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The Effects of Interstate Speed Limit Increases: Fatality Rates and Traffic Diversion Versus Speed Spillover

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by

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Abstract

This thesis examines two panel data sets of 48 states from 1981 to 2009 and utilizes ordinary least squares (OLS) and fixed effects models to explore the relationship between rural Interstate speed limits and fatality rates and whether rural Interstate speed limits affect non-Interstate safety. Models provide evidence that rural Interstate speed limits higher than 55 MPH lead to higher fatality rates on rural Interstates though this effect is somewhat tempered by reductions in fatality rates for roads other than rural Interstates. These results provide some but not unanimous support for the traffic diversion hypothesis that rural Interstate speed limit increases lead to decreases in fatality rates of other roads. To the author's knowledge, this paper is the first econometric study to differentiate between the effects of 70 MPH speed limits and speed limits above 70 MPH on fatality rates using a multi-state data set. Considering both rural Interstates and other roads, rural Interstate speed limit increases above 55 MPH are responsible for 39,700 net fatalities, 4.1 percent of total fatalities from 1987, the year limits were first raised, to 2009.

I. Introduction

Speed limit laws tangibly and routinely affect the daily lives of citizens across the United States. These measures help determine the amount of time Americans spend driving rather than participating in productive or leisurely activities. In addition, police forces must keep speed limits in mind to determine appropriate speeding enforcement mechanisms and funding. Speed limits can also impact fuel consumption. Forester, McNown, and Singell (1984) estimate that the U.S. National Maximum Speed Limit (NMSL) of 55 MPH saved 600 million gallons of gasoline yearly. Perhaps most importantly, speed limits exist mainly to ensure motorist safety. Lower speed limits intuitively would seem to reduce the risk of accidents and associated fatalities. This thesis examines two panel data sets of 48 states from 1981 to 2009 and utilizes ordinary least squares (OLS) and fixed effects models to explore the relationship between rural Interstate speed limits and fatality rates and whether rural Interstate limits affect non-Interstate safety. These models provide evidence that speed limits higher than 55 MPH lead to higher fatality rates on rural Interstates though this effect is somewhat tempered by reductions in fatality rates for roads other than rural Interstates.

II. Literature Review

Widespread speed limit laws have existed in the United States for over a century. According to the Insurance Institute for Highway Safety, states began to set speed limits in 1901. Speed limits remained within the control of the states until World War II. From

1942 to 1945, the War Department maintained a national speed limit of 35 MPH to save gasoline and rubber for war purposes. After the war, the states regained authority over speed limit legislation until fuel resource concerns arose once again in the 1970s. Under pressure during the Arab oil embargo of 1973, Congress declared the National Maximum Speed Limit (NMSL) of 55 MPH in the name of fuel conservation. Congress directed the Department of Transportation to withhold highway funds from any state that did not enact a maximum limit of 55 MPH within 60 days. This measure went into effect when President Richard Nixon signed the Emergency Highway Energy Conservation Act on January 2, 1974. Before the establishment of the NMSL, many state highway limits ranged from 65 to 75 MPH. However, all states had a uniform maximum speed limit of 55 MPH by March 4, 1974, the date which non-compliant states would have faced sanctions for ignoring the NMSL. Public law 93-643, signed January 4, 1975, made the NMSL permanent. The NMSL persisted until Congress passed the Surface Transportation and Uniform Relocation Assistance Act (STURAA) of 1987, allowing states to increase rural Interstate speed limits to 65 MPH. Decreasing oil prices in the 1980s paved the way for this policy. 38 states increased rural highway speed limits to 65 MPH by the end of 1987, with 4 more states joining this group by 1993. President Bill Clinton signed the National Highway Designation Act on November 28, 1995, fully conferring speed limit determination to the states. Table A-1 lists speed limit law changes in the United States. By the end of 1996, 13 states had established a maximum speed limit of 70 MPH, with 11 other states allowing speed limits of 75 MPH. A total of

32 states increased speed limits in some form by the end of 1996. Today, no state retains a maximum rural Interstate speed limit of 55 MPH.

Speed limits impact the average speed of motorists on several types of roadway, including rural Interstates. Unsurprisingly, a lower speed limit leads to slower vehicle speeds. Clotfelter and Hahn (1978) find that average vehicle speeds on U.S. rural highways decreased from 65 MPH to 57 MPH from 1973 to 1974. Forester, McNown, and Singell (1984) examine data from 1952 through 1979, noting that average speeds decreased 4.8 MPH due to the NMSL. Though the NMSL did lower average vehicle speeds, Meier and Morgan (1982) estimate that 54 percent of vehicles exceeded the speed limit in 1979. As expected, vehicle speeds rise along with increased speed limits. Ashenfelter and Greenstone (2002) observe that speeds increased 3.5 percent in 21 states that raised rural Interstate speed limits to 65 MPH after the passage of STURAA. Moreover, median rural Interstate speeds in New Mexico increased by 3 to 4 MPH in the year after the state established a rural highway speed limit of 65 MPH, according to Gallaher et al. (1989). Knowing that speed limits directly influence vehicle speeds, many scholars have analyzed fatality data to determine if higher speed limits then lead to more motor vehicle deaths.

Shifts in maximum speed limits on rural Interstates in the United States have allowed scholars to evaluate a possible link between speed limit changes and road fatalities, both on Interstate and non-Interstate roadways. Studies of the relationship between speed limits and fatalities can generally be categorized chronologically. Reports examine the impact of the uniform NMSL of 55 MPH after 1974, increases to 65 MPH speed limits after the passage of STURAA in 1987, and further increases in speed limits after the NMSL was completely repealed in 1995. Some scholars focus on specific states while other individuals explore aggregated data from many states. Although lower speed limits would seem to promote greater safety, the literature does not reflect complete agreement on this issue. Table 1 presents key findings from the literature spanning across the three periods of major speed limit changes: post-1974, post-1987, and post-1995. In general, scholars do find a link between raised speed limits and fatalities, though there are several exceptions.

Several NMSL studies examine the 55 MPH speed limit with cost-benefit analysis. Clotfelter and Hahn (1978) identify reduced property damage, gasoline saved, and fatalities and injuries averted as advantages of the NMSL. In fact, Interstate fatalities dropped by 16.4 percent from 55,087 in 1973 to 46,049 in 1974. Clotfelter and Hahn also point out time, compliance, and enforcement costs associated with the NMSL. Overall, Clotfelter and Hahn value benefits of the NMSL at $4.4 to $5.21 billion against $2.89 to $3.96 billion in costs. The Transportation Research Board (1984) estimates that the NMSL saved $2 billion in fuel costs, $65 million in tax payment, and 2,000 to 4,000 lives each year. However, the government agency also determines that the 55 MPH speed limit cost 1 billion extra driving hours and $118 million in enforcement spending yearly. Kamerud (1988) considers similar implications of the NMSL, including reduced vehicle wear and higher productivity due to fewer motor vehicle injuries, to determine the cost per life saved by the 55 MPH speed limit. This cost was greatest on rural Interstates compared to other road types, at $4 to $9 million per life saved. Kamerud, then, supports raising maximum rural Interstate speed limits. Forester, McNown, and Singell (1984) find that the NMSL lowered fatalities by 7,466 per year using data from 1952 to 1979. Though Forester, McNown, and Singell identify a tangible safety advantage of the 55 MPH speed limit, they ultimately conclude that the costs of the NMSL outweighed benefits. Finally, Yowell (2005) determines that the NMSL initially led to a decline in highway deaths per mile driven, but the long-term trend in fatalities persisted after adjustment. While many scholars do find that the NMSL reduced vehicle fatalities, support for the NMSL is not uniform across researchers.

Other speed limit fatality studies analyze state increases from the NMSL to 65 MPH limits on rural Interstates in the late 1980s. Ashenfelter and Greenstone (2002) focus on 21 states that raised the rural highway speed limit to 65 MPH and identify a 35 percent fatality increase in these states. Even so, the 65 MPH speed limit saved 125,000 hours and $1.54 million in 1997 dollars per additional Interstate death. Balkin and Ord (2001) point out that rural highway fatalities rose in some states, but this trend was not uniform as Interstate deaths increased in just 19 out of 40 studied states due to higher speed limits. Garber and Graham (1990) find a median 15 percent increase in rural Interstate fatalities associated with the 65 MPH limit, using a data set of 40 states. Considering national data from 1981 to 1995, Houston (1999) recognizes that speed limit increases led to more danger on rural highways. Chang, Chen, and Carter (1993) study January 1975 to December 1989 fatality data. Nationwide highway fatalities significantly increased after states implemented 65 MPH speed limits, but this trend lessened after a one year “learning period.” On a state level, small states that set 65 MPH speed limits on rural Interstates generally experienced greater fatality rates than larger states with speed limit increases. Baum, Lund, and Wells (1989) compare state rural interstate fatality data in individual months after implementation of the 65 MPH speed limit to the same months of 1982 through 1986. Deaths were 15 percent higher in states that raised speed limits to 65 MPH than predicted fatality values had the NMSL persisted in these states. On the other hand, states that kept maximum speed limits at 55 MPH experienced 6 percent fewer fatalities than Baum, Lund, and Wells predicted.

On top of these multi-state studies, some scholars focus on specific states. Gallaher et al. (1989) notes safety drawbacks of New Mexico's 1987 increase to a 65 MPH speed limit. In the year after the implementation of the new limit, there were 2.9 fatal crashes per 100 million vehicle-miles traveled, exceeding a projected value of 1.5 fatal crashes per 100 million vehicle-miles traveled extrapolated from a five year trend of vehicle deaths before the speed limit change. Wagenaar, Streff, and Schultz (1990) determine that the 65 MPH speed limit in Michigan caused a 19.2 percent increase in rural Interstate fatalities, a 39.8 percent increase in serious injuries, and a 25.4 percent increase in moderate injuries. Rock (1995) attributes 345 additional rural accidents with 15 more deaths and 150 more injuries per month in Illinois to the 65 MPH speed limit beginning in 1987. Once again, most but not all studies find a positive link between raising speed limits and higher fatalities.

Finally, many papers explore the possible relationship between speed limits and fatalities after the passage of the National Highway Designation Act in 1995. The National Highway Traffic Safety Administration (1998) finds that states which raised speed limits in 1996 experienced 350 highway deaths above historical trend predictions. These additional fatalities cost $820 million per state in 1996 dollars. Friedman, Hedeker, and Richter (2009) examine fatalities and injuries in fatal accidents from 1995 to 2005 on rural interstates. Speed limit increases led to a 9.1 percent rise in fatalities and a $12 billion cost over the time period studied. In turn, Friedman, Hedeker, and Richter recommend that lower speed limits once again should be implemented on rural Interstates. Farmer, Retting, and Lund (1999) determine that fatalities increased 17 percent in 24 states that raised speed limits in the mid 1990s controlling for vehicle miles of travel. Using a data set from 1992 through 1999, Patterson et al. (2002) posits that states which increased speed limits to 70 MPH and 75 MPH experienced 35 percent and 38 percent higher fatalities than predicted values compared to states with constant maximum speed limits. Balkin and Ord (2001) identify only 10 states with significant road fatality increases out of 36 states that raised speed limits, a similar outcome as Balkin and Ord determine for the 1987 changes. Yowell (2005) fails to find a strong link between speed limits and fatality rates given data from states which increased speed limits after the repeal of the NMSL in 1995. On the other hand, the Transportation Research Board (1998) recognizes that higher Interstate speed limits do raise fatality rates on rural highways but hesitates to reach a conclusion about how higher rural highway limits affect the safety of the entire traffic system.

Again, some papers examine individual state speed limit increases as well. Jehle et al. (2010) examine the effect of the 65 MPH speed limit in New York and actually find that fatalities and fatality rates declined after the state instituted a 65 MPH speed limit in

1995. Moreover, vehicle miles traveled increased on interstates. Jehle et al. attribute the reduction in fatalities to a decrease in speed variance brought about by the more appropriate limit of 65 MPH for most stretches of New York rural Interstates with high design speeds. After Alabama's increase to a 70 MPH maximum speed limit in May 1996, the state experienced significantly more interstate fatalities in 1997 and 1999 but a decline in deaths in 1998 according to Bartle et al. (2003). Iowa experienced a 20 percent increase in state-wide fatal accidents and a 57 percent increase in deaths on rural Interstates due to a maximum speed limit change to 65 MPH in 1996 according to Ledolter and Chan (1996). Despite these foreboding figures, the speed limit increase had no effect on major-injury accidents in Iowa. Similar to the previous groups of studies, scholars roughly report that post-1995 speed limit increases led to more fatalities.

Two competing hypotheses describe the possible effects of raised Interstate speed limits on the rest of the traffic system: traffic diversion and speed spillover. According to the traffic diversion hypothesis, high speed limits on Interstates attract risky drivers, drawing these people away from other roads. Non-Interstates would then become safer. On the other hand, the speed spillover hypothesis stipulates that drivers are likely to maintain higher speeds after exiting Interstates with raised speed limits. High speeds on these roads in turn cause more accidents. Of course, these ideas are not mutually exclusive. Therefore, the net impact of traffic diversion and speed spillover determines the relationship between Interstate speed limits and non-Interstate deaths, as noted by Garber and Graham (1990). Evaluation of the interplay between traffic diversion and speed spillover using national models is mixed. Garber and Graham (1990) focus on the effect of rural Interstate speed limit increases to 65 MPH on rural non-Interstate fatalities. In most states which raised rural Interstate speed limits to 65 MPH, speed spillover dominates traffic diversion, leading to a median 5 percent increase in rural non-Interstate fatalities. Lave and Elias (1994) believe that the NMSL caused a misallocation of police and driver resources, focusing enforcement on rural Interstates even though these roads are the safest functional class and redirecting drivers away from rural Interstates. With a 65 MPH limit, state officers would be less likely to target speeding on rural Interstates and could concentrate on making the entire traffic system safer. Using state-by-state regression analysis, Lave and Elias estimate that the statewide fatality rate on all roads decreases by an average of 3.43 percent with an increase to a 65 MPH speed limit, supporting the traffic diversion hypothesis. Greenstone (2002) reproduces the main regression model used by Lave and Elias with slightly different data but determines that speed limit increases did not significantly affect statewide fatality rates. Rejecting the police and driver reallocation theories, Greenstone simply finds that fatality rates on rural Interstates increase with a 65 MPH maximum limit compared to 55 MPH. Houston (1999) utilizes four fixed effects models of fatality rates of all 50 states from 1981 to 1995. Though Houston finds a positive relationship between the 65 MPH rural Interstate speed limit and rural Interstate fatality rate, three other models provide evidence for the traffic diversion hypothesis. 65 MPH rural Interstate speed limits are negatively associated with fatality rates on rural non-Interstate roads, all roads other than rural Interstates, and all roads, respectively. On the other hand, Grabowski and Morrisey (2007) conclude that the repeal of the NMSL caused a 7 percent to 11 percent increase in rural non-Interstate fatalities and that rural Interstate speed limit increases did not significantly decrease vehicle miles traveled on rural non-Interstate roads.

Other studies focus on traffic diversion versus speed spillover for individual states. Using California accident data covering 1981 to 1989, McCarthy (1994) fails to find a significant effect of the 65 MPH rural Interstate speed limit on highway safety of the state traffic system as a whole. Rock (1995) determines that the Illinois 65 MPH speed limit instituted in 1987 raised accidents on 55 MPH roads, even though vehicle miles traveled data indicate some traffic diversion. Wagenaar, Streff, and Schultz (1990) examine Michigan accident data from January 1978 to December 1988, finding some evidence for speed spillover from 65 MPH Interstates to roads with a 55 MPH speed limit. Finally, Kockelman (2006) uncovers small to negligible speed spillover effects at local sights in Washington State. Table 2 lists results from studies involving speed spillover and traffic diversion.

Several speed limit papers utilize econometric models. Garber and Graham's 40-state study is based on a multiple regression model of monthly time series data for each state from January 1976 to November 1988. The dependent variable of the study is monthly fatalities, derived from the Fatal Accident Reporting System (FARS), also known as the Fatality Analysis Reporting System. Models are constructed with time series data for each state, including a 65 MPH dummy variable which equals 1 for any month in which the state maximum rural Interstate speed limit was 65 and 0 otherwise. Other independent variables include seasonally unadjusted state unemployment rates scaled from 1 to 100, measures of the number of Fridays, Saturdays, and Sundays in each month to control for alcohol trends, a linear time trend, and a dummy variable which equals 1 for months in which a seat belt law was in effect. For ease of comparison across states, the dependent fatality variable is scaled logarithmically in some models. As previously mentioned, Garber and Graham find an increase to a 65 MPH maximum rural Interstate limit is associated with fatality increases on both rural Interstates and rural non-Interstates. Lave and Elias (1994) build on Garber and Graham's methodology by using the same independent variables in their models. Instead of focusing on fatalities from specific functional classes of roads, Lave and Elias use statewide fatality rate for all roads, fatalities divided by vehicle miles of travel. Lave and Elias also construct a model with the log of fatality rate as the dependent variable using data combined from all states. Once again, the models used by Lave and Elias support the traffic diversion hypothesis. Dee and Sela (2003) use a panel data set of the 48 continental states from 1982 to 1999. Since this time period covers several years after the NMSL was repealed, Dee and Sela include a dummy variable for maximum speed limits 70 MPH and above along with the 65 MPH variable. Using a different convention than the earlier studies, speed limit dummy variables equal the fraction of the year in which the given speed limit was in effect. Dee and Sela also utilize a different fatality rate, fatalities divided by 100,000 population. For each model, the natural log of this fatality rate is the dependent variable. Independent variables other than the speed limit indicators are seat belt law dummy variables, state unemployment rate, three drunk-driving law dummy variables, and fixed effects for state and year. The seat belt variables control for primary and secondary seat belt laws, respectively, while the drunk-driving variables cover a state's ability to suspend a driver's license for drunk driving prior to court action, .10 blood alcohol content (BAC) per se laws, and .08 BAC per se laws. Overall, Dee and Sela conclude that the overall effect of speed limit increases on fatality rates is not highly significant. Finally, Grabowski and Morrisey (2007) utilize a 1982-2002 state-year panel data set to study the effect of rural Interstate speed limit increases on fatalities and vehicle miles traveled. The study includes models with fatality dependent variables for all roads in a state and for different functional classes of roads as well as models with the natural log of vehicle miles traveled as the dependent variable. Independent variables are similar to previous studies, with a 65 MPH dummy variable, 70 MPH or above dummy variable, several control variables, and fixed effect variables for state and year. Grabowski and Morrisey determine that rural Interstate speed limit increases caused fatalities to rise on rural Interstates and rural non-Interstate roads and find no evidence that rural Interstate speed limit increases caused a shift of vehicle miles traveled from other roads to rural Interstates.

III. Data and Empirical Methods

The data for this paper are derived from several U.S. government sources and the Insurance Institute for Highway Safety. Data cover the time period 1981 to 2009 for all states excluding Delaware and Hawaii. FARS Encyclopedia coding for roadway function class, the variable used to determine whether an accident is on a rural Interstate or other road, begins in 1981. No roads are currently classified as rural Interstates in Delaware, and Hawaii is the only state with a 60 MPH maximum rural Interstate speed limit.

Dummy variables exist for four levels of state maximum rural Interstate speed limits: 65 MPH, 70 MPH, 75 MPH, and above 75 MPH, expanding on previous econometric papers which only use two dummy variables for speed limits. To the author's knowledge, this paper is the first econometric study to differentiate between the effects of 70 MPH speed limits and speed limits above 70 MPH on fatality rates using a multi-state data set. Seat belt law and blood alcohol concentration (BAC) limit variables control for the effects of these safety laws on fatality rates. Both the speed limit and safety dummy variables follow the same convention regarding time periods of policy change. A variable of a given law equals the proportion of the time period in which the policy in question was in effect, a method used by Dee and Sela (2003). For instance, a state's yearly 70 MPH speed limit variable would equal .5 if a 70 MPH speed limit were enacted in the state on July 1. Similarly, a state's monthly seat belt law variable for April would equal .2 if the law were enacted in the given state on April 25. Finally, models also include a yearly time trend, month dummy variables, and state dummy variables. Tables 3a and 3b list variable definitions and means for monthly and yearly data, respectively. Stata is used for data compiling and regressions.

The dependent variables are fatality rate per 100,000 population in a state and fatality rate per 100 million vehicle miles traveled in a state for monthly and yearly models, respectively. The population fatality rate is also used by Dee and Sela (2003). While the FHWA's Traffic Volume Trends report offers some monthly vehicle mile traveled data by state, monthly vehicle mile data is not substantial enough to include in models for this paper. Instead, this paper utilizes monthly civilian noninstitutional population estimates for each state published by the Bureau of Labor Statistics through the Local Area Unemployment Statistics program. Civilian noninstitutional population includes civilians older than 16 years old who are not institutional inmates or active duty Armed Forces members. Therefore, civilian noninstitutional population can be used as a rough equivalent to the population of individuals in a state able to drive. Fatality data are derived from the FARS Encyclopedia.

This paper outlines four main models, two models each for yearly and monthly data. There is a monthly model with rural Interstate fatality rate as the dependent variable, a monthly model with fatality rate of roads other than rural Interstates as the dependent variable, and the two corresponding yearly models.

$$(Eq. 1)\ fatal\_rate\_pop_{rural\ interstate}$$

$$= \beta_0 + \beta_1 sb\_primary + \beta_2 sb\_secondary + \beta_3 bac\_law$$

$$+ \beta_4 sixty\_five + \beta_5 seventy + \beta_6 seventy\_five + \beta_7 higher\_limit$$

$$+ \beta_8 year + \beta_1' \vec{x}_1 + u_{rural\ interstate\ monthly}$$

$$(Eq. 2)\ fatal\_rate\_pop_{other\ roads}$$

$$= \beta_9 + \beta_{10} sb\_primary + \beta_{11} sb\_secondary + \beta_{12} bac\_law$$

$$+ \beta_{13} sixty\_five + \beta_{14} seventy + \beta_{15} seventy\_five + \beta_{16} higher\_limit$$

$$+ \beta_{17} year + \beta_2' \vec{x}_2 + u_{other\ roads\ monthly}$$

$$(Eq.3)\ fatal\_rate\_vmt_{rural\ interstate}$$
$$= \beta_{18} + \beta_{19} sb\_primary + \beta_{20} sb\_secondary + \beta_{21} bac\_law$$
$$+ \beta_{22} sixty\_five + \beta_{23} seventy + \beta_{24} seventy\_five + \beta_{25} higher\_limit$$
$$+ \beta_{26} year + \beta_3' \vec{x}_3 + u_{rural\ interstate\ yearly}$$

$$(Eq.4)\ fatal\_rate\_vmt_{other\ roads}$$
$$= \beta_{27} + \beta_{28} sb\_primary + \beta_{29} sb\_secondary + \beta_{30} bac\_law$$
$$+ \beta_{31} sixty\_five + \beta_{32} seventy + \beta_{33} seventy\_five + \beta_{34} higher\_limit$$
$$+ \beta_{35} year + \beta_4' \vec{x}_4 + u_{other\ roads\ yearly}$$

$\beta_1' \vec{x}_1$ and $\beta_2' \vec{x}_2$ represent vectors of month dummy variables and state dummy variables with corresponding coefficients while $\beta_3' \vec{x}_3$ and $\beta_4' \vec{x}_4$ are vectors of just state dummy variables and coefficients. The Breusch-Pagan test finds heteroskedasticity in each model. Furthermore, each model tests positive for autocorrelation. Therefore, bootstrapped standard errors are estimated in addition to OLS standard errors. The RESET test reveals misspecification in each model, so refined models with additional independent variables are estimated as well. In analyzing the effect of an independent variable on a given fatality rate, all other independent variables are assumed constant.

The key explanatory variables of this paper are the maximum rural Interstate speed limit dummy variables. Each dummy variable equals 0 for a time period in which a maximum 55 MPH limit was in effect. Therefore, the coefficient on each speed limit variable measures the effect of the speed limit level, 65 MPH, 70 MPH, 75 MPH, or above 75 MPH, on fatality rate compared to a maximum rural Interstate limit of 55 MPH. These dummy variables somewhat simplify the differences of speed limits across states.

While two states may have the same maximum rural Interstate speed limit, the percentage of rural Interstate mileage with the maximum limit differs across states. For example, only certain sections of Interstate 75 and Interstate 71 have the maximum state speed limit of 70 MPH in Kentucky. Similarly, Utah only posts an 80 MPH speed limit on segments of Interstate 15, and exclusively parts of Interstate 10 and Interstate 20 in western Texas have an 80 MPH speed limit. From December 8, 1995 to May 28, 1999, Montana maintained a "reasonable and prudent" daytime speed limit. Since this limit left room for interpretation, Montana is coded with the above 75 MPH speed limit dummy variable equal to 1 during the time in which a "reasonable and prudent" maximum limit was effective. Only Montana, Texas, and Utah had limits above 75 MPH during the 1981 to 2009 period studied in this paper. Though the maximum limit may not appear on all rural Interstates, each state is coded according to maximum limits. In addition, speed limit enforcement can vary from state to state. Tolerance for speeding above a limit ranges from 5 to 15 MPH (Carr 2012). Thresholds for harsh penalties and fines are varying levels above maximum speed limits in different states as well. Several states also have separate speed limits for trucks below the maximum limits for cars. Positive coefficient estimates for speed limit dummy variables in the rural Interstate fatality rate regressions, (Eq. 1) and (Eq. 3), would indicate that speed limit increases lead to higher fatality rates on rural Interstates. With the fatality rate for roads other than rural Interstates as a dependent variable in (Eq, 2) and (Eq, 4), positive coefficient estimates would provide evidence that speed spillover from Interstates raises fatality rates on other roads. Negative coefficient estimates in such regressions would in turn support the traffic diversion hypothesis that risky drivers gravitate to Interstates with high speed limits, making other roads safer.

Seat belt legislation represents an important safety factor to consider in relation to fatality rates, so all models include seat belt law dummy variables. States generally have either primary or secondary seat belt laws. Officers can penalize citizens for the sole offense of not wearing a seat belt under a primary enforcement law. Under secondary enforcement, police can only ticket individuals for not wearing seat belts if another traffic violation has taken place. These laws affect highway safety by increasing seat belt usage. Cohen and Einav (2003) determine that secondary and primary laws raise seat belt usage by 11 and 22 percent, respectively, consequently saving lives. Several other studies find that primary seat belt legislation has a larger negative effect on fatality rate than secondary laws. Farmer and Williams (2005) estimate that switching from secondary to primary laws reduces highway fatality rates by 7 percent, controlling for time and economic effects. Liu et al. (2006) observe lower fatality rates, considering both vehicle miles traveled and population, for states with primary enforcement compared to states with secondary laws. Much like the speed limit variables, the seat belt law dummy variables for primary and secondary enforcement simplify differences between states. Every state has some sort of seat belt enforcement law except for New Hampshire. Seat belt laws for different states have different minimum age enforcement levels and can cover all seats in a car or just front seats. Base fines for first offenses also vary from $5 in Kansas to $200 in Texas. New Mexico assesses points for all seat belt violations, and New York assesses points for violations involving children under 16 years old.

Wyoming and Ohio both have greater fines for drivers who violate seat belt laws compared to passengers. Negative coefficient estimates for the seat belt law dummy variables would support studies which find that seat belt legislation reduces fatality rates. If primary seat belt legislation reduces fatality rates more than secondary seat belt legislation, the primary coefficient estimate will be less, and therefore greater in absolute magnitude, than the secondary estimate.

A blood alcohol concentration variable equals 1 for a month in which a state has a .08 BAC per se law prohibiting driving. Again, the specifics of state laws differ. Some states require an administrative license suspension with a first DUI or DWI offense of varying length by state. Several studies demonstrate a negative effect of .08 BAC laws on traffic fatalities. Hingson, Heeren, and Winter (1996) estimate that 5 states with .08 per se laws experienced significant declines in the proportions of fatal crashes involving drivers with blood alcohol concentration levels higher than .08 and .15, respectively. Apsler et al. (1999) find that .08 BAC laws significantly reduced alcohol-related fatalities in 7 out of 11 examined states. In a study of the .08 BAC law in Illinois, Voas, Tippetts, and Taylor (2001) determine that the law saved 105 lives over the 2-year period of 1998 to 1999. Given the effectiveness of .08 BAC laws, Congress established .08 BAC as a national illegal limit for impaired driving with the DOT Appropriations Act of FY 2001, which threatened to withhold highway construction funds from states which did not comply. By August 2005, all states had enacted .08 BAC per se laws. No state has yet enacted a BAC cutoff below .08. Negative coefficient estimates for the .08 BAC law variables in each regression would provide further evidence that .08 BAC laws reduce highway fatalities compared to higher BAC limits.

Year variables and state dummy variables are included in each model, and month dummy variables are included in the monthly models. The year variable controls for any linear trends from 1981 to 2009 which affect fatality rates not captured by other independent variables. Vehicle safety technology, demographic shifts other than general population fluctuations, changes in transportation engineering standards, and changes in driving habits are some factors possibly captured by the year variable. Negative coefficient estimates for the year variable would express that the combination of these linear trends reduces fatality rates. Dummy variables exist for each state except California, which is arbitrarily chosen for exclusion since California has the most highway fatalities of any state from 1981 to 2009. Therefore, the coefficient estimate of a given state dummy variable expresses the effect of that state on fatality rate, relative to California. State variables account for fixed effects across states such as geography. In addition, state variables also capture factors which remain mostly constant within each state such as driver behavior, weather, demographic differences, and highway maintenance. In the monthly models, each month is represented by a dummy variable except January. Each coefficient estimate of a month variable, then, shows the relative effect of that month on fatality rate compared to January. Since the monthly models do not consider vehicle miles traveled, the month variables may capture some changes in vehicle miles traveled during different times of the year. Figure 1 displays the sum of vehicle miles traveled on all U.S. roads in each month for the time period of study, 1981 to 2009. Vehicle miles traveled are higher in summer months than winter months. Positive summer month variable coefficients would express that fatality rates are higher during these months of high travel compared to January. Month variables also control for seasonal weather patterns.

IV. Rural Interstate Results

Table 4 lists coefficient estimates for the monthly rural Interstate population fatality rate model (Eq. 1) and yearly rural Interstate vehicle miles traveled fatality rate model (Eq. 3). The monthly model explains 48.66 percent of variation in population fatality rate while the yearly model explains 74.29 percent of variation in vehicle miles traveled fatality rate. Since the models display both heteroskedasticity and autocorrelation, the models are also estimated with bootstrapped standard errors. All OLS coefficient estimates that are significant in the monthly model, excluding fixed effects, are still significant with bootstrapped standard errors except the variable for speed limits above 75 MPH. In the yearly model, the primary seat belt law is more significant with bootstrapped standard errors compared to OLS estimates. The yearly 75 MPH variable is significant with OLS standard errors but insignificant with bootstrapped standard errors. A Chow test rejects the null hypothesis of identical coefficient estimates across states. Therefore, a monthly model is estimated with a regression for each state. Since this model allows coefficients to vary by state, it is an unrestricted model. Table 5 presents the number of significant coefficient estimates in the monthly unrestricted model for each speed limit variable. The monthly model presented in the previous section is restricted and does not include different coefficients for each state for variables other than state fixed effects. While a Chow test fails to reject the null hypothesis of varying coefficient estimates across states in the restricted yearly model, unrestricted yearly results are still reported in Table 5 as well. Significance is judged at a .05 significance level unless otherwise noted.

Both monthly and yearly models provide evidence for a positive relationship between rural Interstate fatality rates and speed limits above 55 MPH. In the monthly model, every speed limit dummy variable has a significant, positive effect on fatality rate. The rural Interstate fatality rate is .051 fatalities per 100,000 population higher with a 65 MPH speed limit compared to a 55 MPH limit. 70 MPH speed limits rather than 65 MPH in turn produce greater fatality rates; a 70 MPH limit leads to a rate .114 fatalities per 100,000 higher than the standard 55 MPH case. A 75 MPH limit increases the fatality rate by .086 fatalities per 100,000 while a limit higher than 75 MPH leads to a rate .044 fatalities per 100,000 higher than 55 MPH. Speed limit coefficient estimates follow a similar pattern in the yearly model. The coefficients for the 65 and 70 MPH speed limit variables are positive and significant, the 70 MPH coefficient higher in magnitude. The rural Interstate fatality rate is .183 and .434 fatalities per 100 million vehicle miles driven higher for 65 and 70 MPH speed limits, respectively, compared to a 55 MPH limit. A 75 MPH rather than 55 MPH limit increases the fatality rate .180 fatalities per 100 vehicle miles driven. The coefficient for speed limits higher than 75 MPH is insignificant.

The unrestricted model also provides evidence that increased speed limits raise rural Interstate fatality rates although perhaps not as strongly as the restricted model.

None of the speed limit coefficient estimates in the unrestricted model are significantly negative. Out of 48 studied states, only 14 states have a significant, positive coefficient estimate for the 65 MPH variable. 11 of 20 states with 70 MPH speed limits at some point in the study have a significant, positive coefficient estimate for the 70 MPH variable, further strengthening the result from the restricted model that 70 MPH limits have a greater positive impact on rural Interstate fatality rates than 65 MPH limits. The number of 75 MPH states with positive coefficient estimates for the 75 MPH variable is 5 out of 14. This proportion lies between the corresponding proportions for 65 MPH and 70 MPH, much like the restricted 75 MPH coefficient estimate is between the restricted coefficient estimates for 65 MPH and 70 MPH. Finally, Utah's coefficient estimate for a limit higher than 75 MPH is positive and significant while the corresponding estimates for Montana and Texas are insignificant.

The monthly and yearly rural Interstate models provide different results for safety law dummy variables. Surprisingly, both seat belt law variables and the BAC variable are insignificant. The yearly model produces more expected results for safety variables. As previous scholarly literature predicts, the primary seat belt law dummy variable has a larger negative effect on fatality rate in magnitude and significance than the secondary seat belt law variable. A primary seat belt law reduces the rural Interstate fatality rate by .161 fatalities per 100 million vehicle miles driven while a secondary law reduces the fatality rate by .091 fatalities per 100 million vehicle miles. The BAC variable is insignificant.

Year, state, and month fixed effects significantly impact rural Interstate fatality rates. In both monthly and yearly rural Interstate models, the coefficient for the year variable is significant and negative, possibly indicating that long-term trends such as improving car technology drive down rural Interstate fatality rates. The state fixed effects are jointly significant in both models. Moreover, the month variables in the monthly model are jointly significant as well. Coefficient estimates are all positive except February, most likely due to the relatively lower level of vehicle miles traveled in January and February than other months. Indeed, coefficient estimates are greatest for the high-travel summer months.

V. Roads Other Than Rural Interstate Results

Table 6 lists coefficient estimates for the monthly population fatality rate model (Eq. 2) and yearly vehicle miles traveled fatality rate model (Eq. 4) for roads other than rural Interstates. The monthly model explains 60.61 percent of variation in population fatality rate while the yearly model explains 85.87 percent of variation in vehicle miles traveled fatality rate. Once again, models with bootstrapped standard errors are presented to account for heteroskedasticity and autocorrelation. All significant OLS coefficient estimates are still significant with bootstrapped standard errors in both monthly and yearly models. Since a Chow test rejects common coefficient estimates for each state, monthly unrestricted results are presented in Table 7. The Chow test of the restricted yearly model does provide evidence of different coefficient estimates across states, but unrestricted yearly results can still be found in Table 7.

Though discrepancies between monthly and yearly models exist, generally the models support a net effect of traffic diversion due to rural Interstate speed limit increases. The monthly model provides mixed evidence for the relationship between the fatality rate on roads other than rural Interstates and increased rural Interstate speed limits. Three of the four speed limit coefficient estimates are negative, indicating lower fatality rates on roads other than rural Interstates and a net traffic diversion effect. However, the significant, positive coefficient estimate of the 70 MPH variable provides evidence for speed spillover at 70 MPH rural Interstate limits. Compared to a 55 MPH rural Interstate limit, speed limits of 65 MPH and above 75 MPH account for decreases in the fatality rate of roads other than rural Interstates of .036 and .173 fatalities per 100,000 population, respectively. Meanwhile, the fatality rate on roads other than rural Interstates is .095 fatalities per 100,000 higher with a 70 MPH rural Interstate limit rather than a 55 MPH limit. The 75 MPH variable is insignificant. The yearly model offers clearer evidence for a negative relationship between fatality rate on roads other than rural Interstates and rural Interstate speed limits above 55 MPH. Coefficients on each of the speed limit variables are negative, and all of these coefficients are highly significant. Interestingly, the negative effect of rural Interstate speed limit on the fatality rate of other roads seems to be greater for higher speed limits up to 75 MPH. 65 MPH, 70 MPH, 75 MPH, and above 75 MPH rural Interstate speed limits lead to decreases of .294, .314, .328, and .263 fatalities per 100 million vehicle miles compared to a 55 MPH rural Interstate limit.

Conversely, the monthly unrestricted model supports speed spillover. For 11 out of 48 states, the 65 MPH variable has a positive, significant impact on fatalities on roads other than rural Interstates while this coefficient estimate is significant and negative for only 5 states. None of the speed limit coefficient estimates are significant and negative above 65 MPH. Out of the 20 states with a 70 MPH limit, 8 have positive, significant coefficient estimates. Monthly restricted and unrestricted models, then, both indicate that speed spillover is more prevalent for rural Interstate limits of 70 MPH compared to 65 MPH. 2 of 14 states have positive and significant coefficient estimates for the 75 MPH variable. Finally, none of the higher limit variables have significant coefficients.

Seat belt law variables display expected results while the .08 BAC law coefficient estimates are surprisingly positive in monthly and yearly models. Both seat belt law variables have negative coefficients in the monthly model though the secondary seat belt law variable is insignificant. A primary seat belt law is associated with a decrease of .138 fatalities per 100,000 population in the fatality rate of roads other than rural Interstates. The BAC law variable unexpectedly has a positive, significant coefficient, meaning .08 BAC driving laws seem to drive up fatality rates in the monthly model. This result does not correspond to the hypothesized negative impact of BAC legislation on fatality rates. The yearly model yields similar results as the monthly model. The seat belt law variables are both significant and have negative coefficients. Primary and secondary seat belt laws account for fatality rate reductions of .225 and .173 fatalities per 100 million vehicle miles traveled on roads other than rural Interstates, respectively. The BAC law variable once again has a positive, significant coefficient.

The year, state, and month variables behave similarly to the fixed effects in the rural Interstate models. The year variables in both monthly and yearly models have negative effects on fatality rates of roads other than rural Interstates. The state fixed effects as a group are jointly significant in both models. Once again, month variables in the monthly model are jointly significant, and coefficient estimates are lower for winter months and higher for summer months.

VI. Net Fatalities

The net fatality impact of rural Interstate speed limit increases can be determined using results from both monthly models. Since $\frac{fatalities}{population/_{100{,}000}} = fatalities * \frac{100{,}000}{population}$ and the coefficient estimate of a speed limit dummy variable expresses the change in fatalities per 100,000 population for that speed limit compared to 55 MPH, multiplying the coefficient estimate by $\frac{population}{100{,}000}$ gives an estimate of the fatality impact for a month in which the higher speed limit is in effect. For instance, the net fatalities due to a 65 MPH speed limit compared to a 55 MPH limit in the rural Interstate model for a given state-month is given by the expression below.

$$fatalities\ due\ to\ 65\ MPH\ limit\ on\ rural\ Interstates$$
$$= \frac{\hat{\beta}_4 * sixty\_five * population}{100{,}000}$$

These monthly observations can be summed over all months from 1981 to 2009. The net fatalities caused by different speed limits compared to 55 MPH over this time period are displayed in Table 8. Column (a) lists predicted net fatalities for rural Interstates from 1981 to 2009 due to speed limits higher than 55 MPH. The 70 MPH speed limit has the greatest positive impact on fatalities, even though no state could set a 70 MPH limit until 1995. Column (b) shows results for roads other than rural Interstates. Traffic diversion overrides speed spillover at 65 MPH, 75 MPH, and limits higher than 75 MPH, but speed spillover is much greater at 70 MPH. Column (c) reports predicted net fatalities for the total traffic system. All speed limit levels except for limits higher than 75 MPH lead to positive net fatalities. The bulk of the net fatalities come from 70 MPH limits while the positive figures for 65 MPH and 75 MPH are much smaller. These results suggest that the impact of a speed limit increase on traffic system-wide fatalities differs depending on the exact speed limit level. Up to 2009, these estimates indicate that speed limit increases above 55 MPH resulted in 39,700 extra fatalities on the entire traffic system, 4.1 percent of fatalities from 1987 to 2009. While both monthly models suffer from heteroskedasticity and autocorrelation, the coefficient estimates used in this method are still unbiased. These point estimates do not take into account the significance of coefficient estimates.

VII. Rural Interstate Refined Models

In addition to the main models previously discussed, three more rural Interstate models are estimated due to failed RESET tests. Garber and Graham (1990), among other studies, find a negative correlation between unemployment and highway fatalities. Theoretically, citizens will drive less during times of high unemployment, causing fewer fatalities. Since unemployment is a proxy variable for vehicle miles traveled and the dependent variables of this paper are fatality rates rather than fatalities, unemployment is not included in the main models. However, seasonally-unadjusted unemployment is incorporated into refined monthly models. Table 9 lists refined model results for rural Interstates.

Two refined monthly models and one refined yearly model are presented. The first monthly model includes the same dependent variables as the main model plus unemployment. Unemployment does have a significant, negative coefficient even though the dependent variable is population fatality rate rather than fatalities. A percentage point increase in unemployment reduces fatalities per 100,000 population by .007. Speed limit variable results remain similar to the main model; the 65 MPH, 70 MPH, and 75 MPH coefficient estimates are significant and positive. Another monthly model includes a squared year term, interaction terms of year and the speed limit variables, and interactions between the primary seat belt law and speed limits. Since year ranges from 1981 to 2009 rather than a scale starting at 1, the speed limit coefficient estimates appear much larger in magnitude than the main monthly model. However, the interaction terms between year and each speed limit all have negative coefficient estimates. The positive effect of increased speed limits on rural Interstate fatality rate decreases with time. Finally, a yearly model is estimated with a squared year term and interactions between year and speed limit variables. Once again, the year and speed limit interactions have negative coefficient estimates. Figure 2 provides context for interpreting the speed limit interaction coefficients, which plots the change in VMT fatality rate for different speed limits in the refined yearly model. This fatality rate change is the coefficient estimate of the speed limit variable plus the coefficient of the interaction term multiplied by the year. Figure 2 indicates that speed limits 75 MPH and above have more reduced fatality rate impacts over time than 65 MPH or 70 MPH speed limits on rural Interstates.

$$change\ in\ VMT\ fatality\ rate = \hat{\beta}_{speed\ limit} + \hat{\beta}_{speed\ limit\ *\ year} * year$$

VIII. Roads Other Than Rural Interstate Refined Models

Following the same convention as the rural Interstate models, three refined models for roads other than rural Interstates are estimated due to failed RESET tests. Table 10 shows these results. Unemployment does have a negative effect on the fatality rate of roads other than rural Interstates. A percentage point increase in unemployment lowers the rate by .070 fatalities per 100,000 population. Contrary to corresponding results in the model without unemployment, the coefficient estimate for the 70 MPH variable is negative and significant, supporting the traffic diversion hypothesis, while the 75 MPH and above coefficient estimate is positive. In the second monthly model, the year and speed limit interaction term coefficients are negative once again, though greater in magnitude than the corresponding coefficient estimates for the rural Interstate model. Finally, all year and speed limit interactions except for the term involving 65 MPH have negative coefficient estimates in the yearly model. While the year and 65 MPH interaction term has a positive coefficient estimate, the 65 MPH coefficient estimate is negative. Figure 3 displays the fatality rate impacts of rural Interstate speed limits on other roads in the refined yearly model. While rural Interstate speed limits above 65

MPH have decreasing fatality rate effects, the refined yearly model generally supports speed spillover as fatality rate impacts are mostly positive.

IX. Conclusion

This thesis adds to the bevy of literature which establishes a positive link between maximum state speed limits above 55 MPH and rural Interstate fatality rates. Refined models reveal that this effect may lessen with time, however. The restricted monthly model (Eq. 2) mostly supports the traffic diversion hypothesis though the 70 MPH variable shows signs of speed spillover. Increases of rural Interstate maximum speed limits from 55 MPH to 65 MPH, 75 MPH, and higher than 75 MPH are associated with net negative impact on fatalities of roads other than rural Interstates while raising to 70 MPH increases fatalities. The yearly model (Eq. 4), which accounts for vehicle miles of travel, is more supportive of the traffic diversion hypothesis than the monthly model. The 65 MPH results of these models are similar to Houston (1999), who also finds that 65 MPH limits raise rural Interstate fatality rates but lower fatality rates of other roads. The unrestricted monthly model, however, suggests that speed spillover could cause higher fatality rates on roads other than rural Interstates with high rural Interstate speed limits. Overall, models generally provide evidence that increased rural Interstate speed limits can lower fatality rates on other roads. When considering the consequences of all rural Interstate limits above 55 MPH and fatalities on and off rural Interstates, though, the effect of higher speed limits on system-wide fatalities is positive. According to the restricted monthly models, rural Interstate speed limit increases above 55 MPH are responsible for 39,700 net fatalities, 4.1 percent of total fatalities from 1987, the year limits were first raised, to 2009. Like several other recent papers, these findings prove that the question of whether a maximum 65 MPH limit saves lives posited by Lave and Elias (1994) is now an element within a broader topic; higher limits must be studied as well. While a federal mandate of a 55 MPH speed limit does not appear necessary, the results of this thesis suggest that policymakers should carefully consider the magnitude of rural Interstate speed limit increases and the effects of increases on statewide traffic systems. In particular, changing a maximum limit to 70 MPH seems to substantially raise fatality rates and fatalities.

The relatively mild fatality effects of 75 MPH and higher limits compared to 70 MPH are surprising. Population is ruled out as a determinant of this result since the dependent variable of monthly models is the population fatality rate. The flat landscape of some Western states with high speed limits would seem to be a possible explanation, but state dummy variables should account for geographical effects. Random statistical effects must also be considered. However, speed variance on rural Interstates may be reduced with 75 MPH speed limits or above in these states compared to 70 MPH limits. If so, a decrease in speed variance could account for the mild fatality effects of high speed limits, similar to New York's experience with a 65 MPH maximum speed limit described by Jehle et al. (2010). Future studies could examine this phenomenon with a greater sample of state-months or state-years with high speed limits, especially states with limits higher than 75 MPH.

X. Tables

Table 1: Summary of Previous Interstate Speed Limit Studies		
Time Period	**Study**	**Findings**
Post-1974	Clotfelter and Hahn (1978)	Benefits of NMSL outweighed costs.
	Kamerud (1988)	$4-9 million cost per life saved by NMSL; supported higher speed limits.
	Transportation Research Board (1984)	NMSL saved 2,000 to 4,000 lives annually.
	Forester, McNown, and Singell (1984)	NMSL saved 7,466 lives annually but costs of NMSL outweighed benefits
	Yowell (2005)	NMSL led to initial decline in fatality rates but long-term trend persisted after adjustment.
Post-1987	Ashenfelter and Greenstone (2002)	65 MPH rural Interstate limit led to 35 percent fatality increase in 21 states.
	Balkin and Ord (2001)	Rural highway fatalities increased due to higher speed limit in just 19 of 40 studied states.
	Houston (1999)	Supported traffic diversion hypothesis.
	Chang, Chen, and Carter (1993)	Initial significant increase in highway fatalities due to higher speed limit lessoned after one year "learning period."
	Gallaher et al. (1989)	Fatality rates exceeded trend levels after implementation of 65 MPH limit in New Mexico.
	Baum, Lund, and Wells (1989)	States that raised speed limits experienced 15 percent higher fatalities than predicted model of continuing 55 MPH limits.
	Rock (1995)	65 MPH limit led to 15 more deaths per month in Illinois.
Post-1995	National Highway Traffic Safety Administration (1998)	States with raised speed limits in 1996 experienced 350 deaths above projections.
	Friedman, Hedeker, and Richter (2009)	9.1 percent increase in fatalities due to speed limit increases.
	Farmer, Retting, and Lund (1999)	Fatalities increased 17 percent in 24 states that raised speed limits.
	Patterson et al. (2002)	States that increased speed limits to 70 and 75 MPH experienced 35 and 38 percent higher fatalities than predicted values.
	Balkin and Ord (2001)	Only 10 states with significant fatality increases out of 36 states that raised speed limits.
	Bartle et al. (2003)	70 MPH speed limit in Alabama led to increased fatalities in 1997 and 1999, but fatalities declined in 1998.
	Yowell (2005)	No strong link between speed limit increases in the 1990s and fatality rates.
	Transportation Research Board (1998)	Higher Interstate speed limits raise fatality rates on rural highways.
	Ledolter and Chan (1996)	Iowa change to 65 MPH limit led to 57 percent increase in deaths on rural Interstates.

Table 2: Summary of Previous Speed Spillover and Traffic Diversion Studies	
Study	**Findings**
Garber and Graham (1990)	In most states, speed spillover effect exceeded traffic diversion.
Lave and Elias (1994)	NMSL caused misallocation of police resources; multi-state model supports traffic diversion hypothesis.
Houston (1999)	Using a national data set, rural Interstate speed limit increases to 65 MPH caused fatality rates to decrease on other roads.
Greenstone (2002)	Rural interstate speed limit increases do not significantly affect statewide fatality rates.
Grabowski and Morrisey (2007)	Repeal of the NMSL caused a 7 percent to 11 percent increase in rural non-Interstate fatalities.
Wagenaar, Streff, and Schultz (1990)	Some short-term evidence of speed spillover from 65 MPH Michigan rural Interstates, especially to 55 MPH roads.
McCarthy (1994)	In California, Interstate speed limit increase did not significantly affect fatalities for the traffic system as a whole.
Rock (1995)	Illinois 65 MPH speed limit raised accidents on 55 MPH roads.
Kockelman (2006)	Net spillover effect from increased Interstate speed limits in Washington state was small to negligible.

Table 3a: Monthly Variable Definitions and Means				
Variable	**Definition**	**Rural Interstate or Other Roads**	**Source(s)**	**Mean**
Fatal_rate_pop	Fatalities per 100,000 civilian noninstitutional population	Rural Interstate	FARS Encyclopedia Bureau of Labor Statistics	.1837203
Fatal_rate_pop	Fatalities per 100,000 civilian noninstitutional population	Other Roads	FARS Encyclopedia Bureau of Labor Statistics	1.821771
Sb_primary	Proportion of time period in which primary seat belt law is in effect	Both	Insurance Institute for Highway Safety	.2097087
Sb_secondary	Proportion of time period in which secondary seat belt law is in effect	Both	Insurance Institute for Highway Safety	.5053337
Bac_law	Proportion of time period in which .08 blood alcohol concentration per se law is in effect	Both	National Highway Traffic Safety Administration	.3558411
Sixty_five	Proportion of time period in which 65 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.4379004
Seventy	Proportion of time period in which 70 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.1673885
Seventy_five	Proportion of time period in which 75 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.1143598
Higher_limit	Proportion of time period in which higher than 75 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.0062685
Unemp	Ratio of unemployed to civilian labor force in a state expressed as a percent	Both	Bureau of Labor Statistics	5.875305
Year	Year of observation	Both		1995
State dummy variables	=1 for observation in a given state, 0 otherwise; 48 total state variables	Both		.0208333
Month dummy variables	=1 for observation in a given month, 0 otherwise; 11 total month variables	Both		.0833333 for each month

Table 3b: Yearly Variable Definitions and Means				
Variable	**Definition**	**Rural Interstate or Other Roads**	**Source(s)**	**Mean**
Fatal_rate_vmt	Fatalities per 100 million vehicle miles traveled	Rural Interstate	FARS Encyclopedia Federal Highway Administration	1.295421
Fatal_rate_vmt	Fatalities per 100 million vehicle miles traveled	Other Roads	FARS Encyclopedia Federal Highway Administration	2.042823
Sb_primary	Proportion of time period in which primary seat belt law is in effect	Both	Insurance Institute for Highway Safety	.2097087
Sb_secondary	Proportion of time period in which secondary seat belt law is in effect	Both	Insurance Institute for Highway Safety	.5053337
Bac_law	Proportion of time period in which .08 blood alcohol concentration per se law is in effect	Both	National Highway Traffic Safety Administration	.3558411
Sixty_five	Proportion of time period in which 65 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.4379004
Seventy	Proportion of time period in which 70 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.1673885
Seventy_five	Proportion of time period in which 75 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.1143598
Higher_limit	Proportion of time period in which higher than 75 MPH rural Interstate speed limit is in effect	Both	Insurance Institute for Highway Safety	.0062685
Year	Year of observation	Both		1995
State dummy variables	=1 for observation in a given state, 0 otherwise; 48 total state variables	Both		.0208333

Table 4: Rural Interstate Coefficient Estimates		
Variable	**Monthly Model: Fatality rate per 100,000 population**	**Yearly Model: Fatality rate per 100 million vehicle miles traveled**
sb_primary	-.0002424	-.1612335*&&
sb_secondary	.0096311	-.0907661*&
bac_law	.0001691	.0338675
sixty_five	**.0505589**&&**	**.1825298**&&**
seventy	**.1136297**&&**	**.434473**&&**
seventy_five	**.0858825**&&**	**.1797391***
higher_limit	**.0437105***	**-.1532132**
year	-.0041545**&&	-.027114**&&
	16704 observations	1392 observations
	R^2 = .4866	R^2 = .7429
* represents .05 level significance, ** represents .01 level significance		
& represents .05 bootstrap significance, && represents .01 bootstrap significance		

Table 5: Rural Interstate Regressions, Unrestricted				
	Fatality rate per 100,000 population (monthly model)		**Fatality rate per 100 million vehicle miles traveled (yearly model)**	
Variable	**Positive Coefficients**	**Negative Coefficients**	**Positive Coefficients**	**Negative Coefficients**
65 MPH Dummy	16 of 48 states	0 of 48 states	8 of 48 states	0 of 48 states
70 MPH Dummy	11 of 20 states	0 of 20 states	3 of 20 states	0 of 20 states
75 MPH Dummy	5 of 14 states	0 of 14 states	3 of 14 states	0 of 14 states
Higher Limit Dummy	1 of 3 states	0 of 3 states	0 of 3 states	0 of 3 states

Table 6: Roads Other Than Rural Interstate Coefficient Estimates		
Variable	**Monthly Model: Fatality rate per 100,000 population**	**Yearly Model: Fatality rate per 100 million vehicle miles traveled**
sb_primary	-.1381046**&&	-.2252202**&&
sb_secondary	-.0204024	-.1730404**&&
bac_law	.0586784**&&	.1132445**&&
sixty_five	**-.0359617*&**	**-.2935734**&&**
seventy	**.0954379**&&**	**-.3137555**&&**
seventy_five	**-.0360797**	**-.3280206**&&**
higher_limit	**-.1736075**&&**	**-.263153*&&**
Year	-.0307707**&&	-.0493392**&&
	16704 observations	1392 observations
	R^2 = .6061	R^2 = .8587
* represents .05 level significance, ** represents .01 level significance		
& represents .05 bootstrap significance, && represents .01 bootstrap significance		

Table 7: Roads Other than Rural Interstate Regressions, Unrestricted				
	Fatality rate per 100,000 population (monthly model)		**Fatality rate per 100 million vehicle miles traveled (yearly model)**	
Variable	**Positive Coefficients**	**Negative Coefficients**	**Positive Coefficients**	**Negative Coefficients**
65 MPH Dummy	11 of 48 states	4 of 48 states	0 of 48 states	7 of 48 states
70 MPH Dummy	8 of 20 states	0 of 20 states	0 of 20 states	1 of 20 states
75 MPH Dummy	2 of 14 states	0 of 14 states	0 of 14 states	1 of 14 states
Higher Limit Dummy	0 of 3 states	0 of 3 states	0 of 3 states	0 of 3 states

Table 8: Net Fatalities			
Dummy Variable	**(a) Predicted Net Fatalities, Rural Interstates**	**(b) Predicted Net Fatalities, Roads Other Than Rural Interstates**	**(c) Predicted Net Fatalities, Total**
65 MPH Rural Interstate Speed Limit	14,680	-10,441	4,238
70 MPH Rural Interstate Speed Limit	18,669	15,680	34,349
75 MPH Rural Interstate Speed Limit	3,764	-1,575	2,189
Higher than 75 MPH Rural Interstate Speed Limit	362	-1,439	-1,076
Total	37,475	2,225	39,700

Table 9: Rural Interstate Coefficient Estimates, Refined Models			
Variable	**Monthly Model With Unemployment**	**Monthly Model With Interactions**	**Yearly Model With Interactions**
sb_primary	-.0053771	-.0100246	-.181902**
sb_secondary	.0017568	-.0046383	-.0873658
bac_law	.0045322	.0111248*	.0467948
sixty_five	**.0389628**&&**	**3.935065**	**27.93379**
seventy	**.0940798**&&**	**2.450248**	**45.6676**
seventy_five	**.0682932**&&**	**24.94184****	**112.5364****
higher_limit	**.0308679**	**34.48838****	**174.7068****
unemp	-.0071783**&&	-.0069573**	-
year	-.0041298**&&	-.1334714	-3.32092
year_sq	-	.000033	0008289
year_sixty_five	-	**-.0019636**	**-.0139491**
year_seventy	-	**-.0011934**	**-.0226974**
year_seventy_five	-	**-.0124434****	**-.0562086****
year_higher_limit	-	**-.0172385****	**-.0873965****
sb_primary_sixty_five	-	.0025609	-
sb_primary_seventy	-	-.0274877	-
sb_primary_seventy_five	-	.0157308	-
sb_primary_higher_limit	-	.0842039	-
	16704 observations	16704 observations	1392 observations
	R^2 = .4882	R^2 = .4913	R^2 = .7473
* represents .05 level significance, ** represents .01 level significance			
& represents .05 bootstrap significance, && represents .01 bootstrap significance (only for models without year_sq term)			
Seat belt interactions are not jointly significant for the yearly model and are therefore omitted.			

Table 10: Roads Other Than Rural Interstate Coefficient Estimates, Refined Models			
Variable	**Monthly Model With Unemployment**	**Monthly Model With Interactions**	**Yearly Model With Interactions**
sb_primary	-.1884387**&&	-.0348114	-.0549629
sb_secondary	-.0975818**&&	-.0152272	.0250656
bac_law	.1014492**&&	.0528709**	-.0003655
sixty_five	**-.1496106**&&**	**15.42312***	**-27.7973**
seventy	**-.0961573**&&**	**19.73387**	**18.42552**
seventy_five	**-.208463**&&**	**51.37154****	**10.45339**
higher_limit	**.2994637**&&**	**51.87852***	**12.58628**
unemp	-.0703572**&&	-.085621**	-
year	-.0305293**&&	-7.83272**	-10.06963**
year_sq	-	.0019553**	.0025063**
year_sixty_five	-	**-.0077647***	**.0139416**
year_seventy	-	**-.0098803**	**-.0091551**
year_seventy_five	-	**-.0257159****	**-.0051841**
year_higher_limit	-	**-.0260144***	**-.0062459**
sb_primary_sixty_five	-	-.0325896	-
sb_primary_seventy	-	-.1403116**	-
sb_primary_seventy_five	-	-.3165974**	-
sb_primary_higher_limit	-	-.2857688*	-
	16704 observations	16704 observations	1392 observations
	R^2 = .6225	R^2 = .6316	R^2 = .8790
* represents .05 level significance, ** represents .01 level significance			
& represents .05 bootstrap significance, && represents .01 bootstrap significance (only for models without year_sq term)			
Seat belt interactions are not jointly significant for the yearly model and are therefore omitted.			

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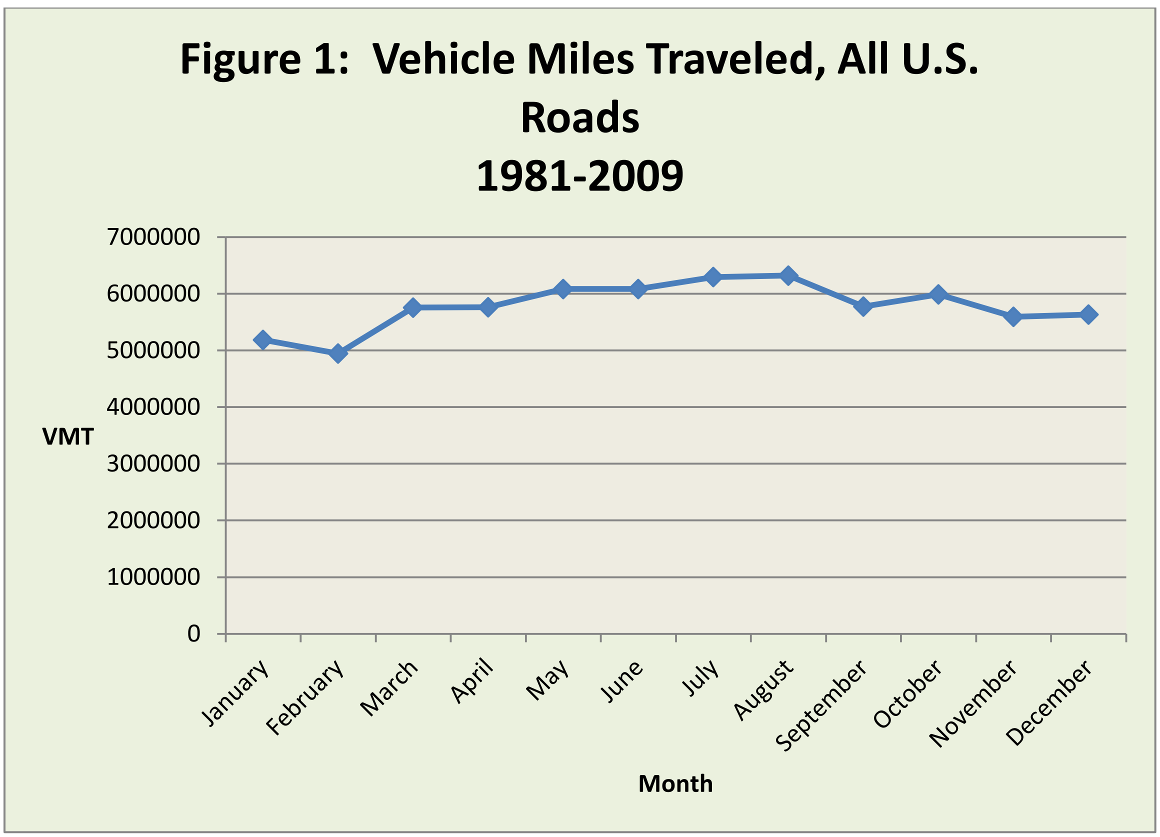
Appendix

Table A-1: U.S. Speed Limit Laws, 1974 – 1995		
Date	**Law**	**Action**
January 2, 1974	Emergency Highway Conservation Act	Established NMSL of 55 MPH
January 4, 1975	Public law 93-643	Made NMSL permanent
April 2, 1987	Surface Transportation and Uniform Relocation Assistance Act	Allowed states to raise rural Interstate speed limits to 65 MPH
November 28, 1995	National Highway Designation Act	Fully repealed NMSL and conferred speed limit determination to states



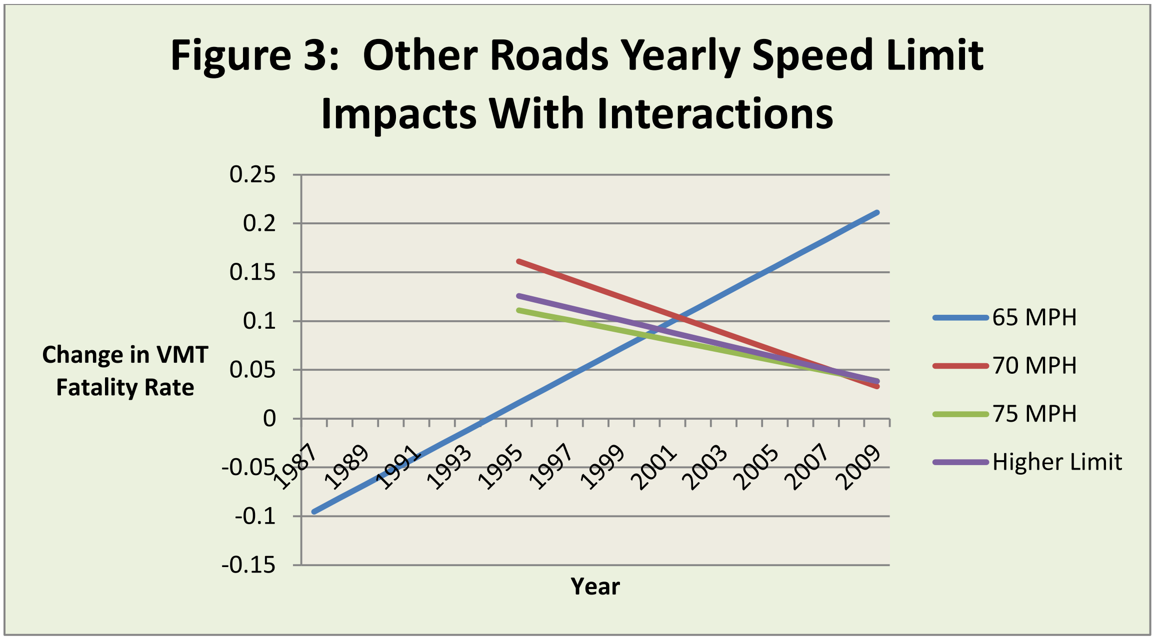


Figure 3: Other Roads Yearly Speed Limit Impacts With Interactions
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
Change in VMT Fatality Rate
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year
65 MPH
70 MPH
75 MPH
Higher Limit

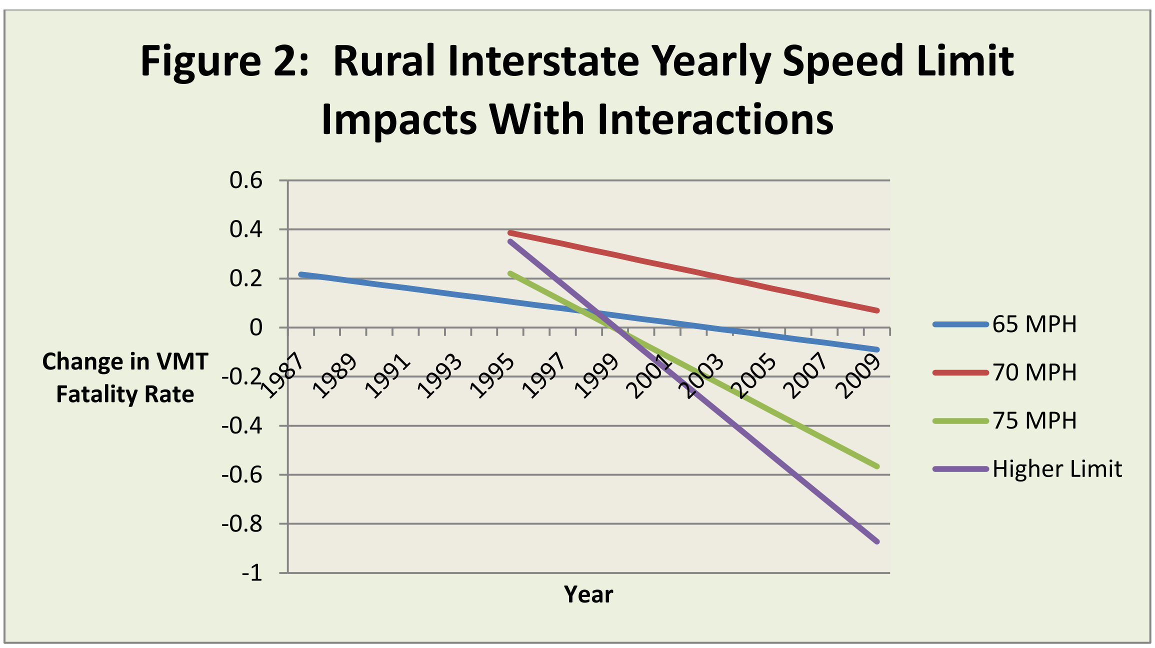


Figure 2: Rural Interstate Yearly Speed Limit Impacts With Interactions
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Change in VMT Fatality Rate
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year
65 MPH
70 MPH
75 MPH
Higher Limit