Appendix to *Innovation Sticks: The Limited Case for Penalizing Failures to Innovate*

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This Appendix first describes the data and methodology employed in our automobile-fatalities analysis. It then supplements Parts II and III of our Article by providing additional examples of innovation penalties in action in addition to background calculations for the fatality analysis.

I. DATA AND METHODOLOGY

Our automobile-fatalities analysis is based on fatality rates per 100,000 registered vehicles by vehicle manufacturer for the years 2000 to 2011. After calculating base fatality rates, we adjust these rates to account for regional variation in fatality rates and between-manufacturer variation in vehicle distribution across the United States.

The crash-fatality data are from the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS), which includes a comprehensive report of every fatal accident in the United States. Each vehicle involved in the accident is required to fill out an accident report. We use four variables in our analysis: car make (manufacturer), body type, number of total fatalities in the crash, and number of fatalities in the vehicle.

We limit our analysis to passenger vehicles—that is, vehicles with a FARS body-type code under forty. This includes cars, SUVs, vans, and light trucks. Vehicles with codes of forty or over include semitrailer trucks, buses, motor homes, tractors, and motorcycles.[1] Notably, we eliminate vehicles, not crashes. For

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1 See National Highway Traffic Safety Administration, *Electronic 2009 FARS Coding and Validation Manual* 275–79 (National Center for Statistics and Analysis 2010).

example, for an accident involving a motor home and a pickup truck, we retain the pickup data but not the motor home data.

We limit our analysis to thirty-seven manufacturers, which represent 99.4 percent of vehicles involved in fatal crashes from the years 2000 to 2011. The manufacturers that we do not consider are either out of business (for example, American Motors and Plymouth) or too rare to produce reliable fleet-size data (for example, Maybach and Ferrari).

Each vehicle-level observation in the FARS data includes two data points regarding fatalities: total fatalities in the crash and fatalities inside the vehicle. From these two numbers, we can further determine external fatalities—people killed while inside other cars or while walking or bicycling—which is equal to total fatalities minus fatalities inside the vehicle. This external-fatalities number can be further decomposed into (1) external fatalities outside vehicles—meaning pedestrians or bicyclists—calculated by subtracting the total number of fatalities inside all vehicles from the total number of fatalities in crashes; and (2) external fatalities inside vehicles, which is the total number of external fatalities minus the external fatalities outside vehicles.

An example might help illustrate these numbers. Consider a crash with five fatalities. The crash involves three cars: A (one fatality), B (two fatalities), and C (zero fatalities). There are two additional fatalities outside of cars. The total-fatality number assigned to all three cars is five. The fatality-in-vehicle numbers are one, two, and zero, respectively. The external-fatality number for A is four, for B is three, and for C is five. The external-fatality (not-in-vehicle) total number is two for all cars. And the external-fatality (in-vehicle) total number is two less than the external-fatalities number, or two, one, and three, respectively.

Because crashes often include more than one vehicle, our total-fatality numbers are often double counted, and external-fatality numbers may also be counted more than once. We attribute the entire accident to each vehicle involved, a practice that is consistent with the regulatory doctrine.

To develop a normalized scale on which to compare manufacturers, we utilize vehicle-registration data from a survey conducted by the Federal Highway Administration (FHWA). The FHWA's Nationwide Household Travel Survey (NHTS) asked Americans in 2001 and 2009 the makes of their cars, among other things. The number of observations in the surveys was 69,000 in 2001[2] and 150,000 in 2009.[3] Because the sampling was not purely random, the NHTS provides analytic weights that represent how many real households are represented by each household surveyed.

From these data, we determine fleet proportion by manufacturer. We linearly interpolate fleet proportion between survey years and use the fleet proportion in 2001 for 2000 and the fleet proportion in 2009 for 2010 and 2011. The year 2009 was the only one that included the manufacturers Smart and Land Rover, so our numbers for those manufacturers reflect only the years 2009 to 2011.

By multiplying the fleet proportion by the number of registered vehicles in the United States—data aggregated from state records by the US Department of Transportation (DOT)—we obtain the total number of registered vehicles in the country by make.

Using the sum of each type of fatality (total, in vehicle, external, inside-car external, and outside-car external) by manufacturer and year as well as the total number of registrations by manufacturer and year, we calculate the number of fatalities per 100,000 registered vehicles by manufacturer. These are our unadjusted fatality rates.

However, some manufacturers may sell more cars in comparatively more dangerous parts of the country than other manufacturers, thus introducing an upward bias to their fatality rates. To control for regional variation in fatality rates and manufacturer variation in vehicle location, we divide the country into four regions consistent with the US Census Bureau's delineation of geographic regions.[4] Using the fatality data and the DOT's state-by-state registration data, we determine how much above or below the weighted-mean fatality rate each region is each year, when the weight is the region's proportion of national registrations. Then, using the NHTS data, we determine the distribution of vehicles by manufacturer across the four regions. The 2001 and 2009 vehicle distributions are averaged to compute each manufacturer's distribution for all years, which we

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2 Federal Highway Administration, *Introduction to the 2009 NHTS* (DOT), archived at http://perma.cc/V8UF-PVN2.

3 Federal Highway Administration, *2009 National Household Travel Survey: User's Guide* *1-2 (DOT, Oct 2011), archived at http://perma.cc/3398-4WJA.

4 See *Census Regions and Divisions of the United States* (Census Bureau), archived at http://perma.cc/29E7-78SQ.

assume does not change. Using these two pieces of information, we can calculate an adjusted rate (fatalities per 100,000 registered vehicles) for each car using the formula:

$$(\text{adjusted rate})_{iy} = (\text{unadjusted rate})_{iy} - \Sigma\,(\text{share}_{ir} * \text{adjustment}_{iyr}),$$

in which *i* indexes manufacturer, *y* year, and *r* region; *share* is that car manufacturer's market share in that region; and *adjustment* is the difference between each region's fatality rate and the national weighted mean. We subtract rather than add in order to adjust manufacturers' rates down if their cars are more prevalent in high-fatality regions. We then use these adjusted rates in our analysis.

Our data, then, comprise the thirty-seven manufacturers over twelve years, and each manufacturer-year includes data on the estimated total number of registrations in that year and each of the fatality rates per 100,000 registered vehicles.

II. Supplement: Additional Existing Examples

A. California's Zero Emission Vehicle Mandate

Another example in the fuel-efficiency area illustrates the potential of sticks that are much more ambitious and also more technology specific. In 1990, California introduced the Zero Emission Vehicle (ZEV) mandate, requiring carmakers operating in California to develop automobiles with zero emissions.[5] The 1990 version of ZEV required 2 percent of California sales to be zero emissions by 1998, 5 percent by 2001, and up to 10 percent by 2003; manufacturers faced a $5,000 penalty per vehicle that was short of the requirement.[6] In 1990, battery-powered electric vehicles were the only option for meeting this requirement. Only General Motors was working on an electric car in the 1980s—the Impact—which was not ready for commercialization.[7] Thus, the ZEV mandate was in reality a mandate to do the R & D needed to produce viable electric cars. Carmakers viewed

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5 See Philippe Larrue, *Lessons Learned from the Californian ZEV Mandate: From a "Technology-Forcing" to a "Market-Driven" Regulation* *15 (Groupement de Recherches Economiques et Sociales, June 2003), archived at http://perma.cc/6LAY-RWDZ.

6 Id at *6. Several other states also adopted the standards, increasing their effect. See id.

7 See *EV1 Electric Automobile* (National Museum of American History), archived at http://perma.cc/33GR-54EC.

the mandate as extraordinarily demanding, and they insisted that it could not be met.[8]

California's ZEV program does, however, seem to have spurred research and innovation. The best evidence of this comes from patent patterns,[9] emphasizing the point that we make in our Article: carrots and sticks can be—and in many cases are and should be—combined. The number of patents for electric-vehicle-related technology increased dramatically in the period from 1992 to 1998.[10] General Motors purportedly spent $1 billion on ZEV technology during this time period.[11] Also in the early 1990s, a number of high-tech California firms sprung up to develop products for the ZEV market.[12] And within existing battery companies, researchers turned some of their attention to the electric-car market.[13]

The ZEV program appears to be a good candidate for sticks for the same reasons described in our discussion of the CAFE program.[14] In addition, the ZEV program helps illustrate some of the limits of innovation sticks that we describe more theoretically in Part I of the main text.[15] The ZEV program arguably represents the government's attempt to pick winners, and it has not been fully successful in projecting the possible pace of technological change. In 1996, California decided to suspend the 1998 and 2001 deadlines because battery technology was not progressing quickly enough.[16] The ZEV mandate was further modified to allow hybrid and other vehicles to count for partial ZEV credits.[17] In the terms we use in our Article, sticks may face credibility problems, perhaps particularly when they are applied to powerful industries. Nonetheless, these problems may not be insurmountable.

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8 See Larrue, *Lessons Learned from the Californian ZEV Mandate* at *7 (cited in note 5).

9 See Andrew Burke, Ken Kurani, and E.J. Kenney, *Study of the Secondary Benefits of the ZEV Mandate* *11–12 (University of California, Davis Institute of Transportation Studies, Aug 1, 2000), archived at http://perma.cc/D6K6-WJMA.

10 See id at *17.

11 See Committee on State Practices in Setting Mobile Source Emission Standards, *State and Federal Standards for Mobile-Source Emissions* 169 (National Academies 2006).

12 See Larrue, *Lessons Learned from the Californian ZEV Mandate* at *9 (cited in note 5).

13 See id at *10.

14 See Part II.A.1 in the main text.

15 See Part I.C in the main text.

16 See Larrue, *Lessons Learned from the Californian ZEV Mandate* at *11–12 (cited in note 5).

17 See id at *15; Gary E. Marchant, *Sustainable Energy Technologies: Ten Lessons from the History of Technology Regulation*, 18 Widener L J 831, 838 (2009).

Notably, the ZEV program continues—California has recently announced a 15.4 percent ZEV goal by 2025[18]—and it appears to have had positive effects, although it has not had all the effects that were desired. The field of electric cars has dramatically expanded in recent years, with Chevrolet, Ford, Honda, Hyundai, Nissan, Tesla, and Toyota all offering or about to offer electric cars.[19] Battery-powered electric cars are also no longer the only option: many car companies have announced plans for hydrogen–fuel cell cars to be released by 2016.[20]

B. Tobacco Look-Back Penalties

In an effort to resolve litigation against the tobacco industry while generating revenue for the states and reducing the prevalence of youth tobacco use, tobacco companies and states reached a proposed settlement agreement in 1997 that included an element that would have produced failure-to-innovate incentives.[21] While the agreement's implementing legislation was ultimately unsuccessful, its "look-back" provisions—which were excluded from subsequent settlements[22]—represented potential innovation sticks aimed at reducing youth-smoking rates.

Specifically, the proposed agreement established state-specific standards for reductions in youth smoking. For example, the agreement required that, within ten years after its implementation, states would have had to have effected at least a 60 percent reduction in youth-cigarette-use rates and a 45 percent reduction in smokeless tobacco use among youths.[23] If these standards were not met, industries would have been subject to a mandatory fine calculated from the estimated profits gained from youth consumers in excess of the standards, with an inflation-adjusted maximum fine of about $2 billion for each industry.[24] The potential fine could have been reduced by a maximum of 75 percent for tobacco companies on a showing of full implementation of measures to reduce tobacco use among youths, reasonable

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18 John O'Dell, *Will California's Zero-Emissions Mandate Alter the Car Landscape?* (Edmunds.com, May 27, 2015), archived at http://perma.cc/U2EP-6HRA.

19 Id.

20 Id.

21 See *Proposed Tobacco Industry Settlement* (CNN, June 20, 1997), archived at http://perma.cc/59BC-FK76 ("Proposed Tobacco Settlement").

22 Michael Givel and Stanton A. Glantz, *The "Global Settlement" with the Tobacco Industry: 6 Years Later*, 94 Am J Pub Health 218, 219–20 (2004).

23 *Proposed Tobacco Settlement* (cited in note 21).

24 See id.

efforts to curtail youth tobacco use, and the absence of actions to thwart meeting the reduction standards.[25] In theory, these look-back penalties represented a robust incentive for tobacco manufacturers to reduce youth tobacco use. However, unlike our preferred implementation, which would be technology agnostic, the proposed incentives were substantially tied to states enacting a prespecified set of provisions.[26]

A nontraditional measure makes sense here to address the market failure associated with the incentives that companies have to increase youth smoking despite its social consequences. A stick approach is plausibly more appropriate than a carrot approach because this is a good example of an area in which we have few concerns about undercompensation and because there are many inexpensive ways for companies to reduce youth smoking (for example, by shifting ad campaigns or developing savvy antismoking campaigns targeted at youths). Additionally, if requiring companies to internalize more of the costs of youth smoking were to force some of them out of the industry or to raise the price of cigarettes, this would likely be a net gain from a welfarist or public health perspective. Again, this example raises concerns about the credibility of sticks, and it also gives us an example of a distributional concern in play: net transfers to tobacco companies in order to reduce youth smoking would likely be seen as perverse, insofar as the companies are thought—particularly in the course of the litigation in question—to bear responsibility for the problem in the first place. The issue is not merely moral; if we reward firms for reversing negative effects for which they are considered responsible, we might reasonably expect more bad effects to follow.

C. Negligent Failure to Test and the State-of-the-Art Defense in Tort Law

Companies that manufacture faulty products face liability in tort if they fail to comport with legal requirements.[27] Tort law thus acts as a stick, and in certain dimensions it may serve as an innovation stick. Particularly relevant here are the doctrine

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25 See id.

26 See Jeremy Bulow and Paul Klemperer, *The Tobacco Deal*, 1998 Brookings Papers on Econ Activity: Microecon, 323, 382 (1998) (arguing that "the incentives for reducing underage smoking should be directed at state governments, which would be responsible for the efficacy of antismoking programs").

27 See Restatement (Third) of Torts: Products Liability § 1 (1998).

regarding a company's duty to test its products and the so-called state-of-the-art defense to tort liability. These obligations arise under state law and are not uniform across jurisdictions. For our purposes, it is sufficient to look to the Restatement (Third) of Torts ("the Restatement") and at certain leading cases that reflect the general view of these doctrines.

Under the Restatement, there are three types of product defects: (1) design defects, which occur when the foreseeable risks of the product could be reduced by the manufacturer's "adoption of a reasonable alternative design"; (2) manufacturing defects, or departures from the planned design; and (3) warning defects, which occur when the manufacturer could have reduced the risk of a product with instructions or warnings when the risk was reasonably foreseeable to the manufacturer.[28] Courts have typically applied the duty to test indirectly, as a way to get at the existence or absence of such design, manufacturing, or warning defects.[29] The manufacturer's knowledge may be relevant to the feasibility of alternative designs or to the reasonableness of warnings, and the duty to test is a way of imputing to the manufacturer knowledge of these possible designs or warnings.[30]

The intuition behind the duty to test is clear: a manufacturer should not be able to shield itself from liability for defective products by failing to undertake research that would have

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28 Id at § 2, comment m.

29 See, for example, *Burton v R.J. Reynolds Tobacco Co*, 397 F3d 906, 920 (10th Cir 2005) ("In Kansas, the core purpose of a duty to test is to avoid production of defective products."); *Kociemba v G.D. Searle & Co*, 707 F Supp 1517, 1527–28 (D Minn 1989) (stating that "[t]his Court has already held that the duty to test is a subpart of the duty to warn" and that "[t]he duty to test is a subpart of the other three duties because a breach of the duty to test cannot by itself cause any injury"). See also Russell J. Davis, Carolyn Bower, and Robert D. Hursh, 1 *American Law of Products Liability* § 11:4 (Thomson/West 3d ed 2005):

> [A] manufacturer's duty to test the product is subsumed under its duties to exercise reasonable care in the design and manufacture of the product and to provide adequate warnings of dangers associated with the product's use; thus, breach of a duty to test is not a separate basis for cause of action based on a claim of negligence.

A minority of courts have found an independent duty to test. See, for example, *Borel v Fibreboard Paper Products Corp*, 493 F2d 1076, 1091 (5th Cir 1973) (finding that, under Texas law, "the manufacturer's duty to test his product is well-established"); *J.B. Horne v Liberty Furniture Co*, 452 S2d 204, 209 (La App 1984) ("[T]he manufacturer has an independent duty to test and inspect its product.").

30 See Restatement (Third) of Torts: Product Liability § 2, comment m (cited in note 27) ("A seller is charged with knowledge of what reasonable testing would reveal. If testing is not undertaken, or is performed in an inadequate manner, and this failure results in a defect that causes harm, the seller is subject to liability for harm caused by such defect.").

revealed such defects. Customers have little ability to conduct testing on their own, making manufacturers, in tort parlance, the cheapest-cost avoiders, particularly when the negative effects of these products are complex and difficult to discern.[31]

In its application, however, the duty to test presents difficulties. In particular, how are courts to know how much testing is adequate? Critics have argued that the case law provides few clear guidelines regarding the extent of the duty to test.[32] Courts tend to speak generally about the foreseeability of the possible harm and the practicability of testing,[33] and their conclusions often turn on very specific facts such as the existence of warning signs that should lead a reasonable manufacturer to further investigate.[34] Notably, courts often speak of the importance of the manufacturer's status as an expert in a particular field.[35] This

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31 See, for example, Wendy E. Wagner, *Choosing Ignorance in the Manufacture of Toxic Products*, 82 Cornell L Rev 773, 798 n 86 (1997); *Dalehite v United States*, 346 US 15, 52 (1953) (Jackson dissenting) ("Where experiment or research is necessary to determine the presence or the degree of danger, the product must not be tried out on the public, nor must the public be expected to possess the facilities or the technical knowledge to learn for itself of inherent but latent dangers.").

32 See, for example, Lars Noah, *Platitudes about "Product Stewardship" in Torts: Continuing Drug Research and Education*, 15 Mich Telecomm & Tech L Rev 359, 365 (2009) (stating that "case law offers essentially no guidance about the contours of such a duty to test"); Daniel R. Cahoy, *Medical Product Information Incentives and the Transparency Paradox*, 82 Ind L J 623, 641 (2007) (noting that "courts rarely engage in hindsight analysis to imagine what studies might have uncovered defects that were not reasonably foreseeable at the time").

33 See E.L. Kellett, *Manufacturer's Duty to Test or Inspect as Affecting His Liability for Product-Caused Injury*, 6 ALR3d 91 (1966) ("Many cases have recognized or applied the general rule that a manufacturer has a duty to test and inspect his products, at least where the nature of the product is such that damage from its use is foreseeable, and where tests or inspections are practicable and would be effective.").

34 See, for example, *Huggins v Stryker Corp*, 932 F Supp 2d 972, 987 n 14 (D Minn 2013) ("[A] manufacturer's duty to additionally test and investigate the propensities of its product is dependent upon the foreseeable risk of harm to potential users in light of current scientific or medical knowledge and discoveries."); *Prather v Abbott Laboratories*, 960 F Supp 2d 700, 713–14 (WD Ky 2013) (stating that the defendant "had an obligation to conduct some amount of testing, defined by what risks the medical community identified or suspected the product to have," but refusing to find the defendant in breach of that duty when contemporaneous medical knowledge did not put the defendant on notice of the risk); *Richter v Limax International, Inc*, 45 F3d 1464, 1471 (10th Cir 1995) (stating that "[m]anufacturers do not have a duty to test for inconceivable dangers, nor do they have a duty to test for every conceivable danger," but finding, in light of widespread biomechanical knowledge, that a trampoline manufacturer had breached its duty to test for the risk of stress fractures to ankles).

35 See, for example, *Feldman v Lederle Laboratories*, 479 A2d 374, 387 (NJ 1984) ("[A] reasonably prudent manufacturer will be deemed to know of reliable information generally available or reasonably obtainable in the industry or in the particular field involved. Such

invokes the potential of yardsticks to reduce information costs, as we describe in our Article.[36] If a court can determine, for example, that most car companies do rollover tests to ensure the safety of their seat belts, then this could serve as evidence that a company that failed to do such tests breached its duty to undertake reasonable tests.[37] Tort law commonly uses custom in an industry to define appropriate standards of care.[38] We imagine an analogous approach, in which custom is determined not with respect to the design of products but rather with respect to the design of R & D programs. While this might be difficult in nonhomogeneous industries, for industries in which firms are in relevant ways similar or in which differences can be accounted for, recourse to custom could help identify a minimum level of R & D that should be required.[39] The results will surely be imperfect.[40] The critical question, however, is how the results would compare to the alternative, in which firms have perverse incentives not to conduct R & D that might discover dangers even though they are in the best position to discover those dangers.

The state-of-the-art defense raises issues similar to those of the duty to test, but in a different posture. Here, companies can escape liability if they show that their products were state of the art such that there was no feasible better design or better warning

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information need not be limited to that furnished by experts in the field, but may also include material provided by others.").

36 See Part I.A in the main text.

37 See *Hopper v Crown*, 646 S2d 933, 945–46 (La App 1994) (holding that a forklift manufacturer "breached its duty to test and experiment commensurate with the danger" when it failed to test the safety of a doorless forklift, knowing that its competitors offered forklifts with doors for safety purposes). This example illustrates that in certain applications, such as those described in our analysis of automobile fatalities, tort law can be a barrier to entry. We acknowledge that such barriers may result in economic inefficiencies. However, we emphasize that tort law, as an innovation stick, is an effective tool of innovation policy that can lead to broader efficiency gains for society.

38 See Dan B. Dobbs, Paul T. Hayden, and Ellen M. Bublick, *The Law of Torts* § 179 (West 2d ed 2000) ("[C]ustom may be admissible as tending to show that a party's conduct did or did not meet the reasonable person standard of care."); Kenneth S. Abraham, *Custom, Noncustomary Practice, and Negligence*, 109 Colum L Rev 1784, 1786 (2009) ("Evidence of an actor's compliance with custom is admissible . . . to show reasonable care, and evidence of an actor's departure from custom is admissible . . . to show negligence.").

39 See notes 49–50 and accompanying text.

40 This is true not only because custom may be difficult to discern but also because courts will make mistakes in discerning it. In addition, entire industries may underinvest in R & D, creating circularity problems. In theory, yardsticks can move the entire field to better performance because firms that can excel have an incentive to move ahead of their peers. But a dynamically efficient feedback loop of this sort would be very difficult to achieve with the blunt weapon of tort law due to the many factors that mediate the relationship between tort liability and long-term corporate decisionmaking.

given the state of knowledge at the time.[41] The point of the defense is to provide a safe harbor to ensure that manufacturers are not penalized for undertaking tests—an activity that could otherwise be perversely deterred by tort law.[42] But the doctrine serves this purpose well only if it correctly identifies the level of testing that is appropriate to trigger the safe harbor. Consequently, as some courts have recognized, the state of the art should be defined "in terms of what the industry as a whole knew *or could have discovered by properly fulfilling their duty to test* these products."[43]

This raises the key question for this innovation stick: What level of testing should be required before the safe harbor applies? Jurisdictions have taken two main approaches to defining the technological standard required to show that a product is state of the art. Some ask whether there was no feasible safer product, while others ask whether the defendant's product conformed to industry standards.[44] The former appears to impose very high information burdens on the court, but the latter seems likely to provide inadequate incentives to test.[45] A better approach might have yardstick qualities, and it might ask courts not to determine that there was no product possibly safer than

41 See, for example, James Boyd and Daniel E. Ingberman, *Should "Relative Safety" Be a Test of Product Liability?*, 26 J Legal Stud 433, 435 (1997). See also Jane Stapleton, *Liability for Drugs in the U.S. and EU: Rhetoric and Reality*, 26 Rev Litig 991, 1011 (2007) ("[W]here the alleged 'defect' consists of a failure to warn of a risk, and where such a warning was impossible given the state of the art of the epidemiological data relating to the drug at the time it was supplied, that claim of 'defect' will fail."). In most jurisdictions, state-of-the-art evidence is "only a factor in determining liability," but in a minority of states (at least twelve), it is a conclusive defense and usually operates by establishing a rebuttable presumption that the relevant product was not defective. Boyd and Ingberman, 26 J Legal Stud at 441 (cited in note 41).

42 See Wagner, 82 Cornell L Rev at 794–96 (cited in note 31). This example helps illustrate the point about baselines made above. See notes 38–40 and accompanying text. As a safe harbor, we might also conceive of this as an innovation carrot: a firm enjoys the benefit of a defense from liability if it conducts the right level of R & D.

43 *Dartez v Fibreboard Corp*, 765 F2d 456, 463 (5th Cir 1985) (emphasis added). See also *Artis v Corona Corp of Japan*, 703 A2d 1214, 1217 n 6, 1218 (DC App 1997) (citing the *Dartez* formulation favorably and reversing a grant of summary judgment for the defendant because the lower court failed to consider what a "competent manufacturer reasonably could have developed at the time the [product] was manufactured and sold," despite the lack of commercially available safety measures at the time of the injury).

44 See Boyd and Ingberman, 26 J Legal Stud at 436–40 (cited in note 41) (surveying cases and jurisdictions that apply these two standards).

45 For further discussion of the inadequate incentives to test, see id at 439–40.

the defendant's but rather to use industry standards to require above-average safety and above-average investments in R & D.[46]

We do not wish to overstate the power of tort law to directly promote investments in research on product safety. Courts have found the extent of the duty to test difficult to define (though as just suggested, some of the informational problems that courts face might be minimized with yardstick approaches). Other aspects of tort liability also undermine its potential to serve as an effective tool of innovation policy. In particular, plaintiffs bear the burden of proving causation—but depending on how that requirement is construed and the level of evidence required to get to a jury, plaintiffs may be unable to make this showing in the absence of epidemiological (or similarly systematic) research that connects the product in question to the harms that the plaintiffs have suffered.[47] There is thus a circularity problem: plaintiffs may be unable to prevail on a theory of failure to test unless they already know what testing would have shown.[48] This can be seen as an innovation stick that is imposed on the wrong party: plaintiffs are denied relief for their injuries unless they perform expensive studies that identify the causes of those injuries, even though manufacturers are in a superior position to perform studies.

Our analysis offers reasons that courts might be appropriately cautious regarding the deployment of this particular innovation stick, and it also offers a clear account of its importance. Caution seems appropriate because courts may not know what level of R & D is appropriate. But as we have described, yardstick

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46 See id at 435–36 (noting that if a test incorporates government standards, it may reduce the underprovisions and overprovisions of safety that occur under other tests).

47 See Wagner, 82 Cornell L Rev at 774–75 (cited in note 31).

48 For an expansive understanding of how causation might be understood in this context, see *Zuchowicz v United States*, 140 F3d 381, 386–87 (2d Cir 1998) (affirming a lower court's decision allowing expert witnesses to testify regarding causation in a drug case, despite the fact that no epidemiological or associated clinical trial evidence was available). Epidemiological evidence is not always required. For example, courts may allow a jury to infer causation from circumstantial evidence of exposure, along with symptoms that have no other known explanation. See Dobbs, Hayden, and Bublick, *The Law of Torts* at § 191 (cited in note 38). Plaintiffs with unusual symptoms may thus be able to get to a jury without scientific proof of causation, while those who have symptoms that could be caused by many things—by cancer, for example—may have a much more difficult time showing causation without epidemiological proof. See Daniel A. Farber, *Toxic Causation*, 71 Minn L Rev 1219, 1251–53 (1987). Sometimes causation will also be unproblematic. If the plaintiff is injured in a car crash because a seat belt disengaged during a rollover, the cause of the injury will not be difficult to discern—although the appropriate level of R & D might be.

approaches—based on a kind of customary level of R & D—can help mitigate the problem. At a minimum, courts should be aware of the importance of the failure-to-test doctrine as well as of the radical underinvestment in testing that is likely to follow if companies are not obliged to test their products in reasonable ways. Courts might also begin to develop the significance of the doctrine if they invite evidence regarding industry R & D standards relevant to a particular context. Another way to make more-extensive use of tort law as an innovation stick would be to shift the burden to companies to disprove causation if they fail to undertake a defined level of minimal testing with the appropriate level of testing defined by industry.[49] Statutes could be used to define the appropriate level of testing, reducing the information burden on courts and increasing predictability for industry.[50] This would replicate something akin to the FDA standards forbidding the sale of drug products without certain levels of testing submitted in advance, although using not a property rule (the FDA's ban on marketing) but rather a liability rule (in the form of compensatory tort liability).[51] The information asymmetries between consumers and producers in such cases would appear to make such an approach very valuable, perhaps when combined with a set of traditional or nontraditional carrots.

III. SUPPLEMENT: ADDITIONAL AUTOMOBILE-FATALITIES ANALYSIS

Given that automobile fatalities involving laggard manufacturers are not well internalized—as presented in our discussion supporting Table 2 in the main text—we ask: How concretely

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[49] Professor Wendy Wagner has proposed a system like this for toxic torts. As she envisions it, the plaintiff would establish a prima facie case by showing:

> (1) inadequate minimal testing on a product, (2) normal or foreseeable exposure to the product, and (3) serious harm that might be causally linked to exposure to the product. The plaintiff could satisfy the harm element, depending on jurisdiction, by demonstrating the existence of latent physical harms (e.g., cancer, reproductive ailments), emotional harms, medical monitoring costs, or an increased risk of latent physical harm.

Wagner, 82 Cornell L Rev at 834–35 (cited in note 31) (citations omitted).

[50] See id at 807–09.

[51] Because tort law is keyed to harm, such a model would not generate impetus to show evidence of effectiveness as FDA requirements do. Line-drawing issues—for example, about when such testing should be required (for some products but not others) and how courts would determine industry standards—would of course follow.

might a CAFE-like system be applied to internalize these costs of above-median fatality risks?

One way to internalize the costs of above-median fatalities would be to introduce financial penalties that are a function of how much a manufacturer's historic fatality rate has exceeded the median manufacturer rate on a year-by-year basis.[52] As with Table 2 in the main text, the per-vehicle penalties reported below in Table 1A are best construed as upper-bound estimates; enlightened regulations might phase in the penalties so that manufacturers with poor safety standards would have time to correct their ways.[53] By estimating the per-vehicle costs associated with excess fatalities, Table 1A dramatizes the extent of the problem.

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52 To translate the flow of annual manufacturer penalties into a one-time charge, we calculate the present value of a ten-year annuity—assuming that the average car stays on the road for ten years—at a 5 percent discount rate.

53 Our current approach also penalizes manufacturers for their stocks of cars that are on the road. While it is ultimately appropriate to have manufacturers internalize the costs of excess danger produced by their stocks of historic sales, another phase of penalties might limit manufacturer liability to those cars that were sold after the regulation went into effect.

TABLE 1A. ESTIMATES OF ABOVE-MANUFACTURER-MEDIAN FATALITY RATES AND ASSOCIATED PER-VEHICLE COSTS[54]

	Average Fatality Rate over Median		Per-Vehicle Time-of-Purchase Cost for Fatalities above Median		Per-Vehicle Time-of-Purchase Cost for Fatalities above Median, Controlling for Miles Driven	
	(Fatality Rate/100,000 Vehicles), Based on Twelve-Year Average		($/Vehicle), Based on Twelve-Year Average		($/Vehicle), Based on Twelve-Year Average	
	Total Fatalities	External Fatalities	Total Fatalities	External Fatalities	Total Fatalities	External Fatalities
Mitsubishi	7.83	2.62	$4,596	$1,535	$3,895	$941
Land Rover	4.67	4.47	$2,742	$2,622	$2,301	$2,468
Kia	3.71	1.04	$2,179	$610	$3,115	$720
Pontiac	3.52	0.06	$2,065	$37	$1,718	$5
GMC	3.02	3.51	$1,769	$2,061	$1,350	$1,572
Isuzu	2.67	0.40	$1,570	$235	$2,041	$215
Chevrolet	2.67	1.22	$1,568	$718	$1,499	$380
Hyundai	1.25	0.09	$733	$51	$1,119	$83
Ford	1.07	1.72	$629	$1,008	$681	$723
Acura	1.02	0	$601	$0	$361	$0
Dodge	0.72	2.57	$423	$1,511	$0	$827
Jeep	0.64	1.37	$378	$804	$387	$458
Infiniti	0.64	0.88	$376	$514	$473	$481
Nissan/ Datsun	0.07	0.01	$40	$6	$37	$13
Plymouth	0.04	0	$24	$0	$75	$0
Jaguar	0.03	0.05	$17	$28	$698	$330

[54] The first two columns are the twelve-year-average fatality rates over median for each manufacturer. Only manufacturers who have had a total-fatality rate over median in at least one of the years 2000 to 2011 are shown here. The second two columns show the average social costs per year, annuitized at 5 percent for ten years. This represents the average external fatalities at the time of purchase of the average vehicle made by that manufacturer and at the time of purchase for total or external fatalities. Average yearly social cost per vehicle, which we annuitize above, is calculated by dividing each manufacturer's fatality rate over the median rate by 100,000 vehicles and multiplying that number of fatalities by $7.4 million, the value of a human life as calculated by the EPA, and then averaging over 12 years. Nineteen car manufacturers produced below median for both total- and external-fatality rates for all twelve years.

Oldsmobile	0.01	0	$4	$0	$846	$0
Lincoln	0	0.01	$0	$4	$232	$117
Porsche	0	0	$0	$0	$968	$98
Mercury	0	0	$0	$0	$244	$0
Mercedes-Benz	0	0	$0	$0	$34	$16

The "state-based costs of death from crashes" have been an independent concern of the Centers on Disease Control and Prevention (CDC), which in 2005 estimated the state-specific costs of crash deaths.[55] But somewhat bizarrely, the CDC's comparison of states does not control for differences in population size. Thus, the CDC website warns that "half of all costs [from crash deaths] were found in 10 states."[56] The CDC notes that "[t]he ten states with the highest medical and work loss costs were California ($4.16 billion), Texas ($3.50 billion), Florida ($3.16 billion), Georgia ($1.55 billion), Pennsylvania ($1.52 billion), North Carolina ($1.50 billion), New York ($1.33 billion), Illinois ($1.32 billion), Ohio ($1.23 billion), and Tennessee ($1.15 billion)."[57]

It should hardly be surprising, however, that California and New York, because of their sheer population sizes, are ranked among the top ten most costly states in terms of fatal-crash costs even though these states rank below median in terms of both total and external fatalities. If we instead simply divide the CDC cost estimates by the number of registered automobiles in each state, we see a ranking that closely parallels the ranking in Figure 4 in our Article, with Mississippi, Arkansas, and South Carolina as the most fatal states.

In Table 2A, we present estimates for above-state-median fatality rates, calculated analogously to the estimates in Table 2 in the main text.[58] Table 2A also reports the per-vehicle social costs at the time of purchase for fatalities over median based on

55 See *State-Based Costs of Deaths from Crashes* (CDC, Sept 10, 2014), archived at http://perma.cc/2D6U-PJZ6. See also generally Rebecca B. Naumann, et al, *Incidence and Total Lifetime Costs of Motor Vehicle-Related Fatal and Nonfatal Injury by Road User Type, United States, 2005*, 11 Traffic Injury Prevention 353 (2010).

56 *State-Based Costs of Deaths from Crashes* (cited in note 55).

57 Id.

58 Above-median fatality rates—both total and external—are calculated by subtracting the fatality rate for each state in each year from the median fatality rate for that year. These differences are then averaged over the twelve years in the sample. Twelve states have total- and external-fatality rates that never exceed the median rate and do not appear in the table, as their total- and external-fatality rates over median are zero.

the CDC's cost-calculating methodology, which focuses on the social cost from health care and lost work instead of our cost-of-life approach.[59] Even using the CDC's more conservative valuation method, we find that Mississippi's per-vehicle (point-of-sale) cost would be more than $2,300 and that its annual penalty would be more than $600 million.

TABLE 2A. ABOVE-STATE-MEDIAN FATALITY RATES AND ASSOCIATED PER-VEHICLE COSTS

	Average Fatality Rate over Median		Social Cost at Time of Purchase for Fatalities over Median		CDC Cost over Median per Vehicle
	(Fatality Rate/100,000 Vehicles), Based on Twelve-Year Average		($/Vehicle), Based on Twelve-Year Average		($/Vehicle), 2005
State	Total Fatalities	External Fatalities	Total Fatalities	External Fatalities	CDC Cost
MS	26.77	9.53	$15,710	$5,594	$2,337
AR	17.64	7.24	$10,354	$4,248	$1,352
SC	15.21	5.25	$8,926	$3,083	$1,229
NM	13.17	3.52	$7,729	$2,064	$1,055
WV	13.00	4.44	$7,630	$2,606	$839
WY	11.25	1.93	$6,600	$1,131	$526
AZ	11.06	4.43	$6,489	$2,598	$1,023
NV	10.98	4.61	$6,446	$2,703	$1,099
KY	10.72	4.65	$6,288	$2,729	$852
NC	10.05	4.28	$5,898	$2,509	$775
MT	9.55	1.45	$5,603	$852	$454
LA	9.31	3.58	$5,463	$2,102	$851
TN	9.08	3.42	$5,326	$2,010	$671
AL	8.46	3.34	$4,966	$1,960	$703
MO	8.26	3.29	$4,849	$1,929	$686
OK	8.13	4.03	$4,772	$2,365	$339
TX	7.12	3.64	$4,181	$2,134	$436
FL	6.01	3.04	$3,524	$1,782	$441
GA	5.12	2.64	$3,003	$1,549	$370

59 For a fuller description of the CDC's methodology, which was estimated solely for 2005 data, see Naumann, et al, 11 Traffic Injury Prevention at 354–55 (cited in note 55).

SD	4.87	0.78	$2,859	$461	$297
ID	4.62	0.70	$2,711	$408	$307
DC	4.58	1.87	$2,685	$1,096	$0
KS	4.35	2.42	$2,554	$1,420	$295
ME	2.66	0.76	$1,562	$443	$27
DE	2.58	1.86	$1,511	$1,094	$6
ND	2.01	0.71	$1,182	$417	$119
IN	1.43	1.08	$837	$635	$266
WI	1.04	0.33	$609	$192	$112
PA	0.83	0.20	$485	$116	$76
UT	0.83	0.14	$485	$84	$0
NE	0.74	0.63	$435	$368	$0
VT	0.60	0.29	$352	$170	$0
MD	0.50	0.42	$292	$245	$0
OR	0.49	0.09	$289	$52	$12
CO	0.41	0.06	$241	$33	$0
HI	0.35	0.00	$206	$2	$0
AK	0.13	0.08	$79	$44	$0
VA	0.06	0.00	$38	$0	$0
IA	0.00	0.04	$0	$26	$0
MI	0.00	0.19	$0	$110	$0

	Average Yearly Social Cost of Fatalities over Median		CDC Cost over Median per Vehicle	Social Cost at Time of Purchase for Fatalities over Median, Corrected for Miles Driven	
	($ Million), Based on Twelve-Year Average		($ Million), 2005	($/Vehicle), Based on Twelve-Year Average	
State	Total Fatalities	External Fatalities	CDC Cost	Total Fatalities	External Fatalities
MS	$4,070	$1,450	$605	$13,127	$4,498
AR	$2,630	$1,080	$343	$9,126	$3,760
SC	$3,870	$1,330	$533	$7,611	$2,558
NM	$1,550	$415	$212	$8,527	$2,506
WV	$1,400	$477	$154	$7,805	$2,763
WY	$540	$93	$43	$6,877	$1,312
AZ	$3,390	$1,350	$534	$6,336	$2,605
NV	$1,100	$463	$188	$6,783	$2,934

KY	$2,800	$1,220	$379	$5,449	$2,424
NC	$4,670	$1,980	$614	$4,899	$2,125
MT	$722	$109	$59	$4,704	$676
LA	$2,680	$1,030	$418	$4,073	$1,549
TN	$3,450	$1,310	$435	$4,176	$1,561
AL	$2,890	$1,140	$409	$3,846	$1,523
MO	$2,900	$1,150	$410	$4,255	$1,726
OK	$2,000	$989	$142	$3,850	$2,012
TX	$8,700	$4,450	$908	$2,970	$1,653
FL	$6,710	$3,400	$840	$3,223	$1,716
GA	$3,050	$1,570	$375	$1,427	$902
SD	$310	$51	$32	$2,563	$403
ID	$458	$69	$52	$3,123	$640
DC	$80	$33	$0	$2,124	$957
KS	$782	$434	$90	$2,090	$1,288
ME	$209	$59	$4	$990	$268
DE	$140	$103	$1	$1,353	$1,090
ND	$111	$40	$11	$724	$354
IN	$562	$438	$179	$391	$439
WI	$361	$114	$66	$391	$144
PA	$619	$148	$97	$781	$293
UT	$106	$18	$0	$446	$81
NE	$94	$81	$0	$514	$468
VT	$24	$12	$0	$180	$94
MD	$149	$126	$0	$27	$108
OR	$111	$20	$5	$685	$149
CO	$124	$18	$0	$189	$12
HI	$23	$0	$0	$1,957	$350
AK	$6	$3	$0	$600	$168
VA	$32	$0	$0	$0	$0
IA	$0	$11	$0	$0	$23
MI	$0	$119	$0	$0	$8

A. Accounting for Differences in Teenage and Under-the-Influence Driving

Of course, as with our manufacturer proposal, a necessary condition before imposing such a state-incentive regime would be considering the possibility that state actions could reduce the risk of fatalities. It would be inappropriate to deploy innovation sticks to incentivize manufacturer or state responses to above-median fatality rates if there were no credible actions that the manufacturer or state could take to reduce those rates. In this Section, we estimate the extent to which our above-median estimates are driven by differences in teenage-driving and under-the-influence-driving fatality rates, and we assess the extent to which a manufacturer or state might respond to such fatality-rate influences.

The fatality rates experienced by manufacturers and states might also be impacted by differences in the recklessness of their drivers. Teenage-male drivers and people driving under the influence of drugs or alcohol have dramatically higher accident rates.[60] Manufacturers of identical automobiles might experience different fatality rates just because of differences in the extent to which manufacturers attract particularly reckless drivers. This Section empirically investigates the connection between teenage and under-the-influence driving and the elevated fatality rates of manufacturers and states. But, in contrast to the "miles driven" influence, we do not believe that innovation sticks should be adjusted for reckless-driver influences. We reach this conclusion because we believe that manufacturers and states that have disproportionately reckless drivers are likely to be able to adopt cost-effective measures to deter the recklessness or mitigate the impact of recklessness.[61]

We begin our analysis by reporting the proportion of fatalities that come from accidents in which a teenage male was driving or in which the driver was under the influence of drugs or

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60 Allan F. Williams has found that, in the year 2000, teenage males were roughly twice as likely to be involved in a fatal crash as teenage females per licensed driver. Allan F. Williams, *Teenage Drivers: Patterns of Risk*, 34 J Safety Rsrch 5, 6–7 (2003). The dangers of drunk driving are well documented. See, for example, *Impaired Driving: Get the Facts* (CDC, Jan 13, 2015), archived at http://perma.cc/BX4Z-3YQL (noting the CDC's statistic that one-third of all traffic deaths are alcohol related).

61 See Part III.B in the main text.

alcohol.[62] Table 3A reports the five highest proportions by manufacturer and state.

TABLE 3A. HIGHEST MANUFACTURER AND STATE PROPORTIONS OF TOTAL FATALITIES INVOLVING A TEENAGE-MALE DRIVER OR A DRIVER UNDER THE INFLUENCE OF DRUGS OR ALCOHOL

Manufacturer	Percentage of Fatal Accidents Involving Teenage Males (%)	Manufacturer	Percentage of Fatal Accidents Involving Drugs or Alcohol (%)
Acura	16.3	BMW	26.1
Honda	11.9	Porsche	25.2
Mitsubishi	11.7	Audi	24.8
Pontiac	11.1	Jaguar	22.6
Audi	10.7	Saab	22.4

State	Percentage of Fatal Accidents Involving Teenage Males (%)	State	Percentage of Fatal Accidents Involving Drugs or Alcohol (%)
NE	10.8	SD	34.3
ID	10.0	MT	32.5
RI	9.7	WV	29.9
KS	9.6	ND	29.8
UT	9.5	WY	29.3

Table 3A reports that more than one-quarter (26.1 percent) of fatal accidents involving a BMW occurred when the BMW driver was under the influence and that more than one-third (34.3 percent) of fatal accidents in South Dakota involved at least one driver who was under the influence. These simple statistics might suggest guidelines for action. If South Dakota or

62 Teenage-male totals are calculated from sex and age variables in the FARS data (age is between fourteen and twenty). Only drivers are considered. Drug and alcohol totals are calculated from the drug and alcohol flags ("drugs" and "drinking") in the FARS data. If the "yes/no" alcohol or drug flag is missing in those data, we assume that drugs and alcohol were not a factor in the accident.

Montana wants to reduce fatalities in their states, taking action against drunk driving might be an important place to start. But a manufacturer or state might have a high fatality proportion merely because it has been inordinately successful in reducing other causes of fatalities. For example, BMW has the highest manufacturer proportion of driving-under-the-influence fatalities, but it has a below-median fatality rate (as indicated by its absence from the above-median analysis in Table 1A). If BMW wants to reduce its fatalities further, it might want to consider taking actions to deter or mitigate the impact of drug- and alcohol-related driving. The evidence presented in Table 3A, however, is not sufficient to establish that BMW has an above-median risk of under-the-influence fatalities.

Table 4A responds to this concern by reporting the likelihood ratio of teenage-male fatality rates relative to the share of a manufacturer's or state's cars more generally (that is, the proportion of drunk drivers involved in fatal accidents for a manufacturer or state divided by the proportion of nationally registered cars made by a manufacturer or in a state). Acura, for example, is estimated to have a teenage-male likelihood ratio of 2.19, because Acura has a 0.84 percent share of registered cars but a 1.84 percent share of fatal accidents in which a teenage male was driving. Table 4A reports the ten highest and five lowest likelihood ratios for each of the four categories.

TABLE 4A. HIGHEST MANUFACTURER AND STATE LIKELIHOOD RATIOS OF TOTAL FATALITIES INVOLVING A TEENAGE-MALE DRIVER OR A DRIVER UNDER THE INFLUENCE OF DRUGS OR ALCOHOL[63]

Manufacturer	Likelihood Ratio: Teenage Males	Manufacturer	Likelihood Ratio: Drugs or Alcohol
Acura	2.19	Mitsubishi	1.72
Mitsubishi	2.12	Pontiac	1.49
Pontiac	1.75	Isuzu	1.43
Isuzu	1.35	Chevrolet	1.37
Chevrolet	1.29	GMC	1.35

63 Likelihood ratios are the manufacturers' or states' proportions of drunk drivers involved in fatal accidents divided by the proportion of nationally registered cars made by that manufacturer or located in that state.

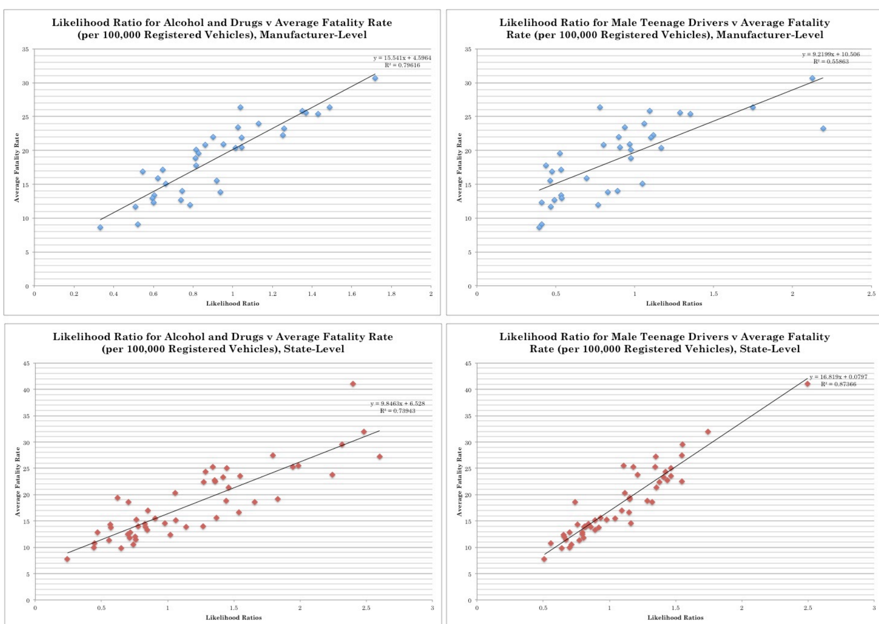
Mazda	1.17	Acura	1.26
Jeep	1.11	Jeep	1.25
Nissan/Datsun	1.10	Ford	1.13
GMC	1.09	Nissan/Datsun	1.04
Ford	1.06	Infiniti	1.04
. . .	. . .	. . .	. . .
Jaguar	0.46	Subaru	0.59
Cadillac	0.44	Buick	0.55
Mercedes-Benz	0.41	Saab	0.52
Saab	0.41	Suzuki	0.51
Volvo	0.39	Volvo	0.33

State	Likelihood Ratio: Teenage Males	State	Likelihood Ratio: Drugs or Alcohol
MS	2.50	WV	2.60
AR	1.75	AR	2.48
SC	1.55	MS	2.40
MO	1.55	SC	2.32
NM	1.55	MT	2.25
KY	1.47	WY	1.99
LA	1.47	NV	1.95
AL	1.44	SD	1.83
NC	1.42	NM	1.80
TN	1.41	KS	1.66
. . .	. . .	. . .	. . .
CA	0.66	MN	0.56
AK	0.65	NY	0.47
CT	0.64	NJ	0.45
NJ	0.56	RI	0.44
MA	0.51	MA	0.24

Unlike the Table 3A proportions, the Table 4A likelihood ratios are independent of how successful a manufacturer or state is in reducing other types of fatalities. Hence, we see that some manufacturers that were prominent in the Table 3A proportions are absent from Table 4A's highest likelihood ratios. BMW had the highest proportion of under-the-influence fatalities but has a likelihood ratio of only 0.83 (because while it has 0.96 percent of registered vehicles, it generates only 0.79 percent of driving-under-the-influence fatalities). Similarly, we see that Honda had the second-highest proportion of teenage-male-driver fatalities but has a likelihood ratio around 1 to 1.05. Overall, Honda is one of the safer cars (as can also be seen by its absence from the above-median analysis in Table 1A).

Stepping back, we see a strong positive correlation between the manufacturers and states that have the highest fatality likelihood ratios for teenage-male and under-the-influence driving and the manufacturers and states that have the highest total-fatality rates. Figure 1A plots the four scatter diagrams showing the extent of these correlations.

FIGURE 1A. LIKELIHOOD RATIOS FOR TEENAGE-MALE AND UNDER-THE-INFLUENCE DRIVING AND AVERAGE FATALITY RATES, AT THE MANUFACTURER AND STATE LEVELS



The figures collectively show surprisingly tight positive linear correlations between the likelihood ratios and the total-fatality rates—with R-squared from univariate regressions ranging from 55.9 percent to 87.4 percent. These correlations may well be driven by unaccounted-for common factors. For example, something else about Mississippi might cause it to have both a higher alcohol-fatality likelihood ratio and a higher total-fatality rate. Nonetheless, as discussed in Part III.B in the main text, the figures suggest that above-median manufacturers and states might reduce their total-fatality rates by taking action on teenage and under-the-influence driving.

The figures also suggest that variation in the under-the-influence-driving risk is a more important influence than in the teenage-driving risk with regard to variations in manufacturer fatality rates, but that the teenage-driving risk is a more important influence than the under-the-influence-driving risk with regard to variations in state fatality rates.[64]

B. An Alternative Method of Accounting for Overestimated Fatalities

In Table 2 in the main text, we estimate how many lives would have been saved annually on average if the proposed intervention succeeded at merely reducing the fatality rates of above-median manufacturers down to the median industry rate. We deflate our estimates for both the fatalities-over-median estimates and the costs by the number of single-counted fatalities divided by the number of double-counted fatalities. This method deflates every manufacturer by the same amount.

Double counting will result in manufacturers with larger market shares having higher ratios of reported accidents to actual accidents than manufacturers with smaller market shares. To understand why, consider the following stylized example of a market with two manufacturers, Toyota and Ford:[65] There are eighty Toyotas and twenty Fords on the road. Drivers of each make are equally likely to get in an accident. Assume that half the cars for each make crash randomly into another car; there

[64] This can be seen in Figure 1A through the fact that, for manufacturers, the under-the-influence correlation is steeper and has a better fit than the teenage correlation, while for states the teenage correlation is steeper and has a much better fit than we see for the under-the-influence correlation. It might be that teenage males are more evenly distributed across manufacturers because teens are more likely to drive whatever car their parents drive. This might explain the slightly dampened correlation. In contrast, many states have stringent teenage-driving laws that may affect accident rates directly and cause a tighter correlation. Drunk drivers are much more likely to be driving certain makes of cars, causing a close correlation between under-the-influence likelihood ratios and total accident rates. The explanatory power of the likelihood ratio is nearly as high at the state level (with an R^2 of 0.74 versus 0.79).

[65] We thank the editors for proposing this example.

are sixteen crashes between two Toyotas, eight crashes between a Toyota and a Ford, and one crash between two Fords. For simplicity, assume that in each crash there are three fatalities: the drivers of both cars, as well as one pedestrian. The actual number of fatalities is 3 * (16 + 8 + 1) = 75.

The reported total fatalities for Toyota is 120: 40 internal fatalities, 40 external-in-vehicle fatalities (of which 32 were in Toyotas and 8 were in Fords), and 40 pedestrians (1 fatality for each accident involving a Toyota). The true number of fatalities in accidents in which at least one Toyota was involved is 3 * (16 + 8) = 72, and the overreporting ratio for Toyotas is 120 / 72 = 1.667.

Similarly, the reported total fatalities for Ford is 30: 12 internal fatalities (8 from accidents with Toyotas and 4 from the accident between 2 Ford drivers), 8 external-in-vehicle fatalities (all from accidents with Toyotas), and 10 pedestrians (8 + 1 + 1). The true number of fatalities in accidents involving a Ford is 3 * (8 + 1) = 27. The overreporting ratio for Fords is 30 / 27 = 1.111, considerably less than that for Toyota, the manufacturer with a higher market share.

To address this, we calculate manufacturer-specific overreporting ratios from the actual crash data.[66] The denominator for each deflator is the sum of all double-counted total fatalities for a manufacturer, which we have previously calculated. The numerator is the sum of all single-counted deaths for the same manufacturer. To do this, we attribute half of the internal deaths to the manufacturer of the car involved and the remaining half of the internal deaths evenly to the other cars involved in the accident. For example, if four cars were involved in an accident with one internal fatality, half of a fatality would be assigned to the manufacturer of the car in which the person died and one-sixth of a fatality would be assigned to each of the three other manufacturers. External-in-vehicle deaths are assigned using the same rule. For pedestrian deaths, we distribute the fatalities equally—that is, if one pedestrian dies in a three-car accident involving cars of different makes, each manufacturer is assigned one-third of a pedestrian fatality. We reproduce Table 2 using this deflator, finding that the estimates for fatalities

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[66] The estimates in Table 2 in the main text do this for the entire universe of crashes, dividing the number of actual deaths by the sum of all double-counted total fatalities.

over median and for costs are greater than the deflated values presented in Table 2 but less than the undeflated values.

TABLE 5A. OVER-MEDIAN ANALYSIS USING MANUFACTURER-SPECIFIC DEFLATORS[67]

	Fatalities over Median	Proportion of Fatalities over Median (%)	Yearly Cost of Fatalities over Median ($ billion)
Total Fatalities	1445	4.8	14.3
External Fatalities	520	7.1	4.9

[67] This table presents results constructed using manufacturer-specific deflators to account for the overreporting of fatalities.