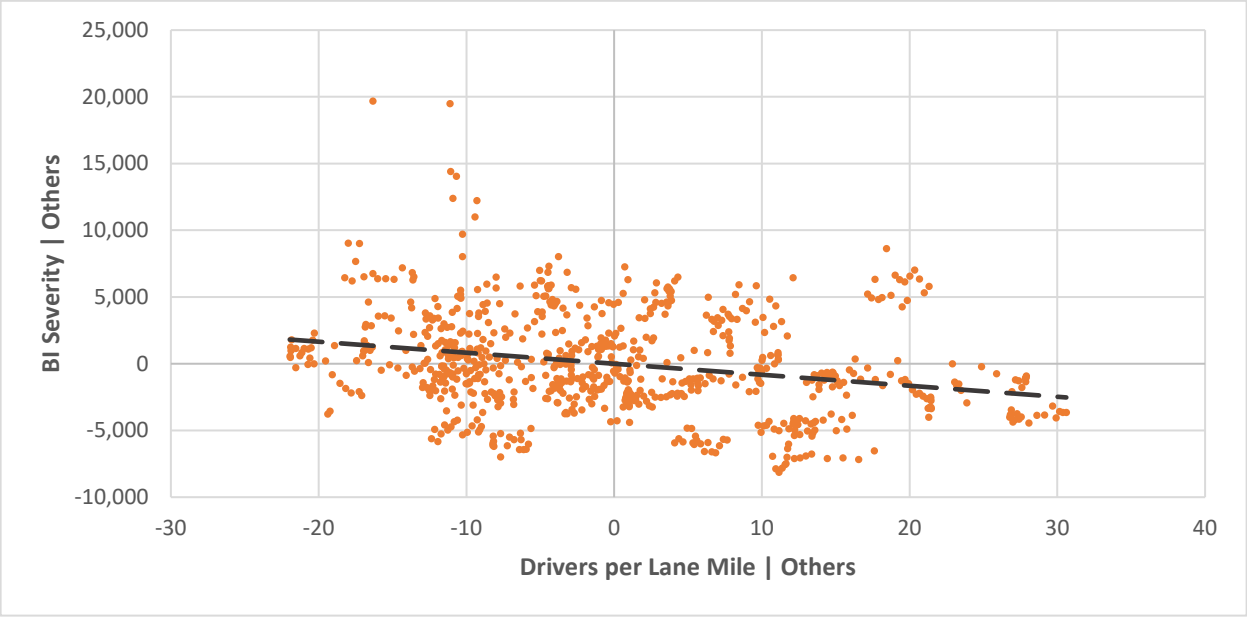
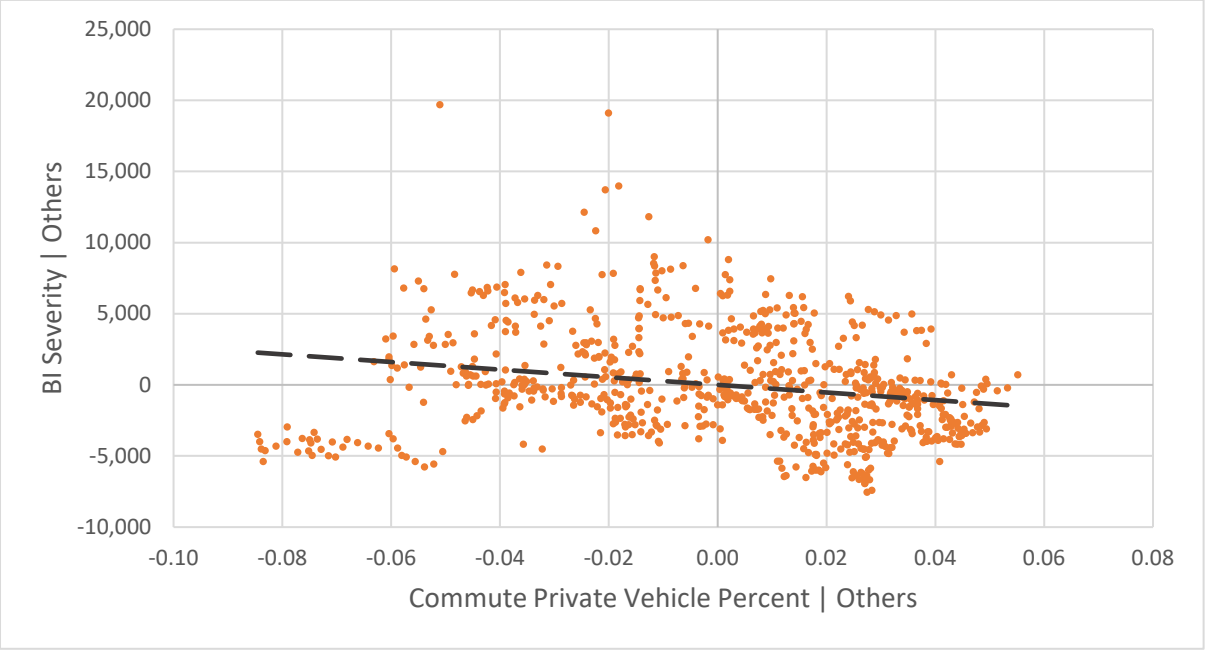


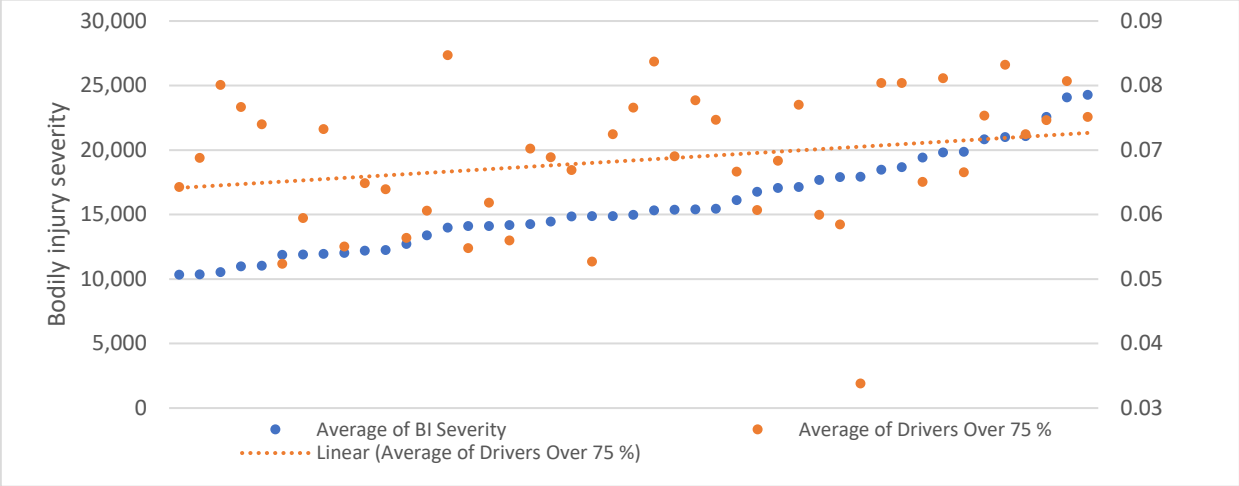
Figure 19
Commute private vehicle percent added variable plot



Drivers over 75

Percentage of the drivers over age 75 has a positive relationship with bodily injury severity. This is one of the stronger relationships we see in the added variable plots and is clearly seen when looking at the plot of states ordered by increasing bodily injury severity in figure 20. This trend makes logical sense considering that a large portion of bodily injury claims are medical expenses, and medical expenses tend to increase as people age. This trend runs opposite of the one we saw where bodily injury frequency decreased as percentage of drivers over 75 increased.

Figure 20
Drivers per lane mile vs. bodily injury severity



Lawyers per 1 million capita

After accounting for the variation due to the other variables in our model, lawyers per 1 million capita has a slightly positive relationship with bodily injury severity. This relationship is weak when compared with the others, but it is statistically significant. Figure 21 shows the added variable plot which displays this relationship. Figure 22 shows the plot of states ordered by increasing bodily injury severity, with lawyers per 1 million capita plotted as well. The trendline for lawyers per 1 million capita has a nominally positive slope. This relationship is interesting because it is only significant after accounting for our other variables.

Figure 21
Lawyers per 1 million capita added variable plot

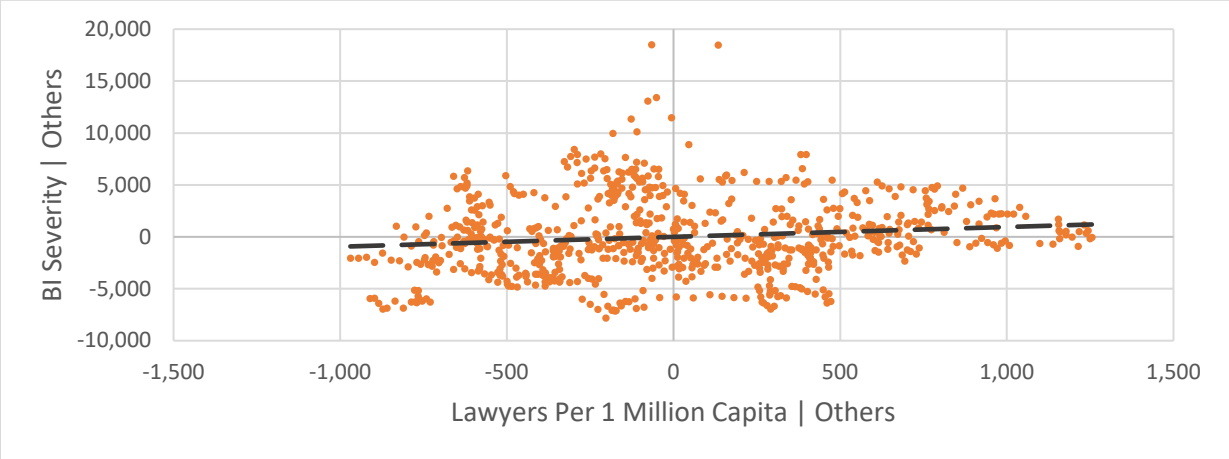
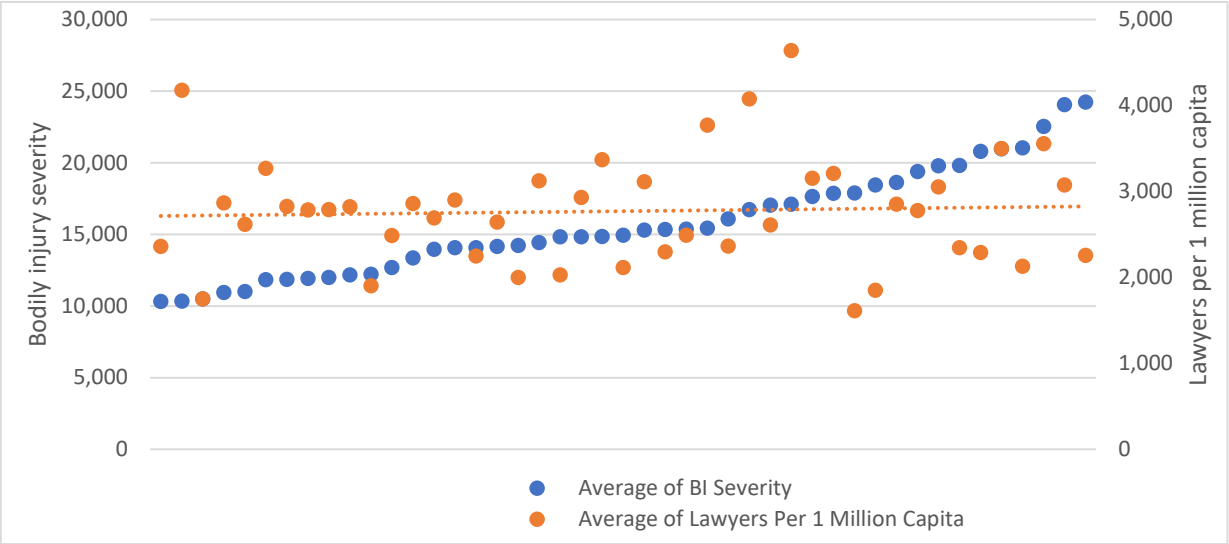


Figure 22
Lawyers per 1 million capita vs. bodily injury severity

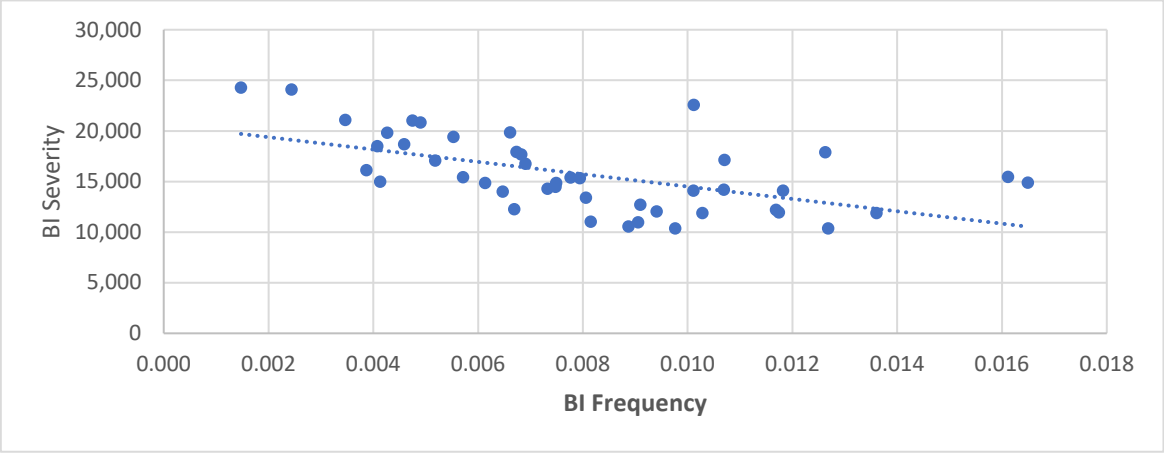


Conclusion

Bodily injury claim frequency increases with rural commute time and road congestion, modelled by drivers per lane mile. After accounting for these variables, increasing urban commute time decreases claim frequency. Bodily injury frequency is also negatively correlated with percentage of drivers over 75, and percentage of drivers under 20.

Bodily injury claim severity is heavily affected by tort system. States under a no-fault system with a verbal threshold often have the highest severity. Bodily injury severity decreases as road congestion increases, again modelled by drivers per lane mile, as well as the percentage of drivers who commute in a private vehicle. Bodily injury severity increases with percentage of drivers over 75 and lawyers per million capita. Some of these variables have opposite effects on frequency and severity, like road congestion and drivers over 75. These factors likely contribute to what appears to be a negative correlation between bodily injury frequency and severity (Figure 23).

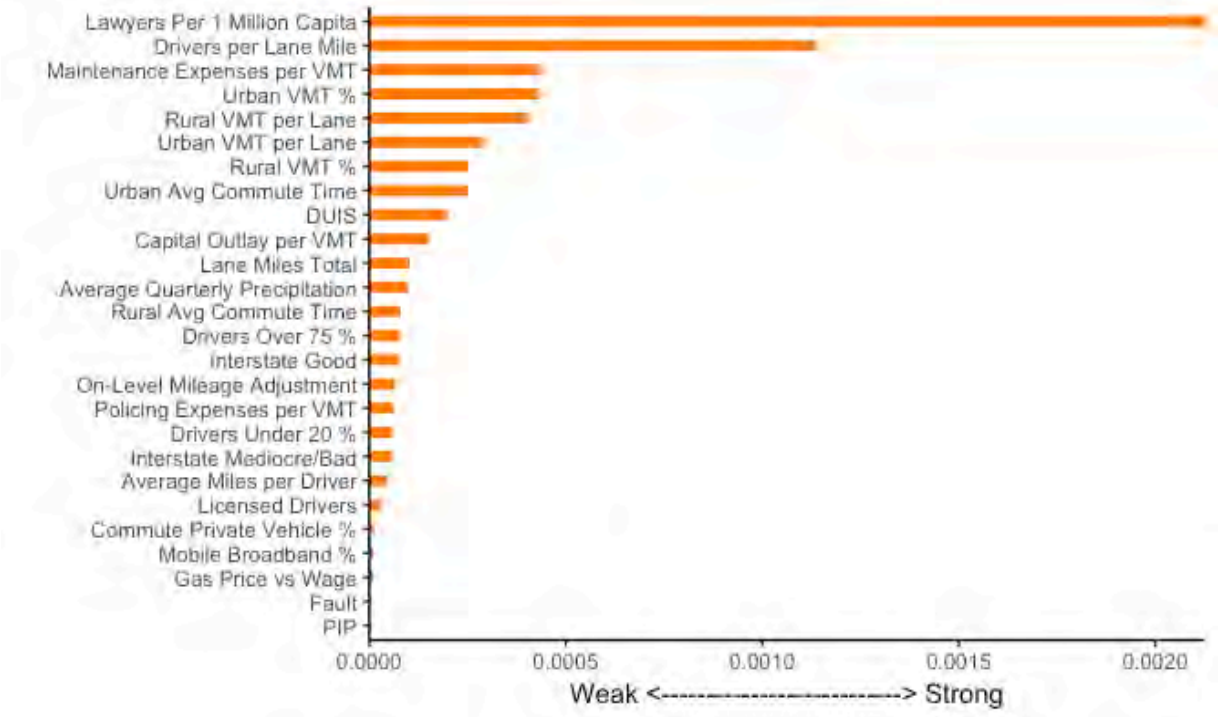
Figure 23
Average bodily injury frequency vs. severity



Personal Injury Protection Claim Frequency

Personal Injury Protection (PIP) insurance is only available in certain states. Some states require it, while in others it is optional. In some states there is a monetary threshold to sue instead of filing a PIP claim, other states have a verbal threshold, meaning it is only legal to sue for certain types of injuries such as disfigurement. The only states considered in this and the next sections of the report are those which have PIP insurance (optional or required). Through a random forest model, the variables consistently found to be most important for PIP frequency include Lawyers per 1 million capita, drivers per lane mile, rural vehicle miles traveled (VMT) per lane, percentage of VMT in urban areas, maintenance expenses per VMT, and urban average commute time. A plot displaying the importance of the top variables is shown in Figure 24. Most of these variables are related to congestion, like drivers per lane mile and rural VMT per lane. It is logical that increased traffic would lead to more accidents and therefore more PIP claims. It is interesting that lawyers per 1 million capita was consistently the most important variable.

Figure 24
Personal injury protection frequency variable importance plot



Lawyers per 1 million capita

Lawyers per 1 Million Capita was consistently the most important variable in explaining PIP Frequency. It appears that as lawyers per 1 million capita increases, so does PIP frequency (see Figure 25). An interesting trend appears when we divide the states by their threshold type. In verbal threshold PIP states, the number of lawyers per capita has a significantly positive effect (Figure 26). In contrast, in monetary threshold PIP states, Lawyers per 1 Million capita does not have a significant effect on PIP frequency after accounting for the other variables (Figure 27).

Figure 25
Lawyers added variable plot (all states)

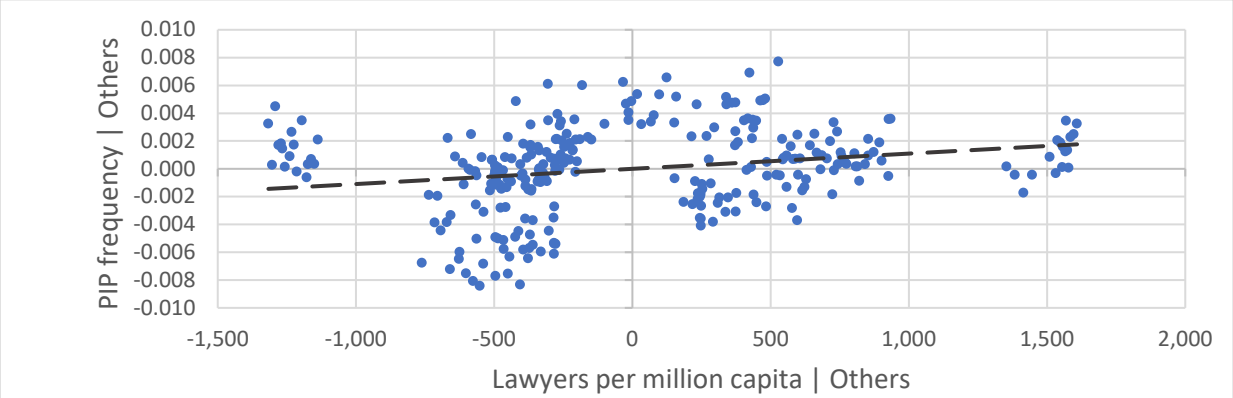


Figure 26
Lawyers added variable plot (verbal threshold states only)

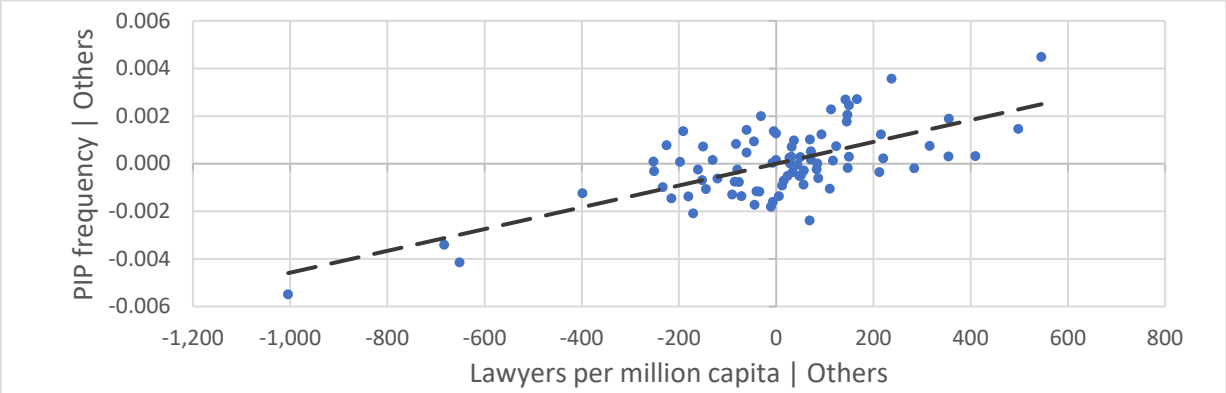
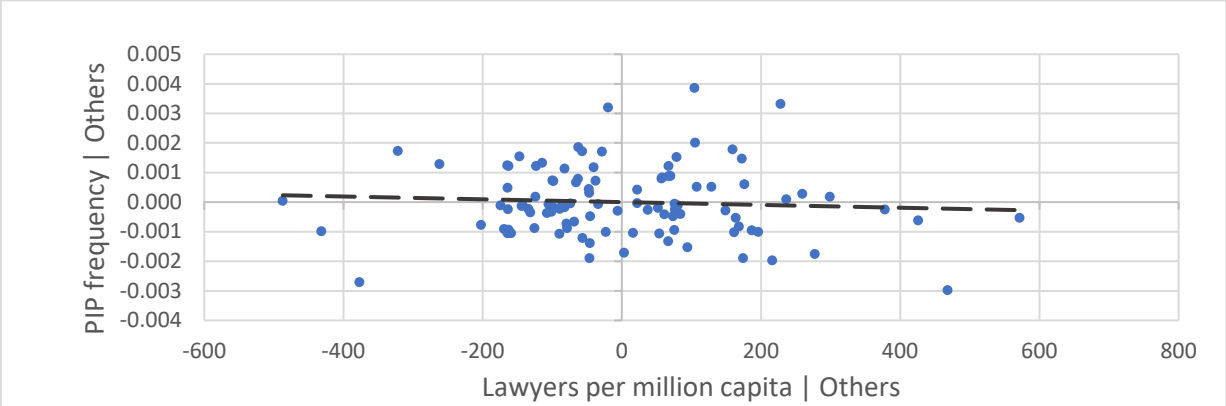


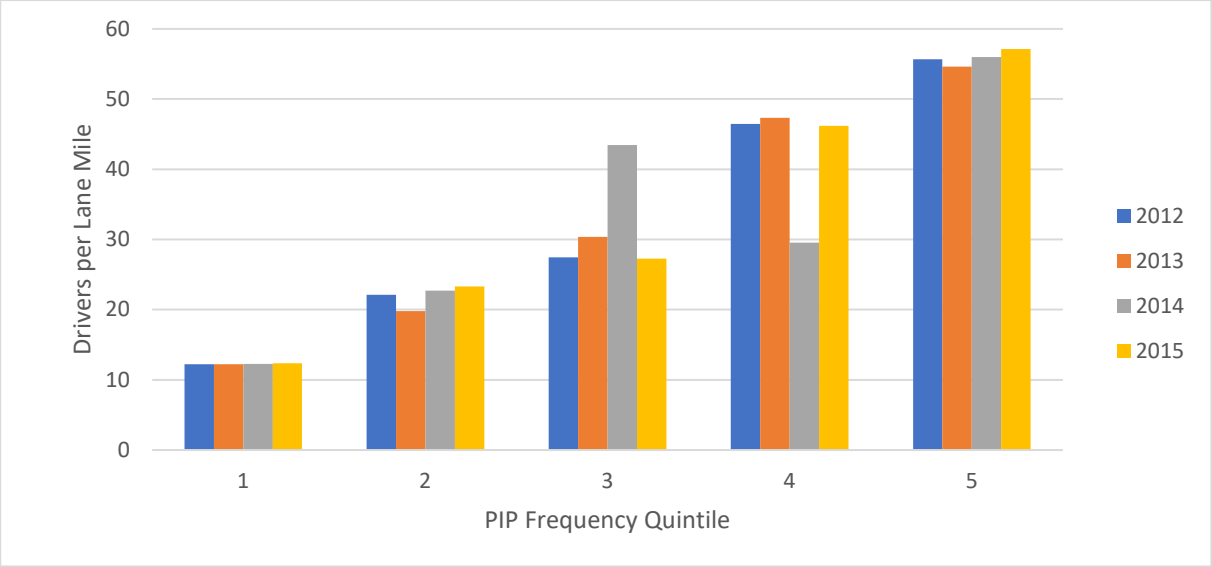
Figure 27
Lawyers added variable plot (monetary threshold states only)



Congestion variables

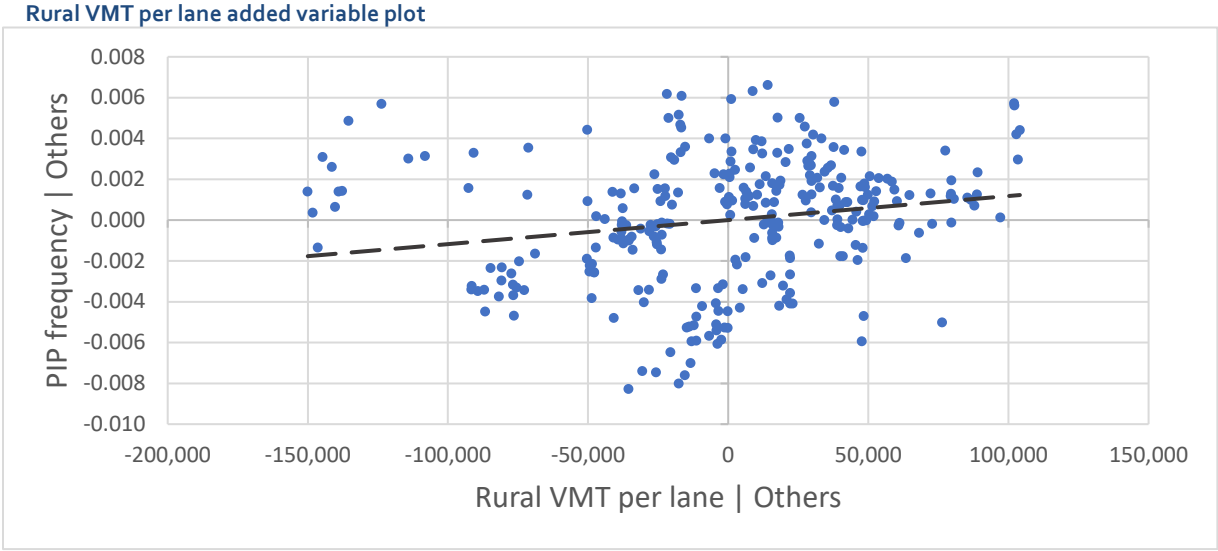
Drivers per lane mile, urban vehicle miles traveled per lane, urban VMT percent, and urban average commute time are all indicators of traffic congestion in an area. As seen in Figure 28, more PIP claims occur in states where there are more drivers per lane mile. The same is true for states with higher urban VMT per lane and a higher percentage of urban VMT. This is intuitive, because we would expect accidents to be more frequent when there are more cars on the road, or when cars are traveling more.

Figure 28
Average drivers per lane mile grouped into quintiles by PIP frequency



There is something interesting about the effect of rural VMT per lane. PIP claim frequency increases with urban VMT per lane. This is true even though the percentage of VMT in urban areas is also positively correlated with PIP frequency. This tells us that urban driving is more likely than rural driving to produce a PIP claim, but higher VMT means higher PIP frequency, whether in rural or urban areas (Figure 29).

Figure 29
Rural VMT per lane added variable plot

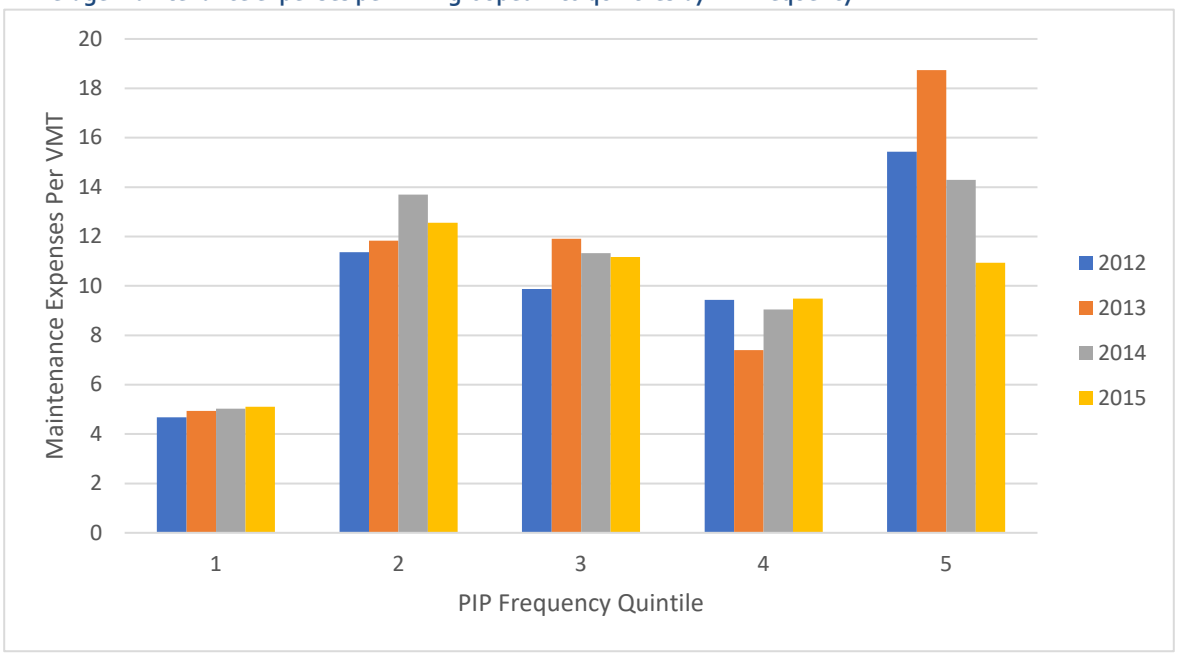


Maintenance expenses per vehicle mile traveled

It is tough to draw conclusions on the effect of maintenance expenses per VMT. Figure 30 shows that the states with average PIP claim frequency have the highest maintenance expenses per VMT while those with the lowest/highest PIP claim severity tend to have the lowest maintenance expenses per VMT.

Figure 30

Average maintenance expenses per VMT grouped into quintiles by PIP frequency



Personal Injury Protection Claim Severity

Michigan

Looking at PIP severity, Michigan stands out as being far above the rest. In figure 31, relative PIP severity is represented by color, and in figure 32 quarterly PIP severity is plotted. PIP severity in Michigan is consistently more than four times the average, and $10,000 above the next highest state, New Jersey. The reason for this is a unique mandate in Michigan's no-fault insurance law that requires the insurance company of an injured driver to pay for "all reasonable charges incurred for reasonably necessary products, services and accommodations for an injured person's care, recovery, or rehabilitation." This is different from other no-fault states that require a minimum amount of PIP insurance coverage, like New York which requires $50,000 in coverage. As a result, Michigan has a small number of large claims that drive up the average severity. The analysis will proceed without Michigan, to avoid confounding the effect of this law with that of our explanatory variables.

Figure 31
PIP severity (dollars per claim) by state

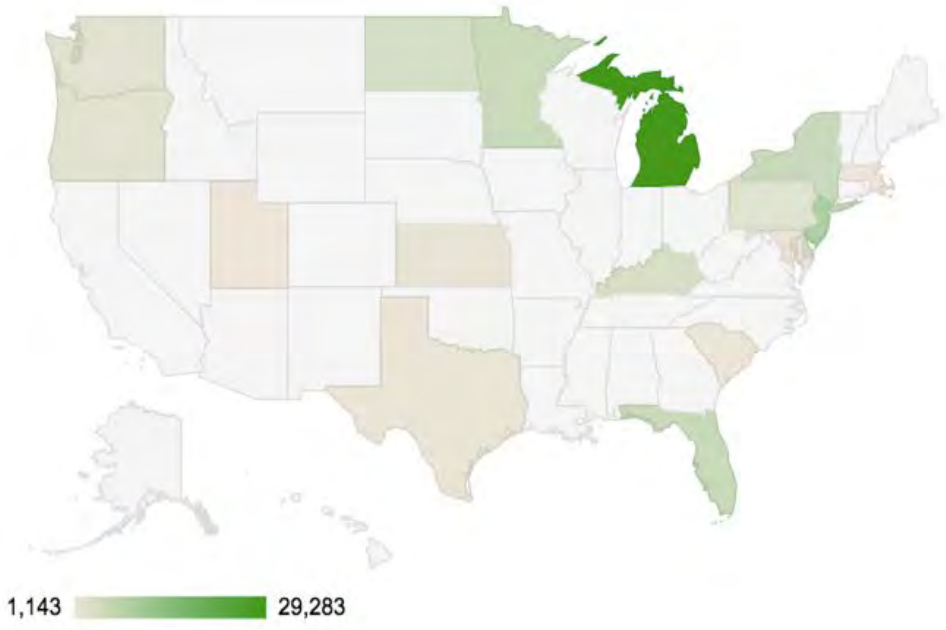
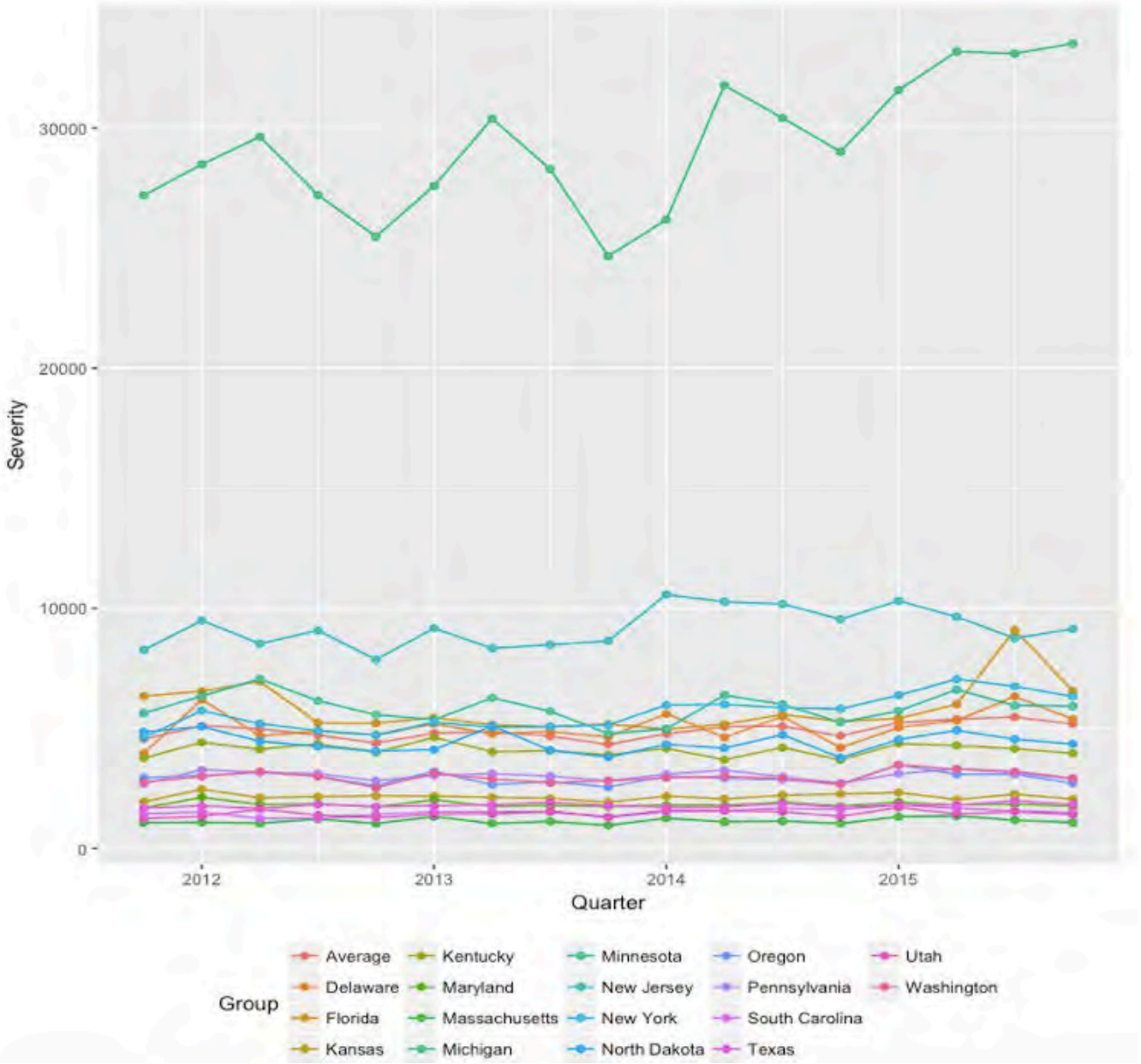


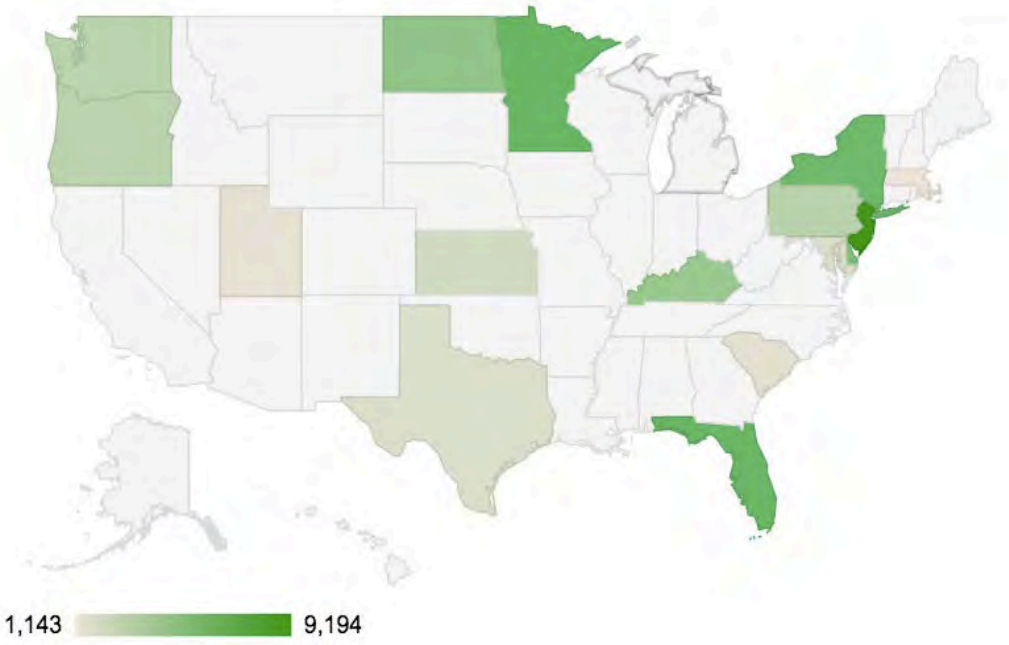
Figure 32
PIP severity (dollars per claim) by quarter



The other states

National private passenger personal injury protection claim severity from 4Q 2011 to 4Q 2015 is shown in figure 33. The states with the highest PIP severity are Michigan, New Jersey, Minnesota, and Florida, and the ones with the lowest are Massachusetts, Utah, and South Carolina. Gray states are ones where PIP insurance is not required. In this plot, Michigan has also been removed so make it easier to see the difference between the levels of the other states.

Figure 33
PIP severity (dollars per claim) by state (with Michigan removed)



A random forest model was fit to determine which factors were useful in predicting PIP severity. Figure 33 shows the relative importance of our variables in predicting PIP severity. Percentage of drivers over 75, percentage of interstate rated mediocre or bad, and drivers per lane mile are some of the most important variables. Plots of some of these variables are in figures 35-37, where states are divided into PIP severity quintiles for each year, and the average of all states in a quintile is plotted for an explanatory variable. It seems that all three variables plotted below have a positive relationship with PIP severity.

Figure 34
PIP severity variable importance plot

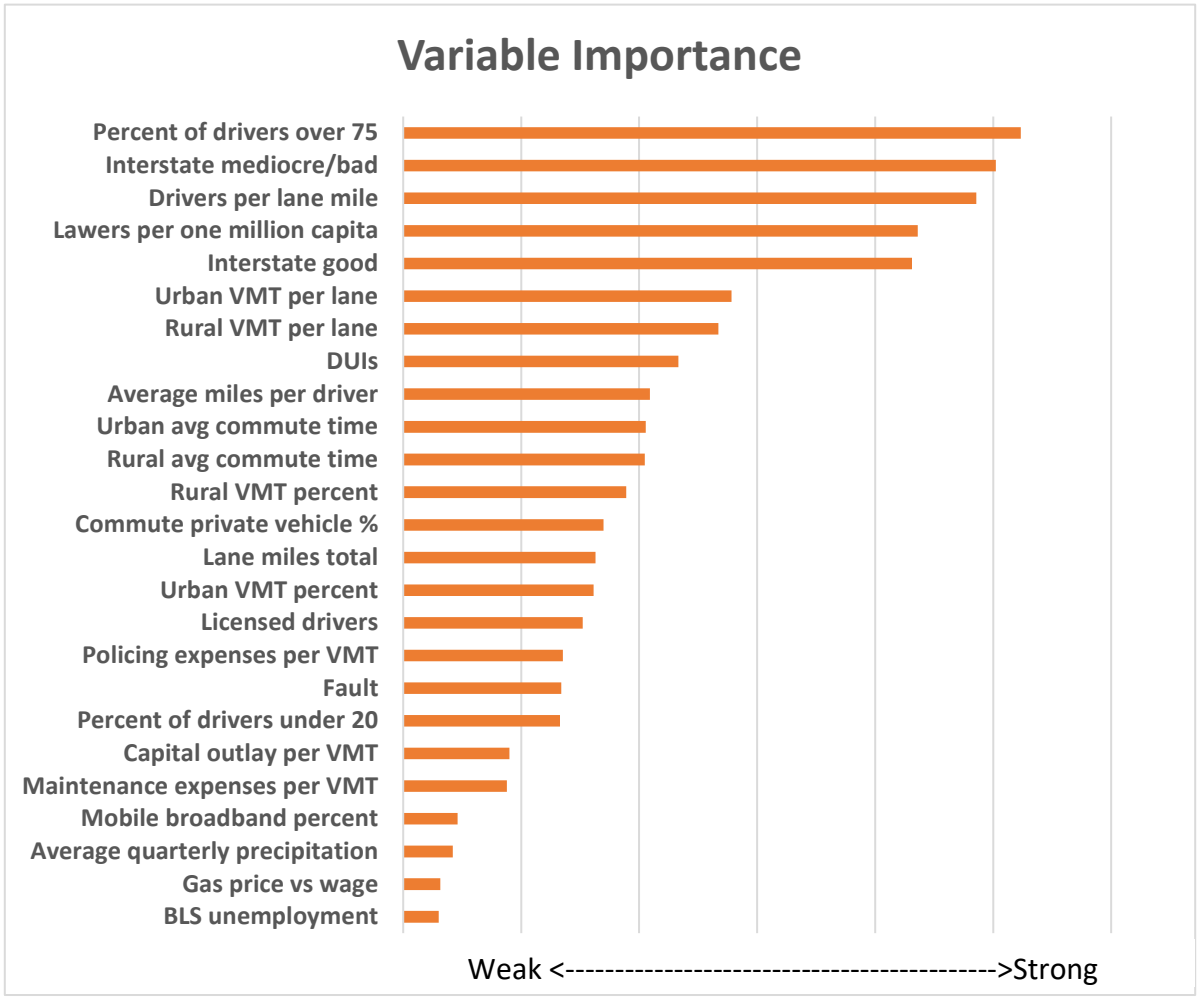


Figure 35
Average rural VMT grouped into quintiles by PIP severity

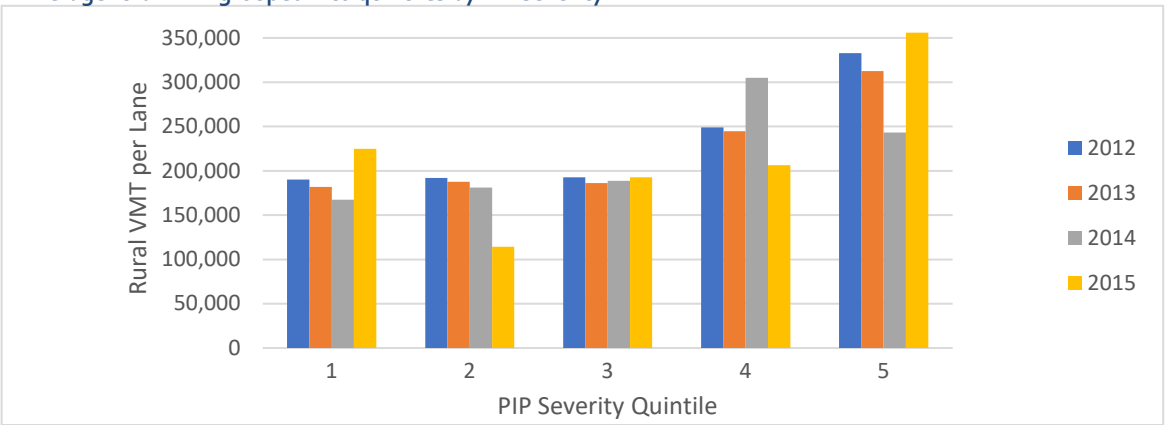


Figure 36
Percent of drivers over 75 grouped into quintiles by PIP severity

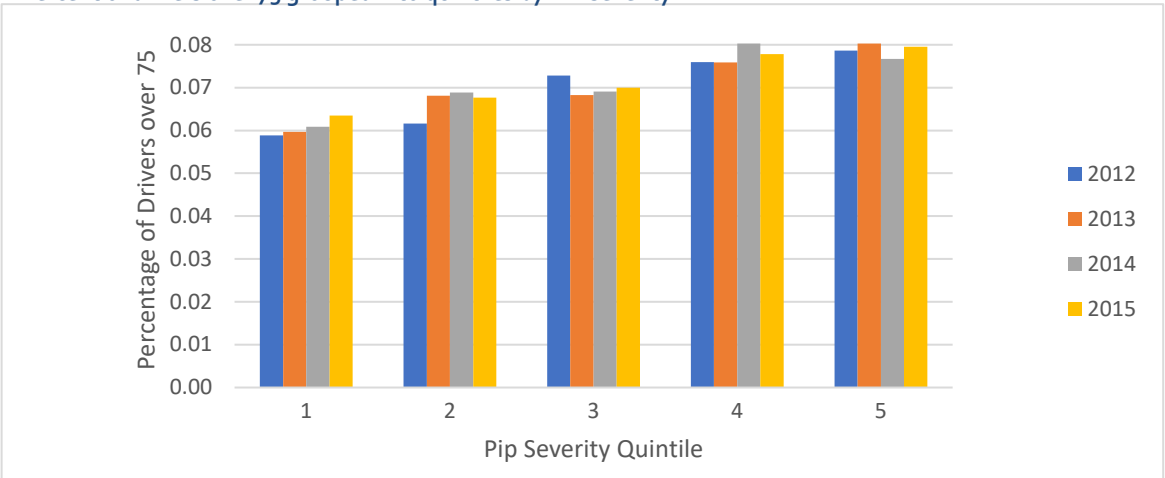
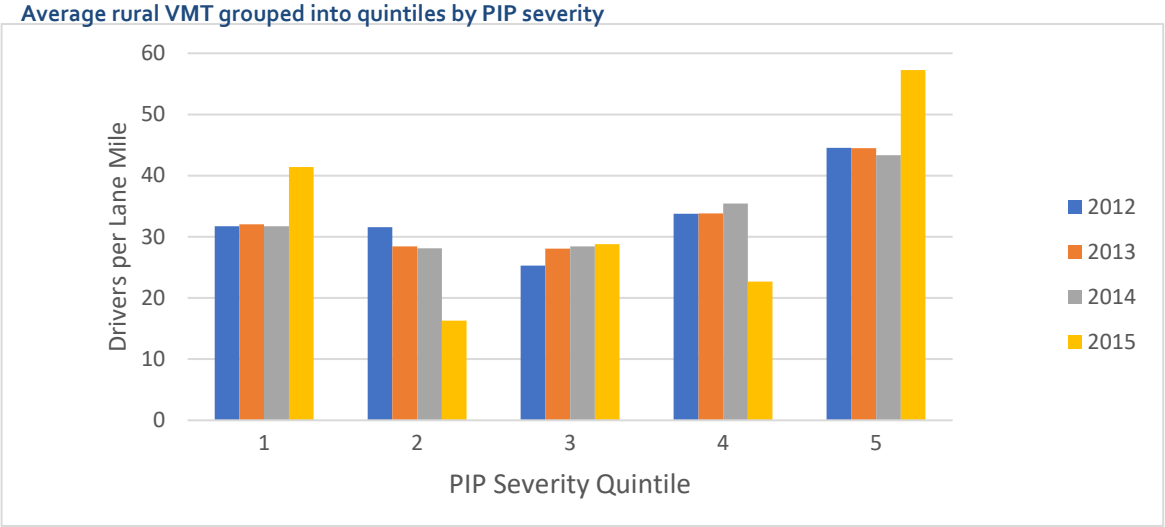


Figure 37
Average rural VMT grouped into quintiles by PIP severity



Percentage of drivers over 75

Percentage of drivers over 75 has a strong positive relationship with PIP severity. This trend is very consistent between states and is consistent across the years included our data. Figure 38 shows the relationship between percentage of drivers over 75 and PIP severity after accounting for the impact of other variables in the model. Figure 39 sorts the states by average PIP severity and displays the positive pattern in the percentage of drivers over 75.

Figure 38

Percentage of drivers over 75 added variable plot

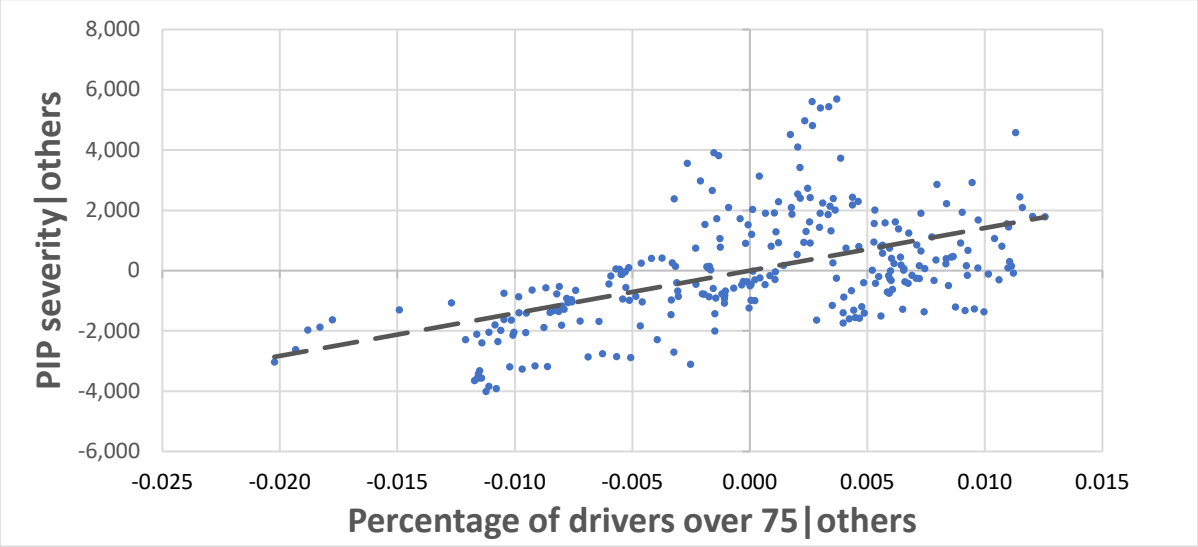
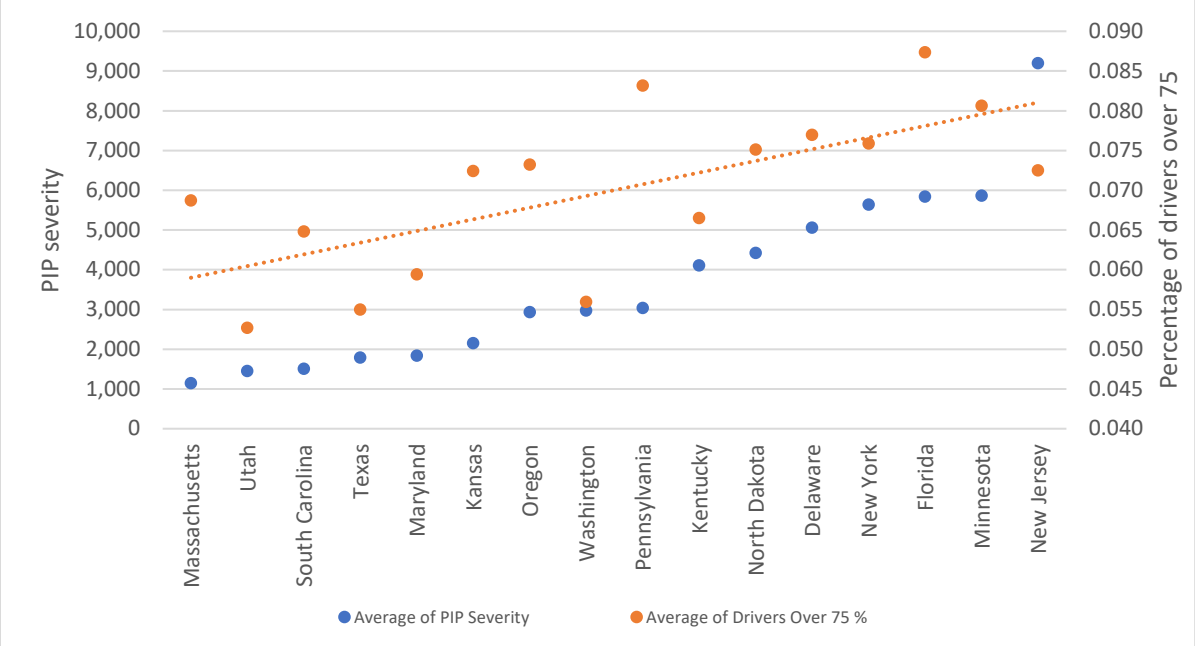


Figure 39

Percentage of drivers over 75 sorted by PIP severity



Interstate quality and urban VMT per lane

Percentage of interstate miles considered mediocre or bad and urban VMT per lane also have positive relationships with PIP severity. Because inflation drives PIP severity up, any variables that increase over time would have a positive relationship with PIP severity, but the percentage of interstate rated bad or mediocre has decreased over this time, and average urban VMT per lane has stayed relatively constant. Added variable plots for these factors are shown in figures 40 and 41.

Figure 40

Percentage of interstate rated bad or mediocre added variable plot

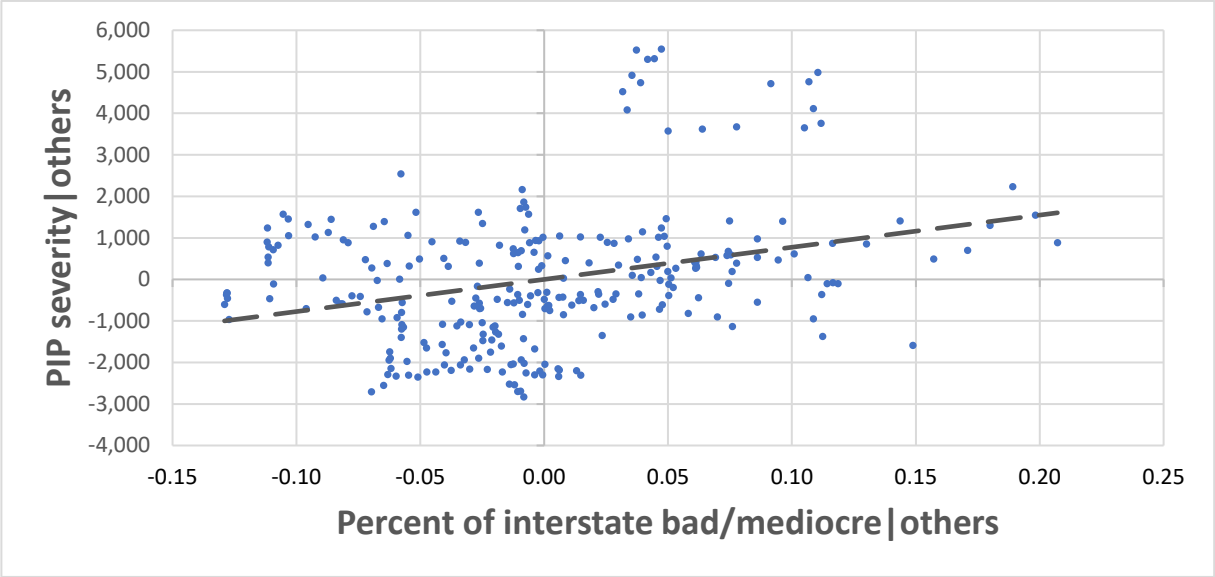
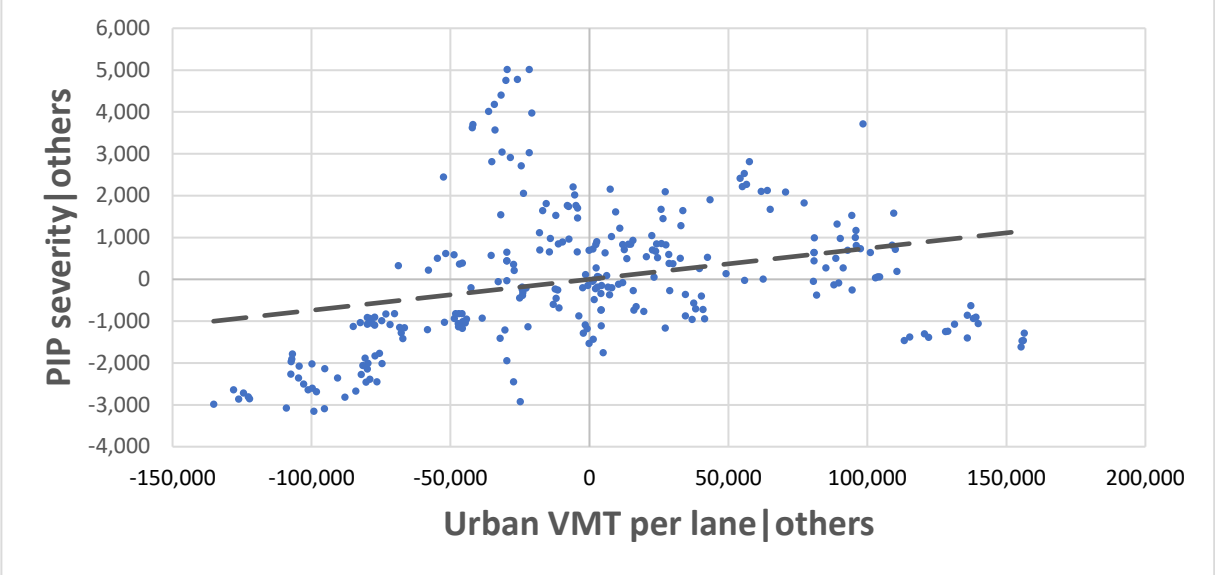


Figure 41

Urban VMT per lane added variable plot



Drivers per lane mile

The relationship between drivers per lane mile and PIP severity depends on what type of states you consider. Looking at all the states together, there seems to be a slight negative relationship (Figure 42). If you break up the states into those with a verbal threshold and those with a monetary threshold, then you see that drivers per lane mile has a negative relationship with PIP severity in monetary threshold states and a positive one in verbal threshold states.

Figure 42
Drivers per lane mile added variable plot (all states)

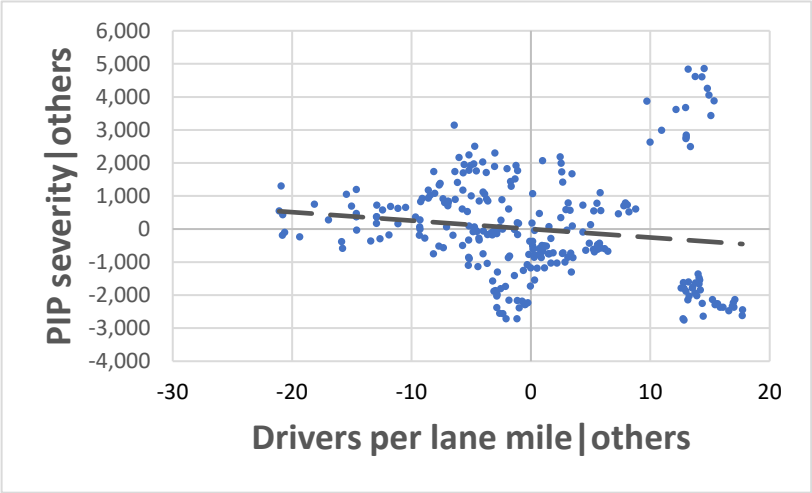


Figure 43
Drivers per lane mile added variable plot (monetary)

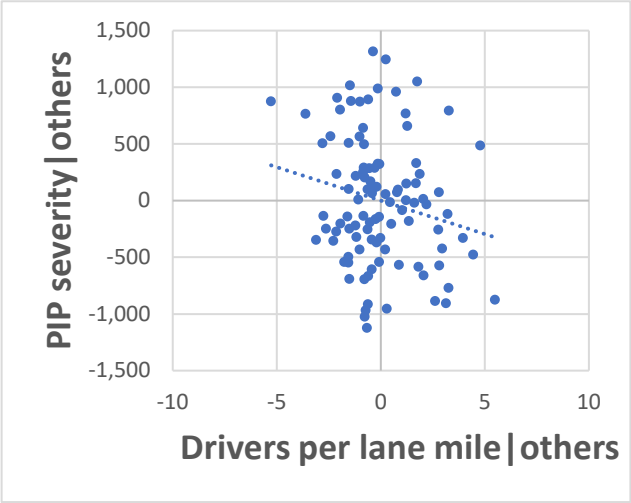
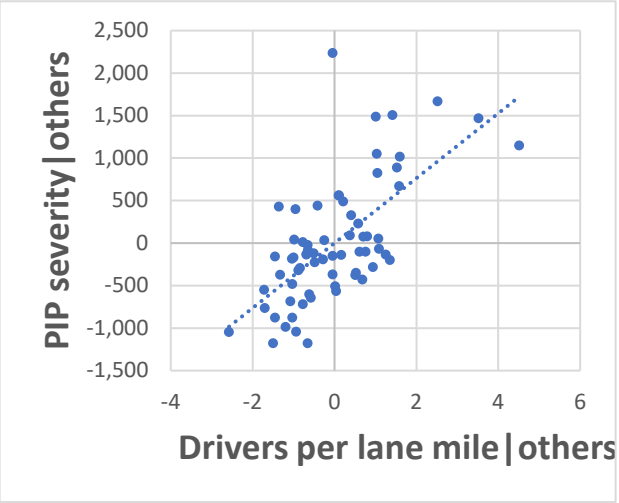


Figure 44
Drivers per lane mile added variable plot (verbal)



Conclusion

PIP claim frequency seems to have two main drivers. The first is the number of lawyers per capita in a state, which only appears to be an important factor in states that have verbal thresholds for lawsuits involving bodily injury claims. The other main factor (in all PIP states) is congestion, which consists of many factors including drivers per lane mile and rural vehicle mile traveled (among others). In most cases, as these factors increase, PIP claim frequency is expected to increase as well.

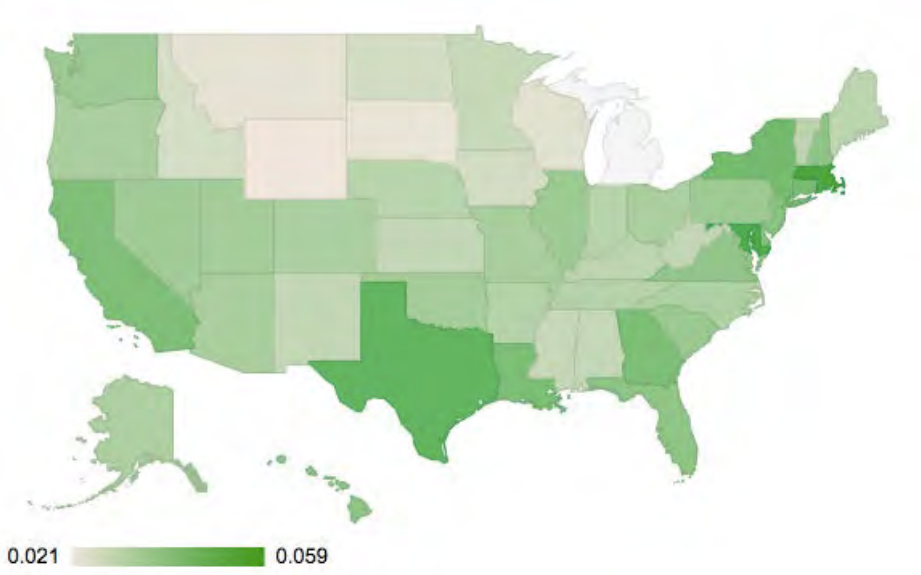
For states with similar regulations regarding PIP insurance, the age of the population has a large effect on severity. A state with a higher percentage of the population over 75 will have higher PIP severity on average. A state with worse interstate conditions will also have higher PIP severity on average, and more miles travelled in urban areas is correlated with higher PIP severity. More road congestion is correlated with higher PIP severity in verbal threshold states, and lower severity in monetary threshold states.

Property Damage Claim Frequency

Michigan

We have seen earlier in this report that Michigan auto insurance laws are significantly different from those of other states. Property damage insurance is no exception. Property damage insurance in Michigan covers damage to vehicles if and only if those vehicles are parked, and coverage that pays for damage to someone else's vehicle in an accident in which you are at fault is offered separately. This is different from all other states, including other no-fault insurance states. Most state laws have bodily injury coverage pay for damage to other vehicles, parked or involved in a collision, as well as damage to other types of property (fences, mailboxes, street lamps, etc.) The effect of this difference is that Michigan has far lower property damage frequency and severity (see Figure 45). This distorts our models if we leave it in by giving significance to variables that have unique values in Michigan. The rest of the analysis for property damage will proceed without Michigan.

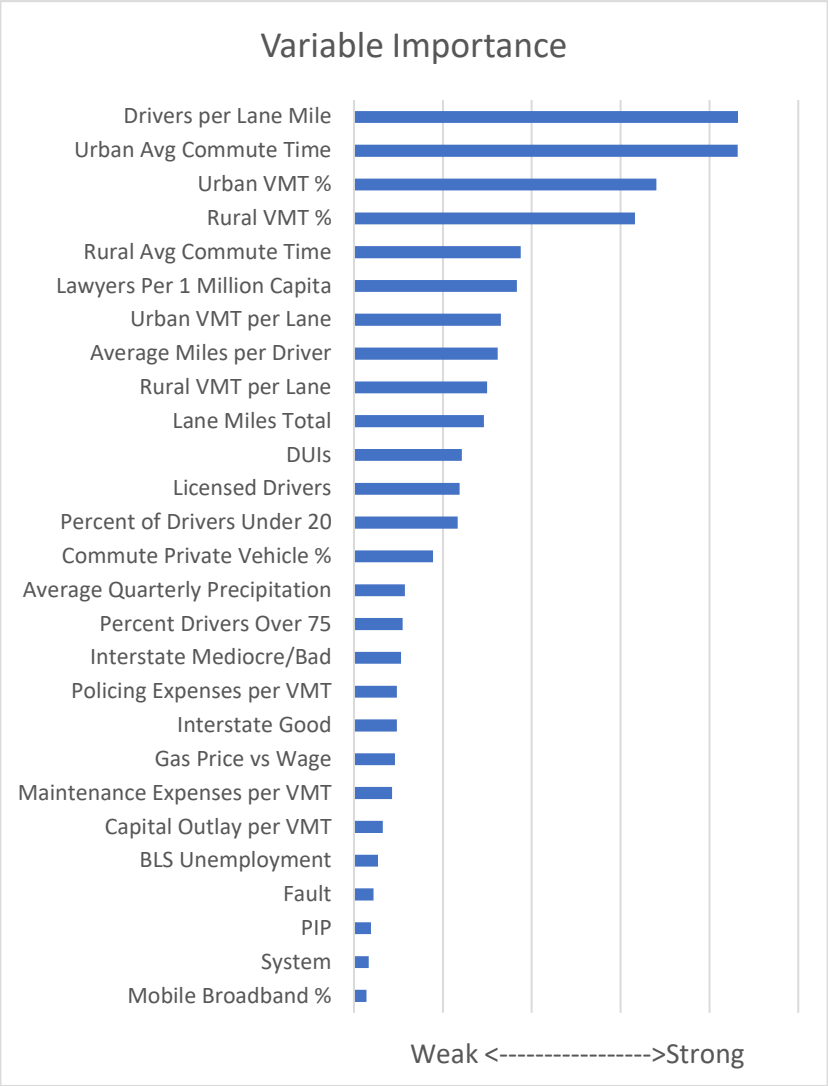
Figure 45
Average property damage claim frequency (claims per car year)



Important variables

As with the other analyses, a random forest model was fit to find variables that were useful in predicting property damage claim frequency, and Figure 46 shows the relative importance of the explanatory variables. Drivers per lane mile is most important, followed by urban average commute time, urban and rural VMT, rural average commute time, and lawyers per 1 million capita. These are some of the variables that we analyzed to determine their effect on bodily injury frequency.

Figure 46
Property damage claim frequency variable importance plot



Congestion variables

Drivers per lane mile has a clearly positive relationship with bodily injury frequency. The added variable plot in Figure 47 shows this relationship after accounting for variation due to other variables, and Figure 48 shows the state to state trend, and the relationship may be even clearer looking at it in this form. This relationship makes sense, more congested roads lead to more accidents involving two parties, and even small accidents without injuries can have property damage claims.

Figure 47
Drivers per lane mile added variable plot

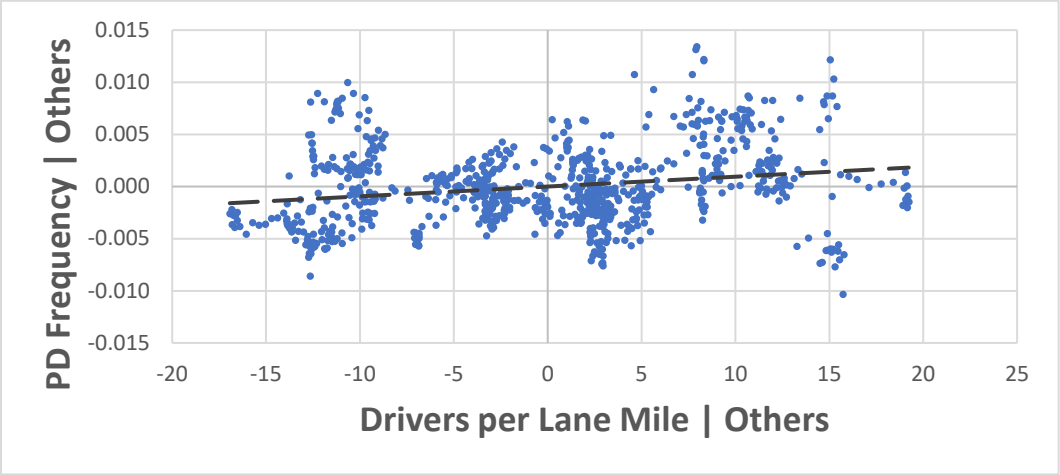
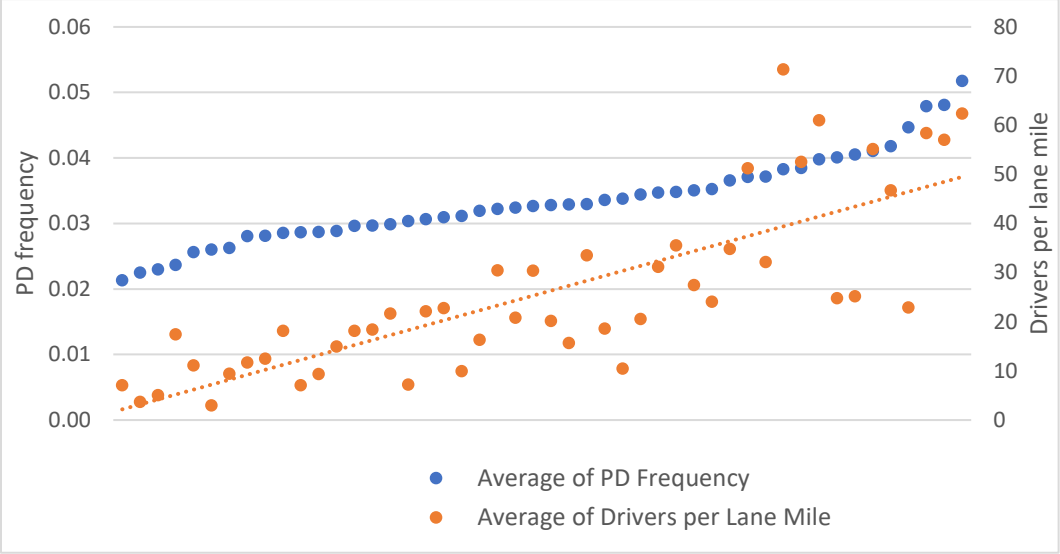


Figure 48
Drivers per lane mile sorted by PD frequency



Urban average commute time has no additional predictive ability after accounting for the other variables. The reason may be because this is somewhat of a congestion variable, and the other two congestion variables model the variation well. The other congestion variable in our model is rural VMT as a percentage of total VMT. An added variable plot (Figure 49) and a state to state comparison are below (Figure 50). Urban VMT also has a strong positive relationship with property damage frequency. These together tell us that road congestion is a main driver of property damage frequency. This is similar to what we found with collision insurance, which makes sense because they both cover damage to vehicles after collisions.

Figure 49
Urban VMT percent added variable plot

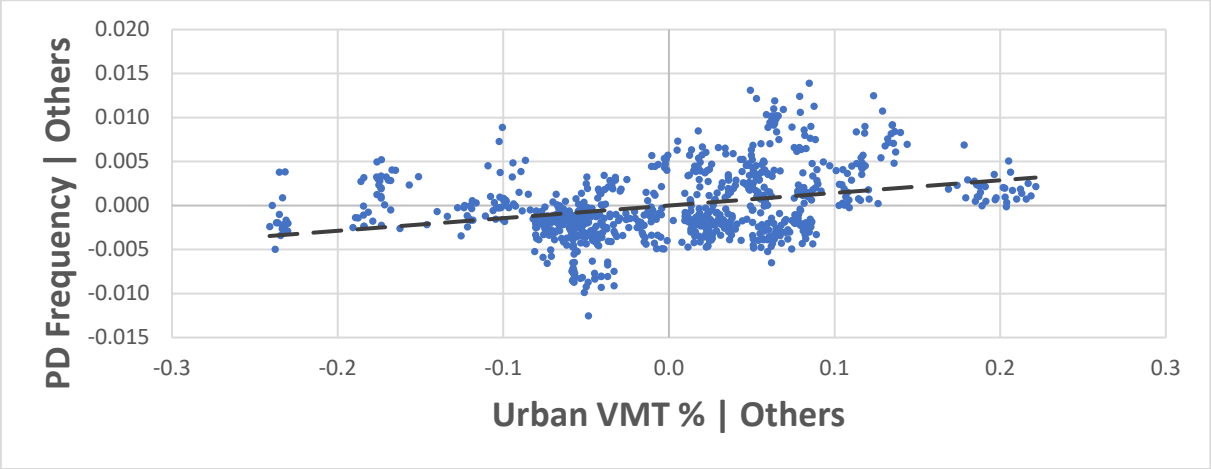
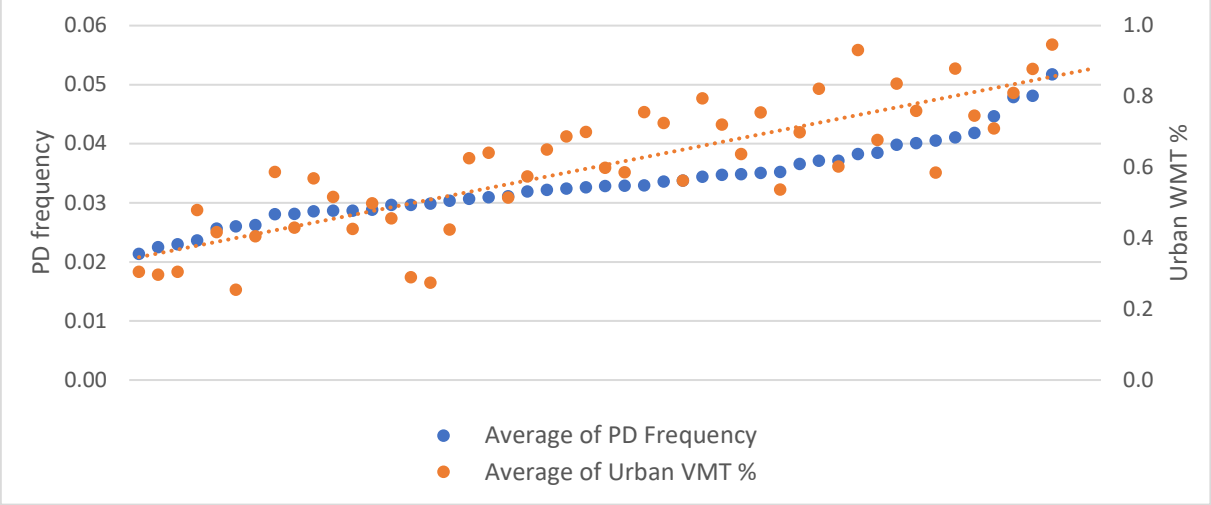


Figure 50
Urban VMT percent sorted by PD frequency (claims per car year)



Rural commute time and lawyers

Rural average commute time has a positive correlation with property damage frequency. It is interesting that this commute variable has a positive relationship while urban commute time had no effect. It could be that rural commute time gives an idea of how many people join the city traffic from afar during the busiest times for traffic. If that isn't the case, there is a less obvious reason for the effect it has on property damage frequency.

Figure 51
Rural average commute time added variable plot

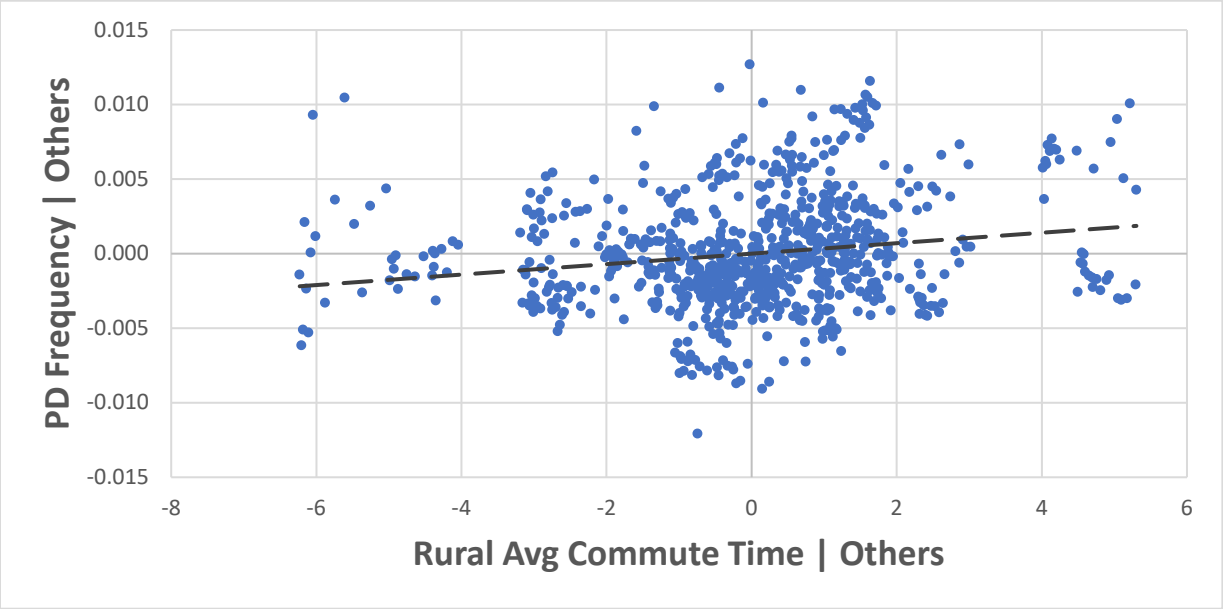
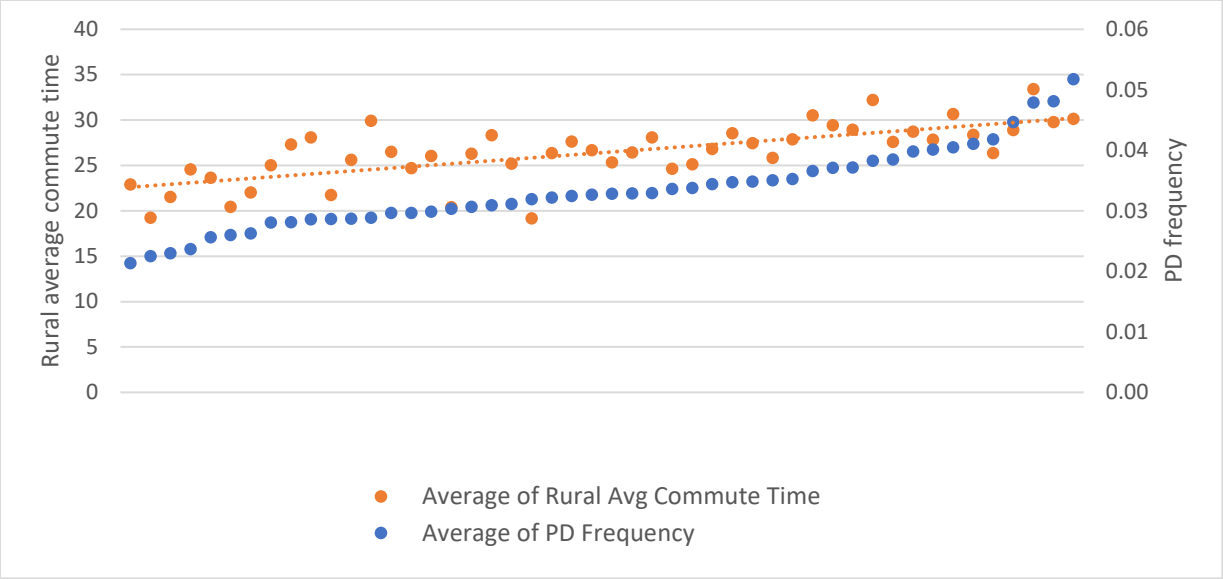


Figure 52
Rural average commute time sorted by PD frequency (claims per car year)



The other interesting relationship we see is with lawyers per million capita. There aren't many coverages where this has a significant impact, and we don't have a great explanation why it would have a big impact on this coverage in particular. The relationship is a positive correlation between the two. This is a coverage that can require a person to sue another party to get reparations, so maybe this is where the density of lawyers has an effect. It could also be that lawyers per million capita tends to be higher in more urban areas, in which case this would be another measure of population density.

Figure 53
Lawyers per 1 million capita added variable plot

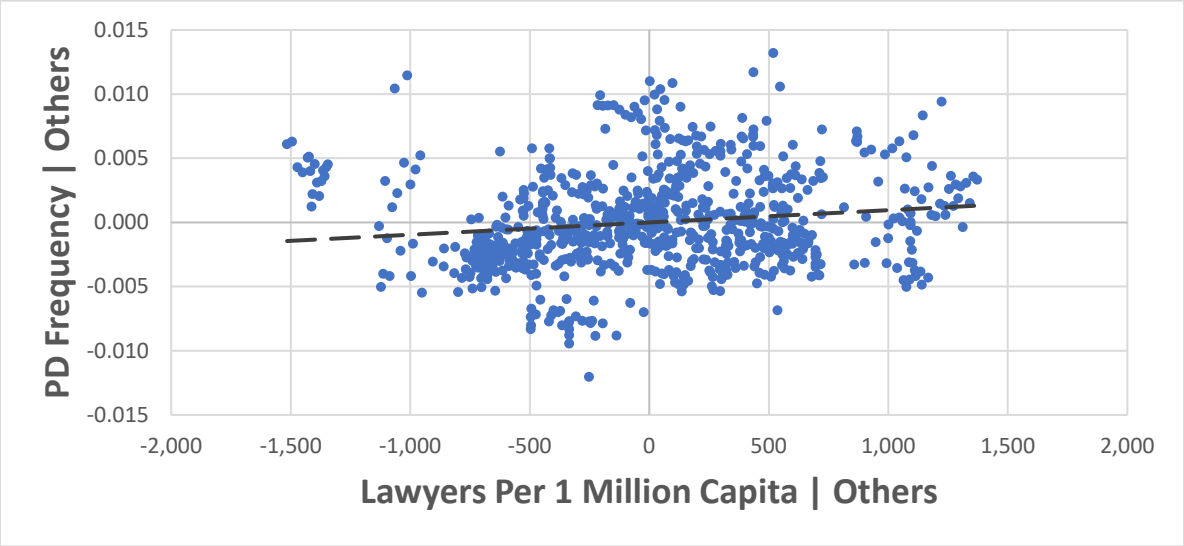
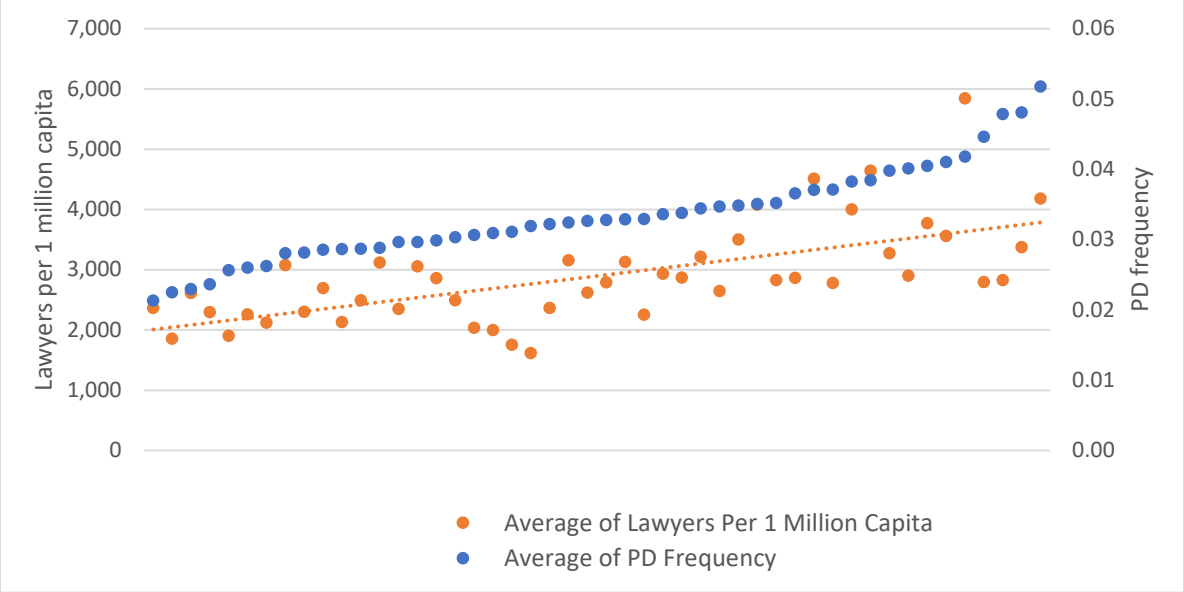


Figure 54
Lawyers per 1 million capita sorted by PD frequency



Property Damage Claim Severity

Variable importance

As with the rest of the coverages, a random forest model was used to find important variables in predicting property damage severity. Some of the most important variables, as seen in figure 55, are gas price vs. wage, mobile broadband percent, average miles per diver, and percentage of people who commute in a private vehicle. Of the top four variables, three of them appear to have little or no effect on property damage severity. Added variable plots for mobile broadband percentage, average miles per driver, and commute private vehicle percentage are seen in figure 56. The mostly flat lines tell us these variables don't add much in predictive ability.

Figure 55
Property damage severity variable importance plots

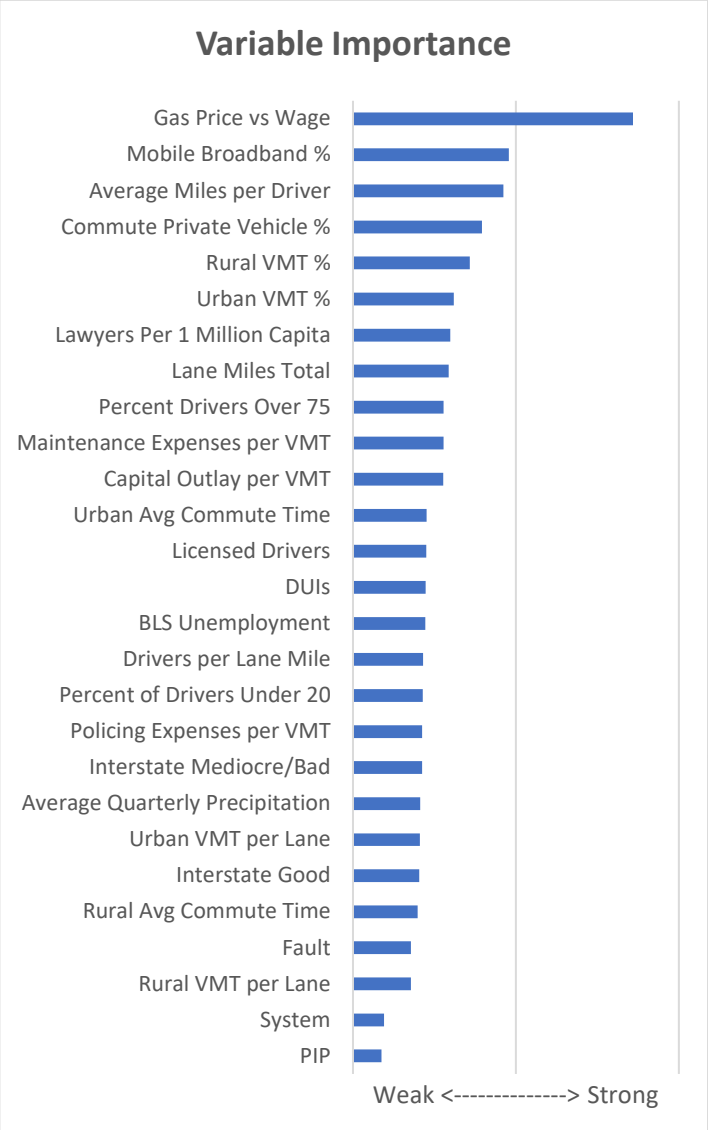
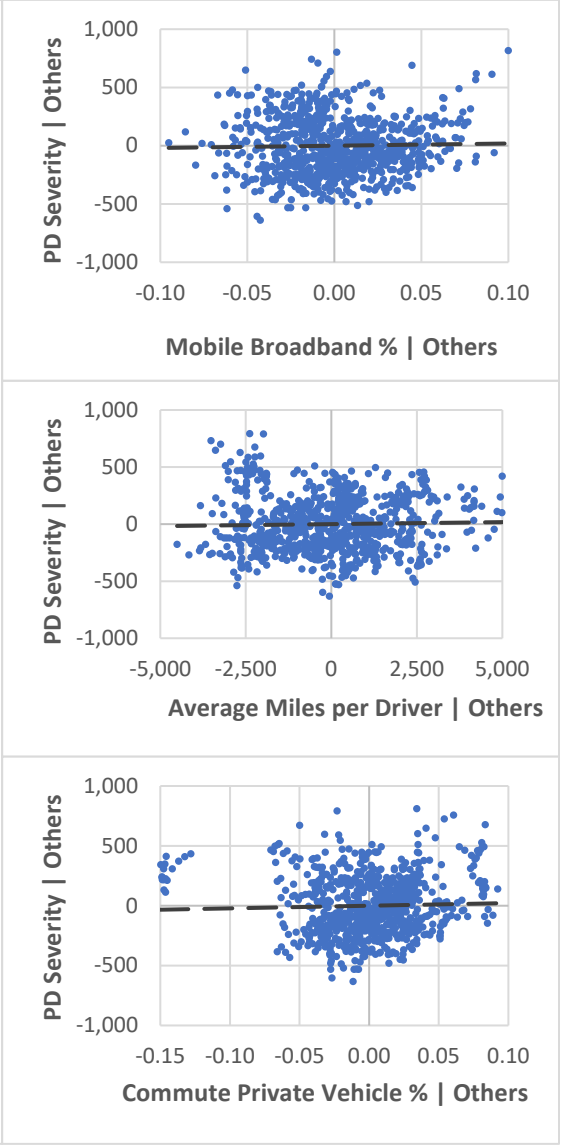


Figure 56
Added variable plots



Gas price vs wage

Gas price vs wage is the one variable among the top six most important variables that actually appears to have some ability to predict property damage severity. Figure 57 is as added variable plot that shows the negative relationship between the two in our data. Digging deeper into the data shows that there are maybe two parts to this relationship. Figure 58 is a plot of both the average property damage severity and gas price vs wage across time. As with the severity of other coverages, there appears to be an inflationary trend, and at the same time the gas price vs wage decreased from 2013 to 2015. Since we expect this inflationary trend in severity, the relationship between severity and any variable that is steadily increasing or decreasing becomes suspect. We also see a slight negative trend in the state to state plot in figure 59, which should not be affected by the inflationary trend. This tells us it is possible that there is a true negative correlation between gas price vs wage and property damage severity.

Figure 57
Gas price vs. wage added variable plot

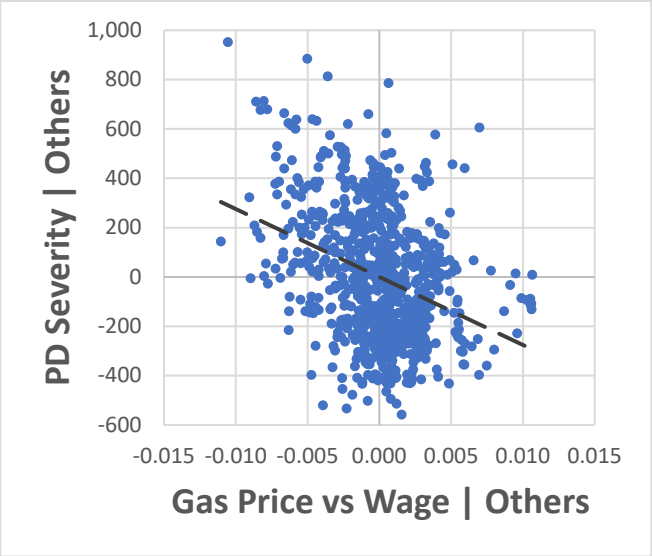


Figure 58
Gas price vs. wage and PD severity by quarter

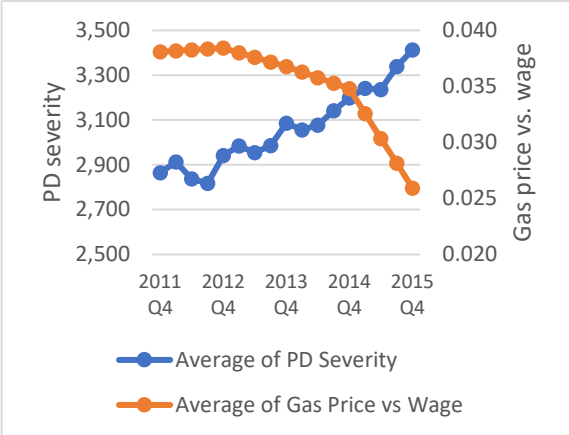
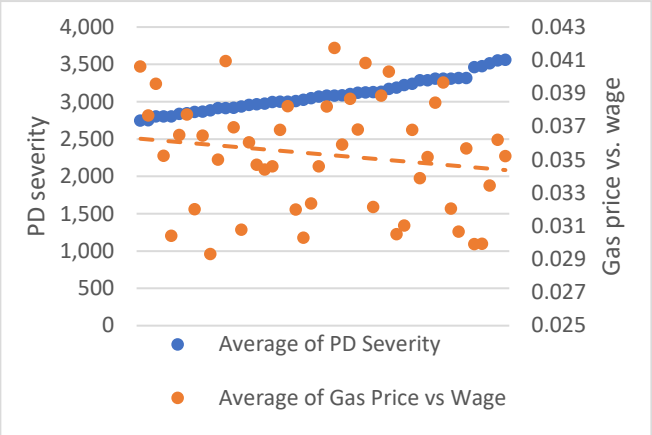


Figure 59
Gas price vs. wage and PD severity by state



Conclusion

Property damage frequency has a positive relationship with many congestion variables, as well as rural average commute time and lawyers per million capita. Property damage severity, after taking out Michigan, has a possible negative relationship with gas price vs wage, but none of our other variables seem to have a substantial impact on it.