AUTO SAFETY IN THE 21st CENTURY: THE TRANSITION TOWARDS AUTONOMOUS DRIVING SYSTEMS

Vikram Maheshri[1]

Summary

Automotive fatality and accident rates have remained stubbornly stable in recent decades. Autonomous driving technologies have the potential to break through and meaningfully improve auto safety. In order to better help the Department of Transportation fulfill its mission to improve safety on America's roadways, we propose to analyze who stands to benefit and how much they stand to benefit from these new technologies. This will allow policymakers in the 21st century to better usher in the transition to a more fully autonomous transportation system.

Research Questions

Ever since Ford Motor Company mass produced the Model T more than a century ago, the automobile industry has introduced significant vehicle safety improvements such as automatic windshield wipers, shatterproof glass, headlights, improved braking, advances in body structure, collapsible steering columns, and occupant safety devices. These features, in combination with changes in driving behavior, particularly with respect to alcohol consumption and seat belt use, and improved roadways have led to a reduction in the national auto fatality rate from over 24 fatalities per 100 million vehicle miles travelled (VMT) in 1921 to 1.1 fatalities per 100 million VMT in 2019 just prior to the Covid pandemic.[2] However, modest declines in the fatality rate in the past two decades – and notable increases since 2020 – have naturally led to the question of what can be done to further improve auto safety.

In recent years, automakers have increasingly installed advanced driver-assistance systems (ADAS), which are a suite of safety features that use artificial intelligence to aid drivers in the operation of their vehicles. These features, such as adaptive cruise control and blind spot collision prevention, represent a substantive leap in safety technology as they can situationally take over the act of driving from the human operator. This represents a far greater level of substitutability for human attention than previous safety features. As autonomous driving technologies progress, it is likely that they will substitute entirely for human drivers at some point in the not too distant future.

If the 20th century was a story of technology complementing human drivers and the 22nd century will be a story of technology fully substituting for human drivers, then auto safety in the 21st century will be a story of the transition from a fully human operated fleet of vehicles to a fully autonomous fleet of vehicles. This transition will unfold along two margins: advanced technologies will gradually assume more driving responsibilities, and vehicles equipped with advanced driving technologies will gradually make up a greater share of vehicles on the road. Using the experience of the last decade or so, we propose to better understand the impending auto safety transition by answering the following questions:

- Who are the early adopters of ADAS? What influences their adoption decisions?

[1] Department of Economics, University of Houston

[2] *Motor Vehicle Traffic Fatalities and Fatality Rates, 1899-2020*, National Highway Traffic Safety Administration.

- How effective have ADAS technologies been in reducing accidents and fatalities?
- Do ADAS-equipped vehicles generate spillover safety benefits to non-ADAS-equipped vehicles?
- What is the appropriate role of public policy to speed up the auto safety transition?

Answering these questions is critical, as autonomous driving technologies are a prime candidate for further improving auto safety in an environment in which the fatality rate has been stagnant.

Data and Methods

Answering these questions will require three complementary sources of data: (1) data on motorists and the specific vehicles that they purchase, (2) data on accidents and the specific vehicles involved, and (3) data on vehicles and the advanced autonomous safety features that they are equipped with. Collectively, the data will enable us to assess the effectiveness of ADAS at reducing accidents and fatalities and to identify early adopters.

We propose to construct a novel dataset that merges all three sources of information. We will do so by combining a large, representative survey of registered drivers in Texas that will be obtained from an outside marketing firm with administrative data on the universe of all accidents in Texas that have been reported to the police since 2010 and hand-collecting data on vehicular safety features directly from auto manufacturers.

We will leverage the staggered roll-out of ADAS in similar vehicles to identify the direct effects of ADAS on accidents and fatalities. We will leverage spatial variation in the adoption of ADAS to identify the spillover benefits of these technologies. These will be inputs into a conceptual policy framework to assess the potential benefits of accelerating adoption of existing and hypothetical advanced driving technologies.

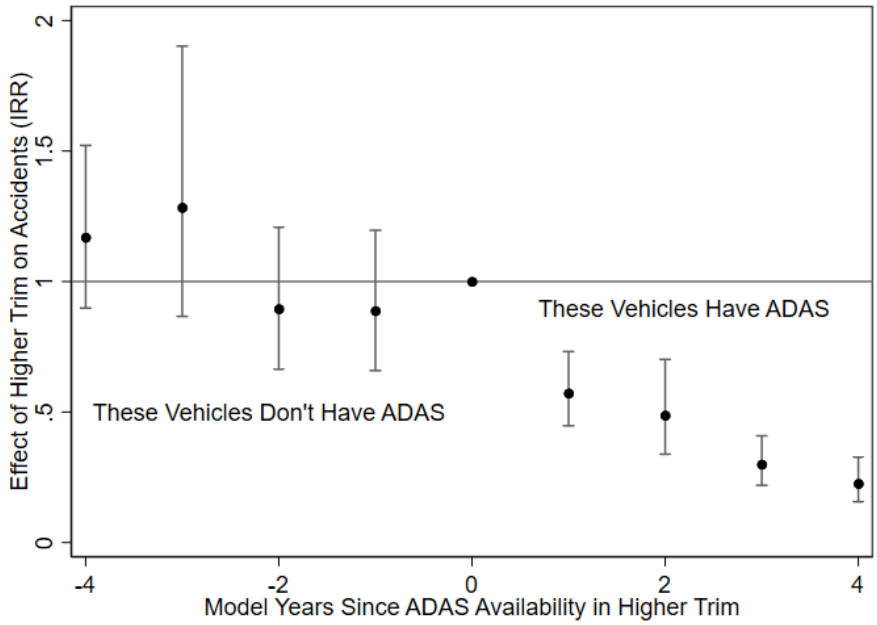
Preliminary Findings

In preliminary work, we have obtained administrative data on accidents and have constructed the accident histories of all registered vehicles in Texas from 2000 to 2018. We have also hand collected data on the availability of ADAS-related safety features in all vehicles that were sold at all trim levels over this period. These two data sources are merged with a matching procedure that decodes the precise trim level of a vehicle from its Vehicle Identification Number.

Using this data, we have arrived at some preliminary results that speak to some of the questions detailed above. Specifically, we have exploited the staggered rollout of the availability of ADAS over time and across different automobile makes, models and trims to identify the causal effect of early ADAS technologies on accident risk. Because vehicles of the same model year, make and model may differ in whether they are ADAS equipped – generally luxury trims will be equipped with ADAS earlier than standard trims – we can identify the effect of ADAS technologies on accident risk under the assumption that drivers did not systematically opt for higher trim level vehicles solely because of the availability of ADAS in its first year of availability. This is a considerably weaker assumption than standard assumptions from this literature.

We find that early forms of autonomous safety systems that assist in both the forward dimension (e.g., automatic emergency braking), and the lateral dimension (e.g., blind spot collision prevention) reduce the prevalence of all accidents by over 50% and they reduce the prevalence of fatal accidents by nearly two thirds. These exceed the estimated effects of other safety technologies such as seat belts and air bags. To give some context and intuition for our identification strategy, we present an event-study style plot in Figure 1.

Figure 1. Event-Study Style Plot of the Effects of ADAS on Accident Prevalence



Higher trim vehicles that at some point are equipped with ADAS exhibit no conditional difference in accident prevalence prior to treatment (we estimate an incident rate ratio of 1), but they exhibit a large and persistent difference in accident prevalence of roughly half after they are treated with ADAS (we estimate an incident rate ratio around 0.5).

Importance of the Findings for the US Department of Transportation

The large, estimated effects of ADAS suggest that policymakers may want to consider mandating these technologies in new vehicles. Indeed, government policies have sought to improve automobile safety by requiring motorists to have a valid driver's license, prohibiting driving under the influence of alcohol or drugs, setting, and enforcing speed limits, and requiring vehicles to satisfy National Highway Traffic Safety Administration (NHTSA) safety standards. A long line of research, however, has questioned both the justification for and effectiveness of government automobile safety policies because consumers' voluntary adoption of vehicles with new safety devices may be promote safety more efficiently and because drivers may adjust their behavior when a new safety technology is installed in their vehicle.[3]

[3] For example, Thaler and Rosen (1976) and Mannering and Winston (1987) found that although federal law in 1968 required seat belts to be installed in all vehicles except buses, many motorists eschewed the safety benefits of seat belts based on a rational cost-benefit assessment of the time and bother costs to fasten seat belts and their effect on

As such, proper guidance to policymakers on mandating new AI enabled safety technologies rests on obtaining two pieces of information: the direct benefits of these technologies on the drivers who choose to adopt them, the indirect external benefits of these technologies on drivers who do not choose to adopt them. We propose to develop a theoretical framework in which these two benefits can be combined to assess the social value of mandating advanced safety technologies. Complicating this exercise is the fact that there is likely substantial heterogeneity in these benefits across drivers, and this heterogeneity is likely to be correlated to the propensity of drivers to be involved in accidents. For this reason, we must estimate a model of the early adoption of ADAS using data on motorists and the vehicles they purchase being particularly sensitive to the heterogeneity across motorists that is observable to us (and would be observable to policymakers).

As opposed to being purely a retrospective analysis of a safety technology that is in the process of being rolled out throughout the nation's vehicular fleet, this project is intended to be forward looking. That is, our policy framework will accommodate estimates of the efficacy of more advanced technologies from the engineering community in order to determine the conditions that an autonomous driving technology would need to satisfy in terms of internal and external effectiveness, cost to motorists, and benefits along the entire distribution of driver safety.

As vehicle technology evolves in future decades to fully autonomous operations, we may enjoy potential social welfare gains in the trillions of dollars from reductions in safety, congestion, and emissions externalities and violent altercations from police stops when it evolves in future decades to fully automated operations. However, automobile safety policies have not historically been guided by a careful assessment of the costs and benefits of the policy to all members of society. We propose to fill this gap.

Research Team

This research will be conducted by a three-person team as follows:

PI: Vikram Maheshri, Associate Professor, Department of Economics, University of Houston
Co-Investigator: Clifford Winston, Senior Fellow, Economic Studies, The Brookings Institution
Research Assistance: Economics PhD Student, University of Houston

Conflict of Interest Statement

Neither the PI nor the co-investigator have any relevant conflicts of interest to disclose.

---

reducing the probability of a fatal accident. Lave and Weber (1970), Peltzman (1975), and Wilde (1976) argued that even when seat belts were fastened, motorists reduced their technological effectiveness by driving faster to reduce travel time, thereby maintaining their exposure to accident risk. Winston, Maheshri, and Mannering (2006) found that motorists' increase in risky driving behavior appeared to offset the initial effectiveness of airbags, which were mandated in 1998.

References

Lave, Lester, and Warren E. Weber. 1970. "A Benefit-Cost Analysis of Auto Safety Features," *Applied Economics*, volume 2, number 2, pp. 265-275.

Mannering, Fred, and Clifford Winston. 1995. "Automobile Air Bags in the 1990s: Market Failure or Market Efficiency?," *Journal of Law and Economics,* volume 38, October, pp. 265-79.

Mannering, Fred, and Clifford Winston. 1987. "Recent Automobile Occupant Safety Proposals," in Clifford Winston and Associates, *Blind Intersection? Policy and the Automobile Industry,* Brookings Institution, pp. 68-88.

Mosquet, Xavier, Michelle Andersen, and Aakash Arora. 2016. "A Roadmap to Safer Driving Through Advanced Driver Assistance Systems," *Auto Tech Review,* volume 5, pp. 20-25.

Peltzman, Sam. 1975. "The Effects of Automobile Safety Regulation," *Journal of Political Economy,* volume 83, August, pp. 677-725.

Thaler, Richard, and Sherwin Rosen. 1976. "The Value of Saving a Life: Evidence from the Labor Market," in Nestor E. Terlecky, editor, *Household Production and Consumption,* National Bureau of Economic Research.

Wilde, Gerald J.S. 1982. "The Theory of Risk Homeostasis: Implications for Safety and Health," *Risk Analysis*, volume 2, December, pp. 209-25.

Winston, Clifford, and Quentin Karpilow. 2020. *Autonomous Vehicles: The Road to Economic Growth?,* Brookings Institution Press, Washington, DC.

Winston, Clifford, Vikram Maheshri, and Fred Mannering. 2006. "An Exploration of the Offset Hypothesis Using Disaggregate Data: The Case of Airbags and Antilock Brakes," *Journal of Risk and Uncertainty,* volume 32, March, pp. 83-99.