This online appendix first supplements Part II by providing additional examples of innovation penalties in action, and then supplements Part III by providing background calculations to the fatality analysis.

Part II Supplement: Additional Existing Examples

i. 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 1999, California introduced the Zero Emissions Vehicle (ZEV) mandate, requiring carmakers operating in California develop automobiles with zero emissions.[1] The 1990 version of ZEV required 2% of sales to be zero-emissions by 1998, 5% by 2001, and 10% by 2003, and manufacturers faced a $5,000 penalty per vehicle short of the requirement.[2] In 1990, battery-powered electric vehicles were the only option for a meeting this requirement. Only GM was working on an electric car in the 1980s (the Impact), which was not ready for commercialization. Thus, the ZEV mandate was in reality a mandate to do the research and development needed to produce viable electric cars. Carmakers viewed the mandate as extraordinarily demanding, and insisted it could not be met.[3]

California's ZEV program does, however, seem clearly to have spurred research and innovation. The best evidence of this comes from patent patterns,[4] emphasizing the point that we made earlier: sticks and carrots 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.[5] GM purportedly spent $1 billion on ZEV technology during this time period.[6] Also in the early 1990s, a number of high-tech California firms sprung up to develop products for the ZEV market.[7] And within existing battery companies, researchers turned some of their attention to the electric car market.[8]

The ZEV program appears a good candidate for sticks for the same reasons described in our discussion of the CAFE program. In addition, the ZEV program helps to illustrate some of the limits of innovation sticks that we described more theoretically in Part I. The ZEV program is a classic example of the government "picking winners," and it has not been fully successful in projecting the possible pace of technical change. In 1996, California decided to suspend the 1998 and 2001 deadlines because battery technology was not progressing quickly enough.[9] The ZEV

[1] See Philippe Larrue, *Lessons Learned from the Californian ZEV Mandate: From a "Technology-Forcing" to a "Market-Driven" Regulation* Université Montesquieu-Bordeaux 15 (June 2003), *available at* http://cahiersdugres.u-bordeaux4.fr/2003/2003-07.pdf.
[2] *Id.* at 6. Several other states also adopted the standards, increasing their effect. *See id.*
[3] *Id.* at 7.
[4] Andrew Burke et al., *Study of the Secondary Benefits of the ZEV Mandate*, University of California-Davis (Aug. 2000), *available at* http://escholarship.org/uc/item/57b4t7nn.
[5] *Id.* at 17 fig.3.1-1.
[6] Nat'l Research Council, State and Federal Standards for Mobile-Source Emissions 169 (2006), *available at* http://www.nap.edu/openbook.php?record_id=11586&page=169
[7] Larrue, *supra* note _, at 9.
[8] *Id.* at 10.
[9] *Id.* at 11-12.

mandate was further modified to allow hybrid and other vehicles to count for partial ZEV credits.[10] Or, in the terms we used above, sticks may face credibility problems, perhaps particularly where they are applied to powerful industries. Nonetheless, these problems may not be insurmountable. Notably, the ZEV program continues: California has recently announced a 15% ZEV goal by 2025.[11] And it appears to have had positive effects, if not all of the effects that were desired. The field of electric cars has dramatically expanded in recent years, with Honda, Toyota, Ford, Chevrolet, and Nissan all offering or about to offer electric cars.[12] 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 2015.[13]

ii. 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 in 1997 reached a proposed settlement agreement which included an element that would have produced "failure to innovate" incentives.[14] While the agreement's implementing legislation was ultimately unsuccessful, its "look-back" provisions—which were excluded from subsequent settlements[15]—represented potential innovation sticks to reduce youth smoking rates.

Specifically, the proposed agreement established state-specific standards for reduction in youth smoking. For example, ten years after the agreement's implementation, the agreement required at least a 60 percent reduction in a state's youth cigarette use rate and a 45 percent reduction of smokeless tobacco use among youth.[16] 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.[17] The potential fine could be reduced by a maximum of 75 percent for tobacco companies upon a showing of full implementation of a number of measures to reduce tobacco use among youth, reasonable effort to curtail youth tobacco use, and absence of action to thwart meeting the reduction standards.[18] 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 tied substantially to states enacting a pre-specified set of provisions.[19]

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[10] *Id.* at 15; Gary E. Marchant, *Sustainable Energy Technologies: Ten lessons from the History of Technology Regulation*, 18 WIDENER L.J. 831, 838 (2009).

[11] John O'Dell, *Will California's Zero-Emissions Mandate Alter the Car Landscape?*, EDMUNDS (June 14, 2012), *available at* http://www.edmunds.com/fuel-economy/will-californias-zero-emissions-mandate-alter-the-car-landscape.html.

[12] *Id.*

[13] *Id.*

[14] PROPOSED TOBACCO INDUSTRY SETTLEMENT (1997), *available at* http://www.cnn.com/US/9705/tobacco/docs/proposal.html [hereinafter TOBACCO SETTLEMENT].

[15] Givel, M. & S.A. Glantz, *The 'Global Settlement' with the Tobacco Industry: 6 Years Later*, 94 Am. J. Pub. Health 218. 219 (2004).

[16] TOBACCO SETTLEMENT, *supra* note .

[17] *Id.*

[18] *Id.*

[19] Jeremy Bulow & Paul Klemperer, *The Tobacco Deal* 1998 BROOKINGS PAPERS ON ECONOMIC ACTIVITY: MICROECONOMICS, 323-394.

A non-traditional 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 where we have few concerns about undercompensation. There are plausibly many inexpensive ways for companies to reduce youth smoking (shifting ad campaigns, or developing savvy anti-smoking campaigns targeted at youth for example). Additionally, if requiring companies to internalize more of the costs of youth smoking were to force some of them from the industry, or raise the price of cigarettes, from a public health / welfare perspective, this is likely a net gain. Again, this example raises the concern about credibility of sticks, and also gives us an example of a distributional concern in play: net transfers to tobacco companies 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.

iii. 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. Tort law thus acts as a stick, and in certain dimensions may serve as an innovation stick. Particularly relevant here is the doctrine 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 and at certain leading cases that reflect the general view of these doctrines.

Under the Restatement, there are three types of product defects: *design defects*, which occur where the foreseeable risks of the product could be reduced by the manufacturer's "adoption of a reasonable alternative design"; *manufacturing defects*, or departures from the planned design; and *warning defects*, which occur where the manufacturer could have reduced the risk of a product with instructions or warnings where the risk was reasonably foreseeable to the manufacturer.[20] 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.[21] The knowledge of the manufacturer may be relevant to the feasibility of alternative designs or the reasonableness of

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[20] RESTATEMENT (THIRD) OF TORTS: PROD. LIAB. § 2 & comment *m* (1998).

[21] *See, e.g.*, Burton v. R.J. Reynolds Tobacco Co., 397 F.3d 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, 1528 (D. Minn. 1989) ("This Court has already held that the duty to test is a subpart of the duty to warn . . . . The 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."); *cf.* Am. L. Prod. Liab. 3d § 11:4 ("[Generally,] 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, e.g.*, Borel v. Fibreboard Paper Prods. Corp., 493 F.2d 1076, 1091 (5th Cir. 1973) (applying Texas law); Horne v. Liberty Furniture Co., 452 So. 2d 204, 209 (La. Ct. App. 1984).

warnings, and the duty to test is a way of imputing to the manufacturer knowledge of these possible designs or warnings.[22]

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 revealed such defects. Customers have little ability to conduct testing on their own, making manufacturers, in tort parlance, the "cheapest cost-avoiders," particularly where the negative effects of these products are complex and difficult to discern.[23]

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 as regards the extent of the duty to test.[24] Courts tend to speak generally about the foreseeability of the possible harm and the practicability of testing,[25] 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.[26] Notably, courts often speak of the importance of the manufacturer's status as an expert in a particular field.[27] This recalls the potential of yardsticks to reduce information costs, as we described above. If a court can determine, for example, that most car companies do rollover tests to ensure the safety of their seatbelts, then this could serve as evidence that a company that failed to do such tests breached

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[22] *See* RESTATEMENT (THIRD) OF TORTS: PROD. LIAB. § 2 comment *m* (1998) ("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.").

[23] *See, e.g.*, Wendy E. Wagner, *Choosing Ignorance in the Manufacture of Toxic Products*, 82 CORNELL L. REV. 773, 773 (1997); Dalehite v. United States, 346 U.S. 15, 52 (1953) (Jackson, J., 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.").

[24] *See, e.g.*, 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").

[25] *See* 6 A.L.R.3d 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.") (citing cases).

[26] *See, e.g.*, Richter v. Limax Int'l, Inc., 45 F.3d 1464, 1471 (10th Cir. 1995) (stating that manufacturers "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 trampoline manufacturer had breached its duty to test for risk of stress fractures to ankles); 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." (citation omitted)); Prather v. Abbott Labs., 3:09-CV-00573-H, 2013 WL 1332903, at *8 (W.D. Ky. Apr. 2, 2013) (stating that 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 defendant in breach of that duty where contemporaneous medical knowledge did not put defendant on notice of risk).

[27] *See, e.g.*, Feldman v. Lederle Labs., 479 A.2d 374, 387 (N.J. 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 information need not be limited to that furnished by experts in the field, but may also include material provided by others.").

its duty to undertake reasonable tests.[28] Tort law commonly uses custom in an industry to define appropriate standards of care.[29] What we imagine is analogous, where 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 non-homogenous industries, in industries where firms are in relevant ways similar or where differences can be accounted for recourse to custom could help identify a minimum level of R&D that should be required.[30] The results will surely be imperfect.[31] The critical question, however, is how they would compare to the alternative, in which firms have perverse incentives not to conduct R&D that might discover dangers, although they are in the best position to discover those dangers.

The "state of the art" defense raises issues similar to that of the duty to test, but in a different posture. Here, companies can escape liability if they show that their product was "state of the art," so that there was no feasible better design or better warning given the state of knowledge at the time.[32] The point of the doctrine is to provide a safe harbor to ensure that manufacturers are not penalized for undertaking tests, which otherwise can be perversely deterred by tort law.[33] But the doctrine only serves this purpose well if it correctly identifies the level of testing that is appropriate to trigger the safe harbor. As such, as some courts have

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[28] *Cf.* Hopper v. Crown, 646 So. 2d 933, 945-46 (La. Ct. App. 1994) (holding that forklift manufacturer "breached its duty to test and experiment" when it failed to test safety of doorless forklift, knowing that its competitors offered forklifts with doors for safety purposes). This example illustrates that tort law, in certain application such as described in our analysis of automobile fatalities, can be a "barrier to entry." We acknowledge that such barriers may result in economic inefficiencies, however emphasize that tort law, as an innovation stick , is an effective tool of innovation policy that can lead to broader efficiency gains to society.

[29] Dan B. Dobbs et al., The Law of Torts, § 179 (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."); *see also* 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.").

[30] See supra note 50 and accompanying text.

[31] That is not only because custom may be difficult to discern, or because courts will make mistakes in discerning it. In addition, entire industries may underinvest in R&D, creating a circularity problem. 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, because of the many factors that mediate the relationship between tort liability and long-term corporate decisionmaking.

[32] *See, e.g.*, James Boyd & Daniel E. Ingberman, *Should "Relative Safety" Be a Test of Product Liability?*, 26 J. LEGAL STUD. 433, 441 (1997); *see also* Jane Stapleton, *Liability for Drugs in the U.S. and EU: Rhetoric and Reality,* 26 REV. LITIG. 991, 1010 (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 (at least twelve states), it is a conclusive defense, and usually operates by establishing a rebuttable presumption that the relevant product was not defective. *See* Boyd & Ingberman, *supra* note 32, at 441.

[33] Wagner, *supra* note ___, at 794-96. This example helps illustrate the point about baselines made above, supra at _. 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.

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."[34]

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.[35] The former would appear to impose very high information burdens on the court, but the latter seems likely to provide inadequate incentives to test.[36] A better approach might have yardstick qualities, and ask courts to determine not that there was no product possibly safer than that of the defendant, but use industry standards to require above-average safety, and above-average investments in R&D.[37]

We do not wish to overstate the power of tort law to directly promote investment 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 the 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 on the level of evidence required to get to a jury, plaintiffs may be unable to do so in the absence of epidemiological research that connects the product in question to the harms that the plaintiffs have suffered.[38] 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 show.[39] This can be seen as an innovation stick that is imposed on the wrong party: plaintiffs are denied relief for their

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[34] *See* Dartez v. Fibreboard Corp., 765 F.2d 456, 463 (5th Cir. 1985) (emphasis added); *see also* Artis v. Corona Corp. of Japan, 703 A.2d 1214, 1217 n.6, 1218 (D.C. 1997) (favorably citing the *Dartez* formulation, and reversing grant of summary judgment for the defendant because lower court had failed to consider what a "competent manufacturer reasonably could have developed at the time the [product] was manufactured and sold," despite lack of availability of commercially available safety measure at the time of the injury).

[35] *See generally* Boyd & Ingberman, *supra* note 32, at 436-40 (surveying cases and jurisdictions that these respective standards).

[36] On the latter point, see *id*.

[37] *Cf*. Boyd & Ingberman, *supra* note ___, at 436 (making this point, though with respect to existing safety without incorporating the duty to test point).

[38] Wagner, supra note 23, at 774-75.

[39] For an expansive understanding of how causation might be understood in this context, see Zuchowicz v. United States, 140 F.3d 381 (2d Cir. 1998) (Calabresi, J.) (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, e.g.*, Reynolds Metals Co. v. Yturbide, 258 F.2d 321 (9th Cir. 1958); Dan B. Dobbs et al., The Law of Torts § 191 (2d ed.). 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 – 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 seatbelt disengaged during a rollover, the cause of the injury will not be difficult to discern, although the appropriate level of R&D might be.

injuries unless they perform expensive studies that identify the cause of those injuries, though manufacturers are in a much superior position to perform studies.

Our analysis above offers reasons that courts might be appropriately cautious regarding the deployment of this particular innovation stick, but also 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 approaches – based upon 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, and 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 invited 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.[40] Statutes could be used to define the appropriate level of testing, reducing the information burden on courts, and increasing predictability for industry.[41] This would replicate something akin to the FDA standards that forbid 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 a liability rule (in the form of compensatory tort liability).[42] The information asymmetries between consumers and producers in such cases would appear to make some such approach very valuable, perhaps combined with a set of traditional or non-traditional carrots.

Part 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, we ask "How concretely might a CAFE-like system be applied to internalize these costs of "above median" fatality risks?"

One such way to internalize these 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 on a year-by-year basis the median manufacturer rate.[43] As with Table 2, the per-vehicle penalties reported below in Table 1A are best construed as an upper bound estimate

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[40] Wendy Wagner has proposed a system like this for toxic torts. *Id.* at 834. 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." *Id*. at 834-35.

[41] *Id*. at 833, 838.

[42] But 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 be required (for some products but not others?), and how courts would determine industry standards – of course would follow.

[43] To translate the flow of annual manufacturer penalties into a one-time charge, we calculate the present value of a 10-year annuity—assuming that the average car stays on the road for 10 years—at a 5% discount rate.

and enlightened regulation might phase in the penalties so that manufacturers with poor safety standards would have time to correct their ways.[44]

Table 1A: Estimates of "Above Manufacturer Median" Fatality Rates and Associated Per-Vehicle Costs

	Average Fatalities 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), 12y average		($/vehicle), based on 12y average		($/vehicle), based on 12y 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	0.4	$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
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

Note: The first two columns are the 12-year average fatality rate over median for each manufacturer. Only manufacturers who have had a total fatality rate over median in at least one of the years 2000-2011 are shown here. The second two columns show the average societal cost per year annuitized at 5% for 10 years. This represents the average fatalities externality at the purchase of the average vehicle made by that manufacturer at the time of purchase for total or external fatalities. Average yearly societal 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

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

that number of fatalities by $7.6 million, the value of a human life as calculated by the EPA, and then averaging over 12 years.19 Manufacturers who produced “below median” for both total and external fatality rates for all 12 years were [19 car manufacturers].

Table 1A, by estimating the per-vehicle costs associated with excess fatalities, dramatizes the extent of the problem.

The “state-based costs of death from crashes” has been an independent concern of the Centers on Disease Control and Prevention (CDC), which in 2005 estimated the state-specific costs of crash deaths.[45] 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] are found in 10 states.”[46] The CDC then lists:

> The 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).

It should hardly be surprising, however, that California and New York, because of their sheer population size, 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 the state, we see a ranking that closely parallels the ranking in Figure 4 with Mississippi, Arkansas and South Carolina as the most fatal states.

We present estimates for “above state median” fatality rates, calculated analogously to the estimates in Table 2, in Table 2A:[47]

Table 2A: “Above State Median” Fatality Rates and Associated Per-Vehicle Costs

	Average Fatalities Rate Over Median		Societal Cost at Time of Purchase for Fatalities Over Median		CDC Cost Over Median per Vehicle	Average Yearly Societal Cost of Fatalities Over Median		CDC Cost Over Median per Vehicle	Societal Cost at Time of Purchase for Fatalities Over Median, corrected for miles driven	
	(Fatality rate/100,000 vehicles), 12y average		($/vehicle), based on 12y average		($/vehicle), 2005	($ Million), 12y average		($ Million), 2005	($/vehicle), based on 12y average	
State	Total fatalities	External Fatalities	Total fatalities	External Fatalities	CDC Cost	Total fatalities	External Fatalities	CDC Cost	Total fatalities	External Fatalities

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[45] 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, 354 (2010).

[46] *See State-Based Costs of Deaths from Crashes*, CENTERS FOR DISEASE CONTROL & PREVENTION, *available at* http://www.cdc.gov/Motorvehiclesafety/statecosts/index.html (last visited Feb. 17, 2014).

[47] “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. Then, these differences are averaged over the 12 years in the sample. 12 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.

MS	26.77	9.53	$15,710	$5,594	$2,337	$4,070	$1,450	$605	$13,127	$4,498
AR	17.64	7.24	$10,354	$4,248	$1,352	$2,630	$1,080	$343	$9,126	$3,760
SC	15.21	5.25	$8,926	$3,083	$1,229	$3,870	$1,330	$533	$7,611	$2,558
NM	13.17	3.52	$7,729	$2,064	$1,055	$1,550	$415	$212	$8,527	$2,506
WV	13.00	4.44	$7,630	$2,606	$839	$1,400	$477	$154	$7,805	$2,763
WY	11.25	1.93	$6,600	$1,131	$526	$540	$93	$43	$6,877	$1,312
AZ	11.06	4.43	$6,489	$2,598	$1,023	$3,390	$1,350	$534	$6,336	$2,605
NV	10.98	4.61	$6,446	$2,703	$1,099	$1,100	$463	$188	$6,783	$2,934
KY	10.72	4.65	$6,288	$2,729	$852	$2,800	$1,220	$379	$5,449	$2,424
NC	10.05	4.28	$5,898	$2,509	$775	$4,670	$1,980	$614	$4,899	$2,125
MT	9.55	1.45	$5,603	$852	$454	$722	$109	$59	$4,704	$676
LA	9.31	3.58	$5,463	$2,102	$851	$2,680	$1,030	$418	$4,073	$1,549
TN	9.08	3.42	$5,326	$2,010	$671	$3,450	$1,310	$435	$4,176	$1,561
AL	8.46	3.34	$4,966	$1,960	$703	$2,890	$1,140	$409	$3,846	$1,523
MO	8.26	3.29	$4,849	$1,929	$686	$2,900	$1,150	$410	$4,255	$1,726
OK	8.13	4.03	$4,772	$2,365	$339	$2,000	$989	$142	$3,850	$2,012
TX	7.12	3.64	$4,181	$2,134	$436	$8,700	$4,450	$908	$2,970	$1,653
FL	6.01	3.04	$3,524	$1,782	$441	$6,710	$3,400	$840	$3,223	$1,716
GA	5.12	2.64	$3,003	$1,549	$370	$3,050	$1,570	$375	$1,427	$902
SD	4.87	0.78	$2,859	$461	$297	$310	$51	$32	$2,563	$403
ID	4.62	0.70	$2,711	$408	$307	$458	$69	$52	$3,123	$640
DC	4.58	1.87	$2,685	$1,096	$0	$80	$33	$0	$2,124	$957
KS	4.35	2.42	$2,554	$1,420	$295	$782	$434	$90	$2,090	$1,288
ME	2.66	0.76	$1,562	$443	$27	$209	$59	$4	$990	$268
DE	2.58	1.86	$1,511	$1,094	$6	$140	$103	$1	$1,353	$1,090
ND	2.01	0.71	$1,182	$417	$119	$111	$40	$11	$724	$354
IN	1.43	1.08	$837	$635	$266	$562	$438	$179	$391	$439
WI	1.04	0.33	$609	$192	$112	$361	$114	$66	$391	$144
PA	0.83	0.20	$485	$116	$76	$619	$148	$97	$781	$293
UT	0.83	0.14	$485	$84	$0	$106	$18	$0	$446	$81
NE	0.74	0.63	$435	$368	$0	$94	$81	$0	$514	$468
VT	0.60	0.29	$352	$170	$0	$24	$12	$0	$180	$94
MD	0.50	0.42	$292	$245	$0	$149	$126	$0	$27	$108
OR	0.49	0.09	$289	$52	$12	$111	$20	$5	$685	$149
CO	0.41	0.06	$241	$33	$0	$124	$18	$0	$189	$12
HI	0.35	0.00	$206	$2	$0	$23	$0	$0	$1,957	$350
AK	0.13	0.08	$79	$44	$0	$6	$3	$0	$600	$168
VA	0.06	0.00	$38	$0	$0	$32	$0	$0	$0	$0
IA	0.00	0.04	$0	$26	$0	$0	$11	$0	$0	$23
MI	0.00	0.19	$0	$110	$0	$0	$119	$0	$0	$8

Table 2A also reports the per vehicle based on CDC cost-calculating methodology which focused on the social cost from health care and lost work instead of our cost-of-life approach.[48] 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 its annual penalty would be more than $600 million.

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

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

i) Teen and Under-the Influence Driving

The fatality rates experienced by manufacturers and states might also be impacted by differences in the recklessness of their drivers. Male-teen drivers and people driving under the influence of alcohol or drugs have dramatically higher accident rates.[49] Manufacturers of identical automobiles might experience different fatality rates just because of differences in the extent to which particularly manufacturers attract reckless drivers. This section will empirically investigate the connection between teen 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 the innovation sticks should be adjusted for reckless driver influences. We reach this conclusion because we believe that manufacturers and states that disproportionately have reckless drivers are likely to be able to adopt cost-effective measures to deter the recklessness or mitigate the impact of their recklessness.

But we begin our analysis by reporting the proportion of fatalities that come from accidents in which a teen male was driving or in which the driver was under the influence of drugs or alcohol.[50] Table 3A reports the 5 highest proportions by manufacturer and by state:

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[48] The CDC methodology which was estimated solely for 2005 data is more fully described in Naumann et al., *supra* note __.

[49] Allan Williams finds that in the year 2000 teen males were about twice as likely to be involved in a fatal crash as teen females per licensed driver. Allan Williams, *Teenage Drivers: Patterns of Risk*, 34 J. SAFETY RES. 5, 6-7 (2003). The dangers of drunk driving are well documented, see, for example,. the CDC's statistic that one third of all traffic deaths are alcohol-related, *Impaired Driving: Data & Statistics*, CENTERS FOR DISEASE CONTROL & PREVENTION, *available at* http://www.cdc.gov/Motorvehiclesafety/Impaired_Driving/data.html (last updated Oct. 2, 2012). \

[50] Teen male totals are calculated from sex and age variables in the FARS data (age between 14 and 20). Only drivers are considered. Alcohol and drug totals are calculated from the alcohol and drug flags ("drinking" and "drugs") in the FARS data. If there the yes-no alcohol or drug flag is missing, we assume that drugs and alcohol were not a factor in the accident.

Table 3A: Highest Manufacturer and State Proportion of Total Fatalities involving a Teen-male Driver or a Driver under the Influence of Drugs or Alcohol

Manufacturer	Fraction of Fatal Accidents Involving Teen Males	Manufacturer	Fraction of Fatal Accidents Involving Alcohol & Drugs	State	Fraction of Fatal Accidents Involving Teen Males	State	Fraction of Fatal Accidents Involving Alcohol & Drugs
Acura	16.3%	BMW	26.1%	NE	10.8%	SD	34.3%
Honda	11.9%	Porsche	25.2%	ID	10.0%	MT	32.5%
Mitsubishi	11.7%	Audi	24.8%	RI	9.7%	WV	29.9%
Pontiac	11.1%	Jaguar	22.6%	KS	9.6%	ND	29.8%
Audi	10.7%	Saab	22.4%	UT	9.5%	WY	29.3%

Table 3A reports that more than a quarter (26.1%) of fatal accidents involving a BMW occurred when a BMW driver was under the influence, and that more than a third (34.3%) of fatal accidents in South Dakota involve at least one driver who was under the influence. These simple statistics might suggest guides for action. If South Dakota or Montana want 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 they have been inordinately successful in reducing other causes of fatalities. For example, BMW has the highest manufacturer proportion of driver under-the-influence fatalities, but has a below-median fatality rate (as indicated by its absence from the above-median analysis in Table 1A). If BMW wants to reduce it fatalities further, it might want to consider taking action to deter or mitigate the impact of alcohol and drug-related driving. Evidence presented in Table 3A, however, is not sufficient to establish that it has an above median risk of under-the-influence fatalities.

Table 4A responds to this concern by reporting the likelihood ratio of teen male fatality rates relative to share of a manufacturer or state cars more generally. Acura is estimated to have a teen-male likelihood ratio of 2.19 because Acura has a .84% share of registered cars, but a 1.84% share of fatal accidents in which with a teen-male was driving. Table 4A reports the ten highest and five lowest likelihood ratios for each of the 4 categories:

Table 4A: Highest Manufacturer and State Likelihood Ratios of Total Fatalities involving a Teen-male Driver or a Driver under the Influence of Drugs or Alcohol

Manufacturer	**Likelihood Ratio - Teen Males**	**Manufacturer**	**Likelihood Ratio - Alcohol & Drugs**	**State**	**Likelihood Ratio - Teen Males**	**State**	**Likelihood Ratio - Alcohol & Drugs**
Acura	2.19	Mitsubishi	1.72	MS	2.50	WV	2.60
Mitsubishi	2.12	Pontiac	1.49	AR	1.75	AR	2.48
Pontiac	1.75	Isuzu	1.43	SC	1.55	MS	2.40
Isuzu	1.35	Chevrolet	1.37	MO	1.55	SC	2.32
Chevrolet	1.29	GMC	1.35	NM	1.55	MT	2.25

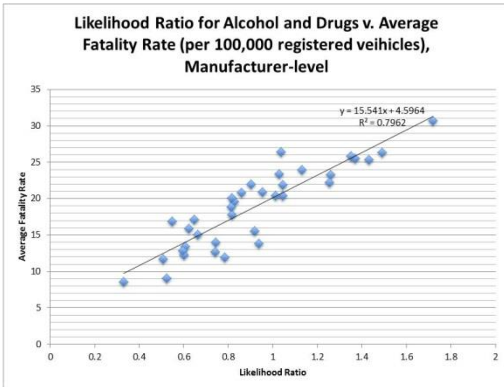
Mazda	1.17	Acura	1.26	KY	1.47	WY	1.99
Jeep	1.11	Jeep	1.25	LA	1.47	NV	1.95
Nissan/Datsun	1.10	Ford	1.13	AL	1.44	SD	1.83
GMC	1.09	Nissan/Datsun	1.04	NC	1.42	NM	1.80
Ford	1.06	Infiniti	1.04	TN	1.41	KS	1.66
…	…	…	…	…	…	…	…
Jaguar	0.46	Subaru	0.59	CA	0.66	MN	0.56
Cadillac	0.44	Buick	0.55	AK	0.65	NY	0.47
Mercedes-Benz	0.41	Saab	0.52	CT	0.64	NJ	0.45
Saab	0.41	Suzuki	0.51	NJ	0.56	RI	0.44
Volvo	0.39	Volvo	0.33	MA	0.51	MA	0.24

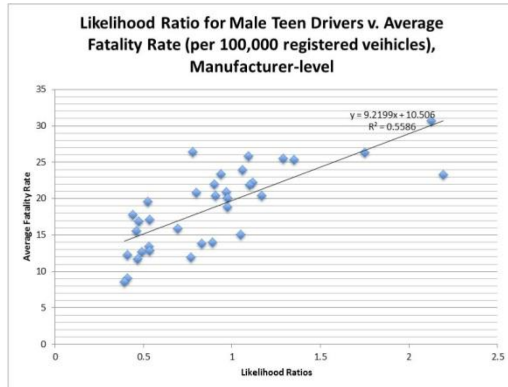
Note: Likelihood ratios are the manufacturer/state proportion of drunk drivers involved in fatal accidents divided by the proportion of nationally registered cars in a state or made by a manufacturer

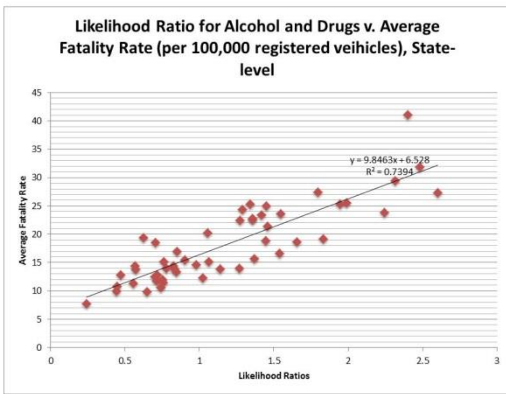
Unlike the Table 3A proportions, the Table 4A likelihood ratios are independent of how successful a manufacturer or a state is in reducing other types of fatalities. Hence we see some manufacturers that were prominent in the Table 3A proportions are absent from Table 4A's highest likelihood ratios. BMW had the highest proportion of under-the-influence fatalities, but has likelihood ratio is only .83 (because while it has .96% of registered vehicles, it generates only .79% of under-the-influence driver fatalities). Similarly, we see that Honda had the second highest proportion of teen male driver fatalities, but has a likelihood ratio close to 1 – 1.05. Overall, Honda is one of safer cars (as can also be seen by its absence from the above-median analysis in Table 1A).

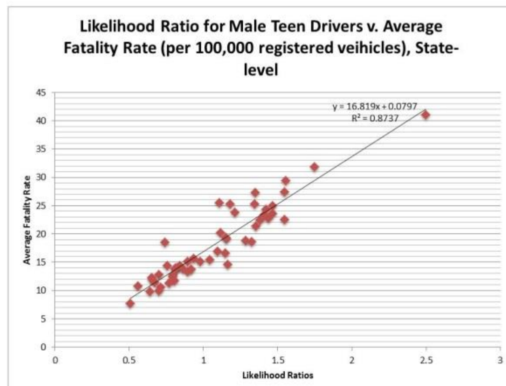
Stepping back, we see a strong positive correlation between the states and manufacturers that have the highest fatality likelihood ratios for teen-male and under-the-influence driving and the manufacturers and states that had the highest total fatality rates. Figures 1A-4A plot the four scatter diagrams showing the extent of these correlations:

Figures 1A-4A: Likelihood Ratios for Teen-Male and Under-the-Influence Driving and Average Fatality Rate, at the Manufacturer and State Level









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 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 3 B of the text, the figures suggest that above-median states and manufacturers might reduce their total fatality rate by taking action on teen and under-the-influence driving.

The figures also suggest that variation in the under-the-influence risk is a more important influence than teen driving risk with regard to variations in manufacturer fatality rates, but that teen driving risk is a more important influence than under-the-influence risk with regard to variations in state fatality rates.[51]

[51] This can be seen in the Figures by the fact that for manufacturers the under-the-influence correlation is steeper and has a better fit than the teen correlation, while for states, the teen 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 drive whatever car their parents are driving. 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 car, 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 (R^2 = .74 v .79).