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Do Vehicle Safety Inspection Programs Lead to Lower Fatality Rates?

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DISCLAIMER

A DATA-DRIVEN ASSESSMENT OF SAFETY INSPECTION PROGRAMS' EFFICACY

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ABSTRACT

Fifteen U.S. states currently require vehicles to undergo periodic safety inspections, to ensure safe tire tread-depth, functioning lights, mirrors and wipers, etc. The effectiveness of these programs has been called into question by several legislatures; since 2000, four of these states have repealed their inspection programs, finding them not to be cost-effective. Applying statistical models to data from the publicly available Fatality Analysis Reporting System (FARS), we analyze the impact of the abolition of safety inspections in these states, on the occurrence of fatal road accidents. We find that on average, the mean number of road fatalities per unit population was higher, five years following the repeal than two years prior. We also propose a generic model to estimate the potential impact of instating or repealing a safety inspection program for a given vehicle population.

Keywords: Vehicle safety, I/M Programs, FARS, statistical analysis

1. INTRODUCTION

Technological advances, and safety regulations continue to improve the safety of new light-duty motor vehicles (LDV's). However, routine maintenance—to ensure proper tire tread-depth, effective brakes, functioning lights, etc.,—is critical to the continued safe operation of LDV's. To ensure adherence to these safety requirements, many jurisdictions (including all E.U. member nations) administer vehicle inspection and maintenance (I/M) programs. Typically, these programs require vehicles to be inspected periodically, and only certified as road-legal after the completion of requisite maintenance to ensure they are safe to operate. In the United States, safety inspection programs (which are managed at the state-level) have received significant political opposition over the last half-century, leading to the abolition of I/M programs in several states. Figure 1 shows that while there were 32 states with I/M programs in the mid-1970's, more than half of these states have since repealed the programs. Much of this opposition posits that inspection programs are not an effective means of preventing road fatalities and are therefore a waste of time and money for vehicle-owners and administrative authorities.

As jurisdictions continue to debate the need for I/M programs, it is imperative that statistical analyses be conducted to assess the effectiveness of safety inspection programs, in achieving their stated aim of preventing road fatalities. Merrell et al. (1999) have applied econometric tools to assess the effectiveness of safety inspection programs, and while they concluded that I/M programs may not have any effect on fatality rates, their analyses are based on data from the 1970's and 80's, and do not benefit from more recent data. As a counterpoint, a time-series analysis conducted by Loeb and Gilad (1984), found the benefits of vehicle inspection programs to outweigh the costs. Other literature published around this time have all used limited datasets and had a high degree of variability in their conclusions on the effectiveness of safety inspection programs (Garbacz, 1990; Loeb, 1990). Sutter and Merrell (2002), go so far as to argue that safety inspections have absolutely no impact on highway safety, and that the states which continue to administer these programs do so purely due to the high "political transaction cost" of repealing them.

A more recent assessment of the abolition of New Jersey's I/M program asserted that there was no link between program repeal and fatal accident rates (Hoagland and Woolley, 2018). However, as discussed further in Section 2, our analyses differ from past literature in scope and methods. Unlike early studies, our research uses up-to-date, publicly available raw data on fatal motor vehicle accidents, from the

U.S. Department of Transportation. Second, rather than focusing on accidents in any one specific state, we intend to apply a pooled regression (and other panel data approaches) to data from every state in the country, allowing us to develop a more robust estimate of the population-adjusted rate of road-accident related fatalities, as a function of the presence or absence of an I/M program in that state. Third, and most importantly, our study considers the long-term effects of establishing or repealing an I/M program, rather than only the immediate effects, as is typical in the literature.

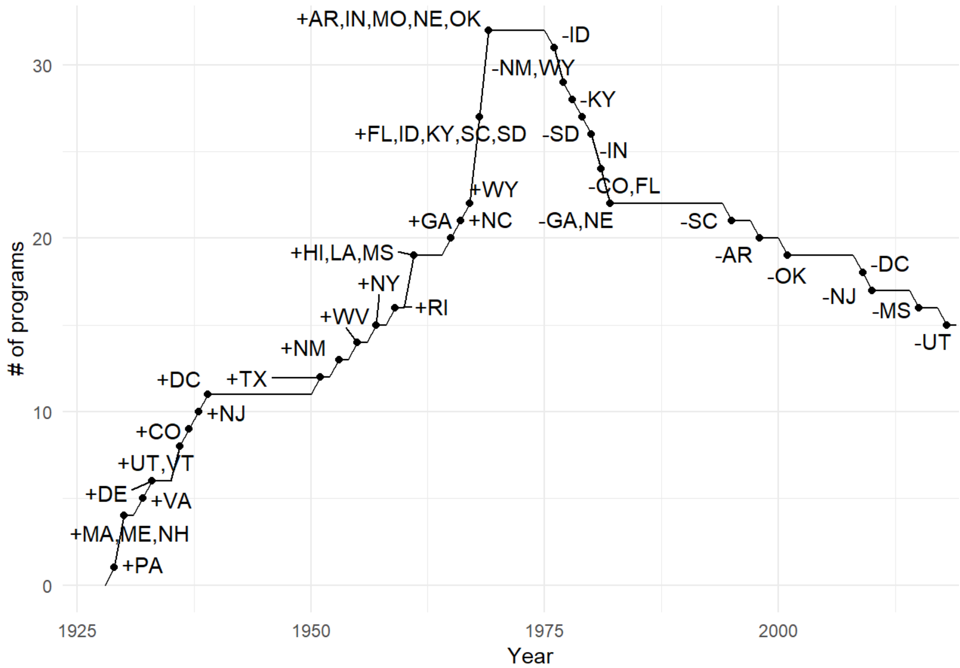

Figure 1: Since 1976, 17 U.S. states have repealed I/M programs

Table I: Nationwide annual road-fatalities have decreased steadily over time.

Year	Fatal Accidents	Vehicles Recorded	Persons Recorded	Total Fatalities	Year	Fatal Accidents	Vehicles Recorded	Persons Recorded	Total Fatalities
1988	42,130	62,703	112,958	*47,087*	2003	38,477	58,877	101,862	*42,884*
1989	40,741	60,870	109,866	*45,582*	2004	38,444	58,729	100,760	*42,836*
1990	39,836	59,292	107,777	*44,599*	2005	39,252	59,495	101,262	*43,510*
1991	36,937	54,795	99,369	*41,508*	2006	38,648	58,094	98,356	*42,708*
1992	34,942	52,227	95,691	*39,250*	2007	37,435	56,253	94,338	*41,259*
1993	35,780	53,777	97,589	*40,150*	2008	34,172	50,660	84,510	*37,423*
1994	36,254	54,911	98,945	*40,716*	2009	30,862	45,540	76,510	*33,883*
1995	37,241	56,524	102,102	*41,817*	2010	30,296	44,862	74,863	*32,999*
1996	37,494	57,347	103,347	*42,065*	2011	29,867	44,119	73,364	*32,479*
1997	37,324	57,060	102,197	*42,013*	2012	31,006	45,960	76,436	*33,782*
1998	37,107	56,922	101,100	*41,501*	2013	30,202	45,101	74,331	*32,893*
1999	37,140	56,820	100,666	*41,717*	2014	30,056	44,950	73,711	*32,744*
2000	37,526	57,594	100,716	*41,945*	2015	32,538	49,478	81,620	*35,484*
2001	37,862	57,918	101,175	*42,196*	2016	34,748	52,714	86,474	*37,806*
2002	38,491	58,426	101,784	*43,005*	2017	34,247	52,645	84,921	*37,133*

2. DATA

The United States National Highway Traffic Safety Administration (NHTSA) administers a database through the Fatality Analysis Reporting System (FARS), which has, since 1976, collected data on motor-vehicle accidents anywhere in the United States, which resulted in at least one fatality. FARS contains information on each accident (location, weather and road conditions, number of vehicles involved, etc.,), in addition to information on individual vehicles involved in these accidents (make and age, vehicle-related contributing factors to the accident, speed, etc.,), as well as demographic information of drivers, passengers and pedestrians. More details, including a full list of fields in the FARS data is available in NHTSA's *Analytical User Manual* (NHTSA, 2016). The models presented below were developed from thirty years' FARS, from 1988 to 2017 (the most recent year for which FARS data are available). During this time, five U.S. states and the District of Columbia repealed their I/M programs. Table I lists some descriptive statistics from these data and shows that the total number of road fatalities have been rather consistently, if slowly, reducing over time. In 2017, 37,133 fatalities were reported nationwide, resulting from 34,247 accidents. These involve all crashes including, for example, those between passenger vehicles and larger highway trucks.

In parallel, we also studied the existence of vehicle component failure-related fatal crashes in FARS. The FARS database has fields that represent "vehicle contributing factors" for issues like tires or brakes that were suspected to have had a contributing role in a crash. Such data should be valuable for a study premised on whether safety inspection program activities can reduce fatalities. However, the degree to which different states and accident investigators enter data into these fields varies widely. A summary of our data analysis on these parts of the FARS data is presented in Appendix A.

3. METHODS

The stated aim of most I/M programs is to reduce fatalities from road accidents by ensuring that vehicles are safe to operate. Therefore, we develop models which aim to assess whether there is any correlation between the presence of an I/M program in a state, and the number of fatalities involving vehicles registered in that state, each year. Specifically, we develop regression models against the population adjusted number of annual statewide fatalities, represented in *fatalities per 100,000 population* (Equation 1).

Equation 1

$$Adjusted\ Fatality\ Rate_{state=A,year=B} = \frac{Total\ Number\ of\ Fatalities\ in\ Accidents\ in\ Year\ B,\ where\ at\ least\ one\ vehicle\ was\ registered\ in\ State\ A}{Population\ of\ State\ A\ in\ Year\ B}$$

It must be noted that while the analyses we conduct are at the state-level, the "state" considered is not the state in which the fatal accident occurred, but in-fact the state to which each vehicle involved in the accident was registered. As discussed in more detail by Hoagland & Wooley (2018), this approach accounts for the fact that vehicles are regulated (and specifically, subject to inspections) based on the state in which they are registered, regardless of where the vehicle was when an accident occurred. Since FARS provides time-series for accidents in each of the fifty states, over a long duration, we developed regressors by-year and by-state, and applied panel data methods to these regressors. Both variations of the model presented in this paper are independently pooled data models. Pooled models were selected since regulations vary between states, and since we assume that the fatality rates in each state and year are independent of fatality rates in other states or years.

3.1 REGRESSORS

In order to develop a panel data type regression model, where the predicted variable is the adjusted fatality rate, as discussed above, we developed a number of regressors (by-year and by-state), which are listed in Table II. Using these regression features, we developed two variations on a pooled panel data model as discussed below.

3.2 FIRST REGRESSION MODEL

We develop a pooled panel data model, regressing every regressor discussed in Table II, against the adjusted fatality rate.

Table II: Panel regression features were developed from FARS data.

Feature	Data Source	Notes
Vehicle mean age	FARS	From vehicles in the FARS database for a given year, which are registered in the given state.
Mean age of driver		
Mean number of vehicles in each accident		
Proportion of vehicles with listed "contributing vehicle failure".		
Proportion of vehicles involved in a DUI-related accident		
Proportion of vehicles involved in speeding-related accident		
Mean number of lanes at accident site		
Proportion of vehicles involved in accident during recorded inclement weather		
VMT per capita	NHTSA (VM-202)	
Proportion of VMT on rural roads		
Active I/M program?	GAO 2015	Binary variable (1 = program exists, 0 = no program)

3.3 FINAL MODEL

The final model was therefore a pooled panel data model, regressing six variables from FARS against the adjusted fatality rate (fatalities/100,000pop).

4. RESULTS

The results from the first model, presented in Table III, show that nine out of the eleven regressors considered appear to have a statistically significant relationship with our dependent variable. The most significant positive effect (increase in adjusted fatality rate with increase in regressors) appears to be from the proportion of miles driven on rural roads. The presence of an I/M program also showed a negative effect of *-0.86.* This can be interpreted as that the presence of a safety inspection program in that state reduces the number of fatalities in a given year by 0.86 fatalities/100,000 population. It is worth noting in this model that the coefficients for the proportion of accidents where inclement weather were recorded, are negative (indicating that, as per the model, when an increased proportion of vehicles registered in a state are involved in accidents due to inclement weather, the adjusted fatality rate reduces). This is a counter-intuitive finding and warrants further analysis. However, based on this first model, it appears that two variables – mean vehicle age, and mean number of vehicles involved in each accident, were found to not be significant ($p < 0.05$). Therefore, these two variables were excluded from analysis in the final model.

Table III: In the first model, several regressors were found to be significant.

Predictors	Estimates	CI	p-value
(Intercept)	6.41	-2.28 – 15.10	0.149
Vehicle Mean Age	0.01	-0.35 – 0.37	0.967
Mean Number of Vehicles in Accident	-2.66	-5.83 – 0.51	0.101

Proportion w/ DUI	5.69	0.31 – 11.07	0.039
Proportion w/ Contributing Vehicle Failure	-23.21	-42.15 – -4.26	0.017
Mean Number of Lanes	3.36	1.62 – 5.10	<0.001
Proportion w/ Speeding	-7.63	-12.26 – -3.01	0.001
Proportion w/ Inclement Weather	-10.98	-16.18 – -5.77	<0.001
Mean Driver Age	-0.2	-0.28 – -0.12	<0.001
Proportion of VMT on Rural Roads	13.84	11.04 – 16.65	<0.001
VMT Per Capita	0.01	0.01 – 0.01	<0.001
Active IM Program? (Binary Variable)	-0.86	-1.71 – -0.01	0.048
Dependent Variable:	Fatalities/100,000 Population		
Observations:	409		
R^2 / R^2 adjusted	0.689 / 0.680		

Our final model shows (Table IV) that several of our regression variables may be statistically significant. Here too, there is a counter-intuitive, negative effect of recorded instances of speeding and inclement weather, which warrant further analysis. The highest positive effects (i.e., regressors correlated to an increase in adjusted fatality rate) were attributable to the proportion of miles typical drivers in each state drive on rural roads (vs. urban roads and highways), followed by the proportion of fatal accidents involving drivers under the influence of alcohol or drugs (DUI). Regarding the presence of I/M programs, the lagged term (i.e., was there an active I/M program in this state five years ago) was found with a high confidence ($p < 0.01$) to have a negative impact on adjusted fatality rates, with a coefficient estimate between -0.42 and -1.97. This may be interpreted to mean that in states which had an inspection program five years before any year being analyzed, the number of road fatalities may be expected to be between 0.42 and 1.97 fewer per 100,000 citizens, than if the state did not have an inspection program. In real terms, for a state such as New Jersey (2017 population, 9.01 million), repealing an existing program could lead to 38-178 additional deaths in the fifth year after the program has been repealed.

Table IV: Final model shows I/M programs to be a significant predictor of adjusted fatality rate.

Predictors	**Estimates**	**CI**	**p-value**
(Intercept)	-0.27	-6.92 – 6.38	0.937
Proportion w/ DUI	3.93	-1.61 – 9.48	0.166
Proportion w/ Contributing Vehicle Failure	-21.45	-40.79 – -2.10	0.03
Mean Number of Lanes	3.07	1.38 – 4.75	<0.001
Proportion w/ Speeding	-5.45	-9.59 – -1.32	0.01
Proportion w/ Inclement Weather	-10.15	-14.66 – -5.64	<0.001
Mean Driver Age	-0.16	-0.24 – -0.09	<0.001
Proportion of VMT on Rural Roads	11.17	8.35 – 13.98	<0.001
VMT Per Capita	0.01	0.01 – 0.01	<0.001
Active IM Program? (lagged 5 years)	-1.2	-1.97 – -0.42	0.003
Dependent Variable:	Fatalities/100,000 Population		
Observations:	361		
R^2 / R^2 adjusted	0.716 / 0.709		

5. DISCUSSION

Our preliminary results show that the presence (or absence) of a vehicle safety inspection program in a U.S. state has a negative correlation to the population adjusted number of fatalities caused by motor accidents involving vehicles registered in that state. Moreover, they show that the ability of vehicle inspections to reduce road fatalities can potentially last for up to seven years. Conversely, our results point to that the negative effects of repealing an I/M program may also last for several years, and that as such, analyses of the relationship between road fatality rates and I/M programs should consider these long-term effects in order to fully capture the correlation.

These results also show that further analyses are required to explain findings surrounding some other regressor variables. For example, both models we constructed appear to show that in states and years where inclement weather was recorded more often, or where vehicle speeding was recorded more often, the adjusted fatality rate was lower. One possible reason for this may be that the resolution of these data in the FARS dataset are very low, and these fields are populated more accurately by first responders in some states than others. Alternatively, it could be that some part of the effects of these variables are already being captured by another variable or an externality. In the future, we intend to add more regressors to our model, to potentially better explain these trends, and to improve models' fit overall (i.e., to improve the R^2 value, a measure of the proportion of data which are correctly explained by our model).

Through the development of these models, we wish to quantify the impact of establishing or repealing vehicle safety inspection programs, allowing legislators to quantitatively estimate the impact of policy-changes on road fatalities in their specific jurisdiction or state, and thus better gauge the cost-effectiveness of I/M programs as a means of preventing road fatalities, in comparison to other possible policy interventions with the same aim.

6. FUTURE WORK

Going forward, we seek to improve on the model above in various ways. First, we believe that a fixed effects models would be more appropriate to use than a pooled model, specifically that we should consider multiple effects for the presence of state inspection programs over time. There could be one variable to note states that never had a program over the time period of the FARS data, and another to capture states who gained or lost a program. Such a model should more accurately capture the expected fatality rate changes associated with programs. Second, we would also like to use a longer time series of the FARS data, and explore the use of different metrics for the fatality rate beyond population, such as registered vehicles. Third, we will explore the use of a log-log based model to help better represent and communicate the percentage change results of fatality rates associated with changes in inspection programs. Finally, the FARS data used above was for all vehicle types, including passenger vehicles crashing into large commercial haul trucks. We also intend to explore the focused subset of crashes involving only passenger vehicles. We will try to collaborate with colleagues with more experience in statistical modeling using causal methods.

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