Innovation Sticks:
The Limited Case for Penalizing Failures to Innovate

Ian Ayres* & Amy Kapczynski**

DRAFT – PLEASE CONTACT US BEFORE QUOTING OR CITING

Abstract: When policymakers and academics think about designing optimal innovation incentives, they almost exclusively limit their considerations to alternative types of reward incentives. But in this article, we show that under specific circumstances innovation sticks – potential penalties for failure to innovate – can play a valuable role in our innovation policy, either alone or in conjunction with innovation carrots. What's more, we provide examples of several innovation sticks that already have been used with apparent success, including the Federal Corporate Average Fuel Economy (CAFE) standards. Finally, we apply our approach to a new area to which we think innovation sticks may be well-suited: the problem of car fatalities. Our model suggests that a relatively simple system of yardstick penalties could help reduce national auto fatalities by as much 20%, simply by bringing laggard entities (companies and states) up to the median.

*William K. Townsend Professor, Yale Law School. ian.ayres@yale.edu

** Associate Professor, Yale Law School. amy.kapczynski@yale.edu

The authors would like to thank Dustin Brockner, Rebecca Buckwalter-Poza, Gregory Conyers, Tanya Kapoor, Kirstin Maguire, Shaun Mahaffy, Dwight Pope and Robert Quigley for excellent research assistance. Yair Listokin, Alan Schwartz and participants at Yale's Innovation Law Beyond IP Conference provided helpful comments.

Introduction

The existing literature on innovation policy has focused dominantly on carrots, or opportunities to gain rewards. Such carrots take many different forms. The legal literature has largely focused on exclusionary carrots, especially on the granting of intellectual property rights.[1] Inducement prizes and government grants have also been widely discussed, particularly in the economics literature.[2] Recent attention has also been given to additional mechanisms such as R&D tax credits[3] and "commons-based" approaches.[4]

This vast literature, however, presents a puzzle: It focuses solely on carrot approaches to innovation, and does not address what role, if any, "sticks" might play in innovation policy.[5] This paper will introduce the concept of innovation sticks as a policy tool, and describe their advantages and limits. Instead of rewarding an actor for innovating, innovation sticks threaten to penalize an actor for failing to innovate. Drawing on the insights of the new "sticks and carrots" literature, we describe why innovation sticks have been invisible in the IP field, and theorize the circumstances in which sticks may be a good policy choice, either alone or – likely more often – in conjunction with traditional or non-traditional carrots.

Because they provide a penalty rather than reward, innovation sticks cannot perform one function that is often assumed essential in the IP and information economics literature – they cannot compensate parties for their investment in information production.[6] This literature thus suggests that innovation sticks should not exist. Yet they do.

---

[1] See, for example, WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW (1st ed. 2003); ROBERT P. MERGES, JUSTIFYING INTELLECTUAL PROPERTY LAW (2011).

[2] *See, e.g.*, Brian D. Wright, *The Economics of Invention Incentives: Patents, Prizes, and Research Contracts*, 73 AM. ECON. REV. 691, 703 (1983); SUZANNE SCOTCHMER, INNOVATION AND INCENTIVES 1-58 (2006)..

[3] Daniel J. Hemel & Lisa Larrimore Ouellette, *Beyond the Patents—Prizes Debate*, 92 TEX. L. REV. 303, 321 (2013); Shaun Mahaffy, Note, *The Case for Tax: A Comparative Approach to Innovation Policy*, 123 YALE L.J. 812 (2013).

[4] *See, e.g.*, YOCHAI BENKLER, THE WEALTH OF NETWORKS: HOW SOCIAL PRODUCTION TRANSFORMS MARKETS AND FREEDOM (2007); . The literature on the commons often emphasizes the importance of market-based or non-pecuniary rewards, though its conception of motivation is more complex than in standard economic accounts.

[5] The only work we are aware of that identifies the potential of innovation sticks is a recent unpublished working paper. See Julien Pénin, Should We Oblige Firms to Invest in R&D? Knowledge Spillovers and the Market of 'Not to Invest in R&D Tradable Permits' (BETA-University of Strasborg-CNRS Nov. 14, 2013), *available at* http://ssrn.com/abstract=2354283. Penin makes the case for one particular kind of stick (a system of tradable permits to "not engage in R&D"), rather than a case for sticks in general. We come to some similar conclusions, particularly regarding the possible promise of sticks, but we develop a set of arguments, for example about the innovation literature, the undercompensation problem, and the possible tradeoffs between non-traditional carrots and sticks, that he does not.

[6] As Gerrit De Geest and Giuseppe Dari-Mattiacci put it, "[c]arrots do two things: they give the agent an incentive to incur some effort cost and they fully compensate the agent for this effort cost (since less than full expected compensation would not incentivize). Sticks, in contrast, do only the former."

Federal Corporate Average Fuel Economy (CAFE) standards, for example, create penalties for car companies whose fleets fail to meet fuel efficiency standards that increase over time.[7] The CAFE program is a stick because it mobilizes penalties rather than rewards, and in our parlance is an "innovation" stick because it plausibly induces innovation or the production of new information.[8] Although there is disagreement about the efficacy of the CAFE program, a National Research Council review in 2002, for example, concluded that "[t]he CAFE program has clearly contributed to increased fuel economy of the nation's light-duty vehicle fleet during the past 22 years."[9] CAFE standards are set by regulators who have long seen them as "technology forcing."[10] Recent amendments have pushed further, to include standards that are "augural, meaning that they represent NHTSA's current best estimate, based on the information available to the agency today, of what levels of stringency might be maximum feasible in those model years."[11] The existing IP literature, however, gives us few tools for understanding why the program might exist, why it might be effective, or whether it is an example of a broader possible set of innovation tools.

Before proceeding, it is important to address whether there is a meaningful difference between carrots and sticks. As Wendy Gordon has seen: "One can verbally transform most benefit questions into 'harms' and vice versa by juggling the baseline from which effects are measured."[12] If automobile manufacturers expected, as one of the costs of doing business, to pay the government $50 million a year for the environmental damage done by their cars, then any possibility to reduce the payment, say, to merely $40 million might be experienced as a carrot. We readily acknowledge that whether something is seen as a carrot or a stick depends upon the baseline framing, which can, in some instances, be malleable. Then again, it is the rare the mousetrap manufacturer who views the failure of the government to grant a 20-year monopoly on a new product as a punishment for not coming up with a better trap. And it is the rare automobile manufacturer who views a CAFE fine as the absence of a reward. As we emphasize below,[13] potential inventors volunteer for carrots, for example, when they apply for a

---

Gerrit De Geest & Giuseppe Dari-Mattiacci, Carrots versus Sticks 16 (Washington Univ. Sch. of Law Working Paper, No. 09-09-03, Aug. 2009), *available at* http://ssrn.com/abstract=1470129.

For a description of why compensation of innovators is typically assumed necessary, see *infra* Part I..

[7] For a fuller description of the CAFE standards, see *infra* Part II.

[8] We return to the question of what we understand by "innovation" in Part I.

[9] NATIONAL RESEARCH COUNCIL, EFFECTIVENESS AND IMPACT OF CORPORATE AVERAGE FUEL ECONOMY (CAFE) STANDARDS (2002).

[10] *See infra* note _.

[11] 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 77 Fed. Reg. 62,624, 62,627 (Oct. 15, 2012) (to be codified at 40 C.F.R. pts. 85, 86 & 600).

[12] Wendy J. Gordon, *Of Harms and Benefits: Torts, Restitution, and Intellectual Property*, 21 J. LEGAL STUD. 449, 451 (1992) ("One can verbally transform most benefit questions into "harms" and vice versa by juggling the baseline from which effects are measured.").

[13] See infra at .

patent. Potential inventors who ultimately fail are unlikely to self-nominate to bear the pain of the stick.[14]

In Part I, we set forth our theoretical account of the potential and limits of innovation sticks. We begin by briefly reviewing the justifications offered for intellectual property, and the main tradeoffs identified in the IP and innovation economics literature between different kinds of carrots, and in particular between what we will call "conventional carrots" (namely, exclusion rights), and "non-traditional carrots" (namely, government grants and prizes). Certain benefits and drawbacks of each of these mechanisms have been long identified in the literature. For example, a key tradeoff between prizes and patents is in the comparative costs (including of error) of government estimation of the value of the desired innovation, versus the comparative cost of the deadweight loss associated with exclusive rights.

We also recount several more recent arguments for the importance of non-traditional carrots, stressing these because they also expand the potential utility of sticks. In particular, non-traditional carrots – and sticks (together, "non-traditional measures") – are particularly useful where predictable market failures exist. For example, markets radically undervalue pollution-saving endeavors from a social perspective, helping to explain the existence of CAFE standards. CAFE gains cannot be induced through market measures (absent a significant market-correcting initiative, such as a carbon tax or higher fuel tax – measures that, however sensible, are widely considered infeasible).[15] In addition, non-traditional measures are especially useful to create incentives for actors, such as states, that are differently situated with respect to markets than are private actors, and so are not significantly incentivized by market-based innovation rewards. We also stress another point, this one less familiar: Innovation is often multi-modal – for example, it may occur via technical change, or via "social" innovation (which may be organizational, political, or even in "lifestyle").[16] Where we are uncertain which mode of innovation is needed (or cheapest), innovation promoting tools that are themselves *agnostic as regards the mode of innovation* may be desirable. Indeed, we may want tools that can be agnostic as to whether achievement comes through innovation or uptake of existing innovations. Sticks and non-traditional carrots have this quality, while traditional exclusion rights do not. Importantly, non-traditional measures also have significant shared drawbacks. Most prominently, to be effective they impose distinctive informational demands on government including, for example, defining the trigger for awarding the carrot or imposing the stick. Because of the importance of this problem, we stress one possible strategy to minimize this informational burden, drawing from the economics literature on "yardstick competition."

---

[14] For those hardcore advocates of the view that every stick can be redescribed as a carrot (and vice versa), our argument is that policy makers should be more willing to move the baseline – as in our car fatality example, by changing the default to a large tax that can only be reduced (a carrot) if the manufacturer exceeds the median rate of safety.

[15] *See, e.g.*, Eduardo Porter, *Taxes Show One Way to Save Fuel*, N.Y. TIMES, Sept. 11, 2012, *available at* http://www.nytimes.com/2012/09/12/business/fuel-efficiency-standards-have-costs-of-their-own.html (noting the recent failure of Obama's carbon allowances measure, and noting that "[a] tax on gasoline doesn't stand a chance").

[16] See infra note _.

Up this point we have been discussing features of an innovation environment that should lead us to consider some kind of non-traditional measure to promote innovation – but when should these be carrots, and when sticks? Part I closes by setting out some of the theoretical benefits and drawbacks of innovation sticks as compared to non-traditional carrots. One key benefit of sticks is that in equilibrium they may not need to be paid. In contrast to the distortions associated with either patent pricing or generating the tax revenue for prizes, the threat of penalties for failure to innovate may produce equilibria with fewer price distortions. Relatedly, when the threat of sticks works to produce innovation, innovators are not compensated for their efforts. This undercompensation of innovative effort in the long run may lead innovators to exit from an industry. This may or may not be a problem. Where sticks are targeted at externalities, they can have salutary effects even if they reduce activity levels. If cars whose benefits do not exceed their costs to third parties are eliminated from the market, this too is a social gain.

Sometimes, though, we will not want to induce exit as a penalty of failing to innovate, making the undercompensation issue more acute. We therefore offer several reasons to think that the undercompensation problem is less extensive than the conventional literature suggests, and here too draw on the insight that innovation is often multi-modal. We suggest that the most important factor in choosing between a stick and a non-traditional carrot is the comparative distortions of undercompensation versus overcompensation. We also identify several other relevant considerations, such as the possibility that sticks impose different informational burdens on government than carrots, or that sticks may be difficult for government credibly to deploy, or that sticks may have adverse distributional consequences. Finally, we point out that innovation sticks can readily be combined with non-traditional and traditional carrots, and suggest some of the benefits and risks of the combined approach.

In Part II, we describe several real-world examples of innovation sticks to make our theoretical analysis more accessible (and in an on-line appendix we describe several more). As with CAFE, several of our examples target private actors. But we also provide examples, such as portions of the "No Child Left Behind" Act, where government actors have been challenged to improve or face financial and non-financial penalties. Some of our examples at least indirectly deploy yardsticks in that the penalty trigger is derived in part from what other actors have achieved or will be able to achieve. A payoff of our theory is to help us understand why sticks may have been used in the cases we identify, and also to suggest that many of these innovation sticks might be more successful in they were more directly tied to yardstick competition to help determine who is penalized and also how large the penalty will be. We also point out how broadly the category of sticks can be conceived. Cap and trade systems, like the Chicago Climate Exchange where more than 350 firms agreed to greenhouse emission caps that reduced by one percent a year, combine carrot and stick incentives in the selling and buying of rights to innovate to save energy.[17] Even simple prohibitions, such as laws that ban incandescent light bulbs or chlorofluorocarbons can be a powerful impetus to innovation.

[17] Ian Ayres & Barry Nalebuff, *Your Personal Climate Exchange,* Forbes 24, 2008; Ian Ayres, Carrots and Sticks, supra note , at 138.

The image of the "light bulb going off" has been a longstanding visual metaphor for the moment of creativity. But our analysis suggests a new meaning. When the Energy Independence Act of 2007 ordained that manufacturers would need to cease manufacturing most incandescent light bulbs by 2014, industry participants had strong incentives to create alternative sources for lighting.[18] The vanishing light bulb above the head is a symbol of a new mode of creativity. Not for nothing is invention said to be "necessity's child." Seen this way, the concept of innovation sticks is very broad indeed. After all, every fine and prohibition might lead to innovation, because innovation can permit actors to avoid or lessen the impact of the penalty. The law against homicide, we might say, does not just prohibit homicide. It also creates incentives for people to torment others in more creative ways, or to develop forms of homicide that avoid detection. We are not convinced that the expansiveness of our concept of innovation sticks is a problem for our account. Interesting things might result from thinking about parking bans and tax systems as sticks that (inadvertently) lead to innovation. Our primary interest, however, is not in investigating the far reaches of the concept, but rather in facilitating our ability to think systematically thorough the virtues and costs of using innovation sticks to induce productive kinds of innovation.

In Part III we offer a proof-of-concept example of a yardstick stick mechanism that addresses the significant problem of automobile fatalities in the United States. We show that identifiable manufacturers and states persistently lag the safety levels attained by their peers. For example, we find that just reducing the fatality rate in these persistently above median states would reduce national auto fatalities by 20% with an annual social benefit of more than $60 billion. Under one thought experiment, CAFE-like penalties would be visited upon actors who failed to keep up with what the median actor had shown was feasible (and these penalties transferred to reward below-median actors who pioneer safety improvements). Neither our empiricism nor our CAFE-like fatality proposal is intended to be definitive. But it is intended to further the plausibility of innovation sticks as powerful and often appropriate policy tool that deserves to be included in policy-making processes.

We do not claim to have exhausted the possible benefits and drawbacks of innovation sticks, but offer a preliminary analysis that shows that innovation sticks deserve – indeed, already have – a place in the policymaker's toolkit. We also highlight key considerations that may make them advisable or unadvisable in particular circumstances. Often the question will be whether innovation sticks should be used in tandem with traditional and non-traditional carrots, so that we should consider whether using both carrots and sticks is preferable to merely relying on carrots.

I. The Case for Sticks

Mapping out the advantages and disadvantages of sticks requires us to first understand some of the limits of conventional innovation carrots, and the possible benefits and drawbacks of non-traditional carrots, because sticks and non-traditional

[18] 42 U.S.C. ch. 152 § 17001 et seq.

carrots have important similarities. After a brief, synthetic review of the key costs and benefits of non-traditional and traditional carrots, we define innovation sticks, describe possible implementations of sticks, and theorize some of their important advantages and disadvantages. We conclude this Part by drawing out characteristics of an innovation environment that may lead us to prefer non-traditional measures over traditional carrots, and that may lead us to choose sticks over non-traditional carrots, or to combine sticks with carrots. Our aim here is not to be fully comprehensive of all possible arguments in favor or against these various mechanisms, but to highlight the main concerns made salient either by the literature or our own examples.

A. The Role of Non-Traditional Innovation Carrots

The existing innovation economics and IP literature typically begins with something like the following account.[19] Information is a public good: as such, it is both non-rival and non-excludable, and difficult to produce in competitive markets absent some form of government intervention. IP rights are such an intervention: they make information more excludable, and so facilitate the production of information goods in private markets. There are other approaches to produce public goods, most prominently government grants – in which governments identify potential innovators and fund their research work *ex ante* – and financial inducement prizes – in which governments offer a financial reward *ex post*, in exchange for an innovation that, in the classic model, is freely disseminated.[20] Both approaches are what we call "non-traditional carrots."

The existing literature thus has focused on various forms of carrots – or incentives to innovators – and in particular on the trade-offs associated with the use of one kind of carrot or another. Both government grants and financial inducement prizes, in their ideal-type form, require free access to the resulting innovations, and so yield information is priced at marginal cost (that is, at zero). As such, they take advantage of the non-rivalrous nature of information, and avoid the efficiency problems associated with pricing information. Given the inevitability of positive transaction costs and the impossibility of perfect price discrimination, therefore, intellectual property rights (IPRs) are expected to "[insert] a wedge between price and marginal cost, creating deadweight loss."[21] This leads to not only static but also dynamic inefficiency, because information is an input and output of its own production process.[22] Non-traditional carrots require taxation and so are also expected to create deadweight loss.[23] But IPRs create the equivalent of a tax on a single market, "which is generally thought to impose greater deadweight loss than the

---

[19] For leading accounts of this sort (which of course differ somewhat in their emphasis and details), see Landes & Posner, *supra* note _, at 13-15, 21-24; Peter S. Menell & Suzanne Scotchmer, *Intellectual Property Law*, *in* 2 HANDBOOK OF LAW AND ECONOMICS 1471, 1476-82 (A. Mitchell Polinsky & Steven Shavell eds., 2007); ROBERT P. MERGES ET AL., INTELLECTUAL PROPERTY IN THE NEW TECHNOLOGICAL AGE 14 (5th ed. 2010). For an influential article making the exclusion point, see Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J.L. & ECON. 1, 11-14 (1969).

[20] See Hemel & Ouellette, supra note , at 321.

[21] LANDES & POSNER, *supra* note ___, at 22.

[22] *See, e.g.*, Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. ECON. PERSP. 29, 31 (1991); *see also* BENKLER, *supra* note ___, at 37-38.

[23] Scotchmer, supra note ___, at 24

broad-based taxation that generates general revenue."[24] It is for this reason that Kenneth Arrow, long ago, insisted that non-traditional carrots are likely superior to traditional (exclusion-based) carrots as a general matter.[25]

Since Arrow's foundational work, economists have developed a more refined account of the tradeoffs between traditional and non-traditional carrots. While doing some violence to a very complex literature, we can identify a few central tradeoffs that are now fairly well-understood.[26] The main benefit of IPRs is that they rely on market signals to allocate investment; in particular, they allow markets to establish the value of innovations.[27] Inducement prizes require governments to establish the value of the innovations that they seek, but like IPRs can be designed to incentivize decentralized efforts among innovators who are assumed to have advantages in calculating their costs of innovation.[28] Government grants, in turn, have special benefits where racing is expected to be a concern, because the government can limit the number of entrants.[29] Among their important drawbacks, grants require the government to not only establish the size of the reward, but also require them ex ante to decide who are likely to be the most successful innovators.[30] Both kinds of non-traditional carrots are often described as having an additional important drawback, namely their susceptibility to rent seeking and corruption.[31]

A newer literature has begun to point out some additional potential benefits of non-traditional carrots, ones that were earlier overlooked. One stems from the fact that excludability, the hallmark of IPRs, in fact exists on a continuum, and is not a simple function of legal status.[32] An innovator who holds a legal entitlement to exclude others may in practice be unable, or only weakly able, to exclude others. Consider here the difference between excluding others from a new prescription diet drug in an environment in which medicines are highly regulated commodities, and excluding others from using a new exercise regime that one has invented and validated.[33] Exclusion is thus not merely

---

[24] Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY 51, 54 (Adam B. Jaffe et al. eds., 2002). See also Ian Ayres & Paul Klemperer, *Limiting Patentees' Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-Injunctive Remedies*, 97 *Michigan Law Review* 985 (1999).

[25] Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY: ECONOMIC AND SOCIAL FACTORS 609, 623 (Richard Nelson ed., 1962).

[26] For a somewhat more detailed overview, see Amy Kapczynski, *The Cost of Price: Why and How to Get Beyond Intellectual Property Internalism*, 59 UCLA L. REV. 970, 1021 (2012).

[27] Wright, *supra* note ___, at 697–98. For some, this creates "distributive" benefits, because those who want innovations pay for them. *See, e.g.*, Gallini & Scotchmer, *supra* note _, at 55. The distributive justice effects of innovation policy, however, are much more complex than this point would suggest. *See* Kapczynski, *supra* note ___, at 1005 & n.132.

[28] Wright, *supra* note ___, at 695.

[29] *Wright, supra note* ___, at 703.

[30] Wright, *supra* note ___, at 703. Shirking may be a special problem here too, though it can be mitigated by repeat-player dynamics. Gallini & Scotchmer, supra note _, at 58.

[31] *See, e.g.*, LANDES & POSNER, *supra* note ___, at 9. Importantly, IPRs are also vulnerable to rent seeking. See Kapczynski, *supra* note ___, at 987..

[32] Amy Kapczynski & Talha Syed, The Continuum of Excludability and the Limits of Patents, 122 Yale L.J. 1900, 1920 (2013).

[33] *Id.* at 1928-36.

a function of law, but also of norms, technologies, and institutions. Importantly, some kinds of information goods are likely to be systematically more amenable to exclusion than others.[34] In such cases, market-based exclusion rights will yield inadequate incentive to innovate, and may also distort innovation incentives toward more excludable solutions.[35] A non-traditional carrot that did not rely upon excludability for its effect, however, can promote innovation in both highly excludable and highly non-excludable innovation symmetrically, and allow the innovator to choose the better (cheaper) path to the desired good.

There is a broader way to put the point: non-traditional carrots, and in particular inducement prizes,[36] can be designed to be agnostic about the mode of innovation chosen, and so promote both excludable and highly non-excludable solutions to a problem. For example, a government might offer a prize for the best means of increasing exercise rates among children, and award the prize to the party that provided the best evidence of increased exercise, whether through a new (excludable) dance-based video game, or through a (highly non-excludable) popular new playground game. Prizes can even be designed to be agnostic about whether improvements come through innovation or rather through rediscovery or adoption of existing innovations. For example, a government might give every school that achieved a certain exercise rate among third-graders a financial reward, regardless of whether it achieved such a rate through innovation, adoption, or rediscovery. Exclusion rights instead require some modicum of originality or novelty, and so cannot encourage actors to select the cheapest and most effective alternative among as wide a range of activities.[37]

Another benefit of non-traditional carrots also emerges from the recent literature. The conventional account that promotes IPRs because of their allocative advantages assumes that markets produce accurate signals for the value of innovation. However, markets in practice are systematically vulnerable to failure. In neo-classical terms, such failures may result, for example, from pervasive externalities (such as the pollution caused by motorists), or from information asymmetries (for example, as exist between a sick person and a pharmaceutical company, or between a driver and the car company that designs a car's safety systems). Scholars of behavioral economics and psychology stress instead biases in perception or cognition, such as the "optimism bias," which could for example discourage consumers from investing adequately in innovations that reduce the

[34] For example, "uses of information goods that manifest in relatively more immaterial fashion will be more difficult to exclude, because the state of technology makes monitoring intangible processes (like thoughts) more difficult than monitoring more tangible things." *Id.* at 1920.

[35] Because excludability is a continuum, and because it does not vary directly with social value, traditional carrots also threaten to distort allocative decisions. Imagine an innovator with two ideas to reduce the health costs of obesity, one of which is technological (for example, a pill or exercise machine, and so highly excludable), and one of which is non-technological (for example, a new exercise regime, which must be validated and so is expensive, but which is highly non-excludable). Traditional carrots will promote the former over the latter, even if the latter would cost less and/or be more effective. This point is described in some detail in Kapczynski & Syed, *supra* note __, at 1921.

[37] 35 U.S.C. § 102(a) (2012); Feist Publ'ns, Inc. v. Rural Tel. Serv. Co., 499 U.S. 340 (1991).

likelihood or cost of accidents.[38] More foundational critiques of markets also point out that market-based measures of social value will systematically underestimate the social value, in welfarist terms, of innovations that serve those with limited ability to pay.[39] Where markets are a poor measure of value – because we value things that aren't measured well in markets, or because of systematic problems with the signals transmitted in market transactions – then market-based signaling will yield inadequate (and distortive) incentives.

Traditional carrots not only have the advantages, but also the disadvantages of market-based signaling. Where markets fail, signals are distorted. Non-traditional carrots, instead, can directly reflect values or information that are not well-presented in markets. Where pollution externalities are endemic, for example, exclusion-based solutions, such as patents for pollution-reducing technologies, will simply replicate them. By using a non-traditional carrot, the rewards available to innovators can be brought closer to their projected social value.[40] Markets also predictably misfire where they depart from competitive conditions, such as where there are significant barriers to market entry. Imperfect competition exists in many domains, both market (as in cases of monopoly and monopsony), and non-market (as exists for many state-based entities, which may have a captive audience or effective monopoly). And where this is so, market signals will likely lead to insufficient innovation, and non-traditional measures may be superior to traditional carrots.

These newer arguments for the benefits of non-traditional carrots do not diminish the potential difficulties associated with such carrots. As noted above, the most important problem with non-traditional carrots is the significant informational burdens that they place on governments. For prizes in particular (which we focus on here as the most similar to innovation sticks), governments must establish the size of the carrot, and thus have a good sense of the value of the desired innovation. Importantly, a governments can use nontraditional carrots (and sticks) without knowing exactly what it wants in return, because carrots and sticks can be defined generally, or define the desired objective in negative terms ("create something *other than this*") rather than in positive terms ("create *that*").[41] But because it must set the level of the reward or fine, the

---

[38] *See, e.g.*, Christine Jolls & Cass R. Sunstein, *Debasing Through Law*, 35 J. LEGAL STUD. 199, 207-08 (2006).

[39] For more on this point, see Kapczynski, *supra* note ___, at 999-1000.

[40] The same point can be made with respect, for example, to the divergence between market value and social value that is generated by the problem of inability to pay. A prize or penalty can directly generate incentives to serve poor populations, and be set at a level far above the level of incentives that markets alone would provide.

[41] For example, government can with either a prize or a stick penalty, push companies away from the use of certain toxic chemicals or energy-hungry devices. Instead of specifying what should replace incandescent bulbs or chloroflurocarbons, governments can give companies incentives (such as a tax rebate for alternative units sold), or penalties (fines for offending units sold or emitted), and leave it to others to come up with alternatives. What is inescapable is the government's need to establish some rough accounting of costs and value, to determine whether such a program will cost more than will be gained. Where the government defines a goal in the negative, there is also the risk that alternatives to the negative generate similar or worse effects. See the below discussion of CFCs for a real-world example of this problem, at note _.

government inescapably must project something about the costs and benefits of the desired shift, even if just at the break-even level.

While this can be a significant problem, it is important to note that it also can be mitigated. For example, the size of a prize need not be determined ex ante, but can be decided ex post, when there may be better information available about demand.[42] A particularly important way to address the information problem that has not been emphasized in the IP literature involves yardstick incentives, which tie the size of rewards or punishments to the yardstick of ones peers. In 1985, Andrei Shleifer's "A Theory of Yardstick Competition" provided an elegant stylized model showing why yardstick incentives could better "assure cost control, prevent waste, and promote cost-reducing innovation."[43] In his model, regulated utilities in different cities were allowed to charge customers a "yardstick" price equal to average cost of the other cities. This yardstick price naturally incorporated both carrot and stick innovation incentives: utilities that innovated to reduce their costs below the average of its peers would earn carrot of enhanced profits, while those utilities that fell behind would feel the sting of selling at a loss.[44] Shleifer showed that yardstick competition among the utilities – to garner the carrot and avoid the stick – was sufficient to induce optimal cost reduction, as long as firms are reasonably identical or have heterogeneity that can be accounted for.[45]

For our purposes, it is worth also noting that yardsticks can be used to set the level of an innovation carrot or stick, for example, by averaging the accomplishment of the relevant firms and establishing fines for laggards below a set threshold (i.e. median, or within a certain percentile of the median), or establishing rewards for those who exceed the average accomplishments of their peers. A combination of carrot and stick, as Shliefer envisions, could also be accomplished with rewards and fines, rather than via price-setting. The central virtue of yardsticks in this context would be, as in Shleifer's model, their ability to help reveal the production costs of firms, here for innovation rather than energy production, more directly to governments. Using yardsticks would minimize the upside risk of asking far too much of firms and thus generating widespread exit from an industry, since by definition some percentage of firms would meet the standard, or would have demonstrated that the result is feasible. Especially if collusion is possible, however, yardsticks could establish thresholds that are too low.[46] Allowing trade between firms of liabilities or potential rewards, as has become familiar through the

[42] Michael Kremer's patent buyout provision, which uses an auction mechanism, is an example of this technique. See Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q. J. ECON. 1137, 1146-47 (1998). So too is the Shavell and Van Yperserle model of a prize whose value is established indirectly, by market sales. See Steven Shavell & Tanguy van Ypersele, *Rewards Versus Intellectual Property Rights*, 44 J.L. & ECON. 525, 542 (2001).

[43] Andrei Shleifer, *A Theory of Yardstick Competition*, 16 RAND J. ECON. 319, 319 (1985).

[44] In our terms, this kind of yardstick competition would also allow the government to be agnostic about what technologies were best used to innovate and indeed whether innovation itself was feasible. More on this in a minute.

[45] *Id.* at 326.

[46] *Cf. id.* at 326 (discussing the problem of collusion).

concept of cap and trade, may also similarly improve the efficiency of non-traditional measures to promote innovation.[47]

Finally, even though government doesn't usually know precisely how an industry will make non-obvious advances over the prior art, some industries seem to be affected by something like Moore's innovation "laws," and where this is so, this provides another metric that can reduce information costs for government. Just as Gordon Moore observed that the number of transistors on integrated circuits tends to double every two years,[48] policymakers can take note that technological innovation predictably enhances the feasible fuel efficiency every year and can base future CAFE standards in part on those predicted advances. Figure 1 in Part III will display a similar innovation trend with regard to automobile fatalities.

In setting the trigger amount for a non-traditional carrot or a stick, government can either augur what is technologically possible (a la CAFE) or it can rely on the yardstick of what competitors have shown to be possible. Each approach has its own relative strengths. For example, as applied to sticks, the augural approach may be able to avoid in equilibrium the imposition of very many penalties, while the yardstick approach necessarily subjects half of the industry to penalties with the attendant distortion inefficiencies associated with those payments. Yardstick sticks by themselves might also not produce sufficient infra-marginal incentives. Manufacturers, who know they are likely to fall below the CAFE fleet mile per gallon ("MPG") cap may have insufficient incentives to pioneer new fuel efficiency innovations. One response to the infra-marginal incentive problem would be to layer different carrots or stick incentives for different margins of success. Thus, we are attracted to way that the CAFE penalties are combined with patent rewards to create a carrot *and* stick regime in which some manufacturers are rewarded via patent for pioneering innovations and other manufacturers are punished via CAFE if they lag behind the possible.[49]

These strategies can help compensate for the inherent weakness of the measures we term "non-traditional," but they do not establish any broad theory of superiority across all domains. We will return to the question of the circumstances when non-traditional carrots and sticks are likely to be preferable to traditional carrots, but first we must have in hand a better understanding of innovation sticks.

B. Introducing Innovation Sticks

[47] For a formal argument in this regard, see Penin, *supra* note _, at *6-7 (describing the virtues of a hypothetical tradable permits to "not invest in R&D").

[48] Gordon E. Moore, *Cramming More Components onto Integrated Circuits*, ELECTRONICS, Apr. 19, 1965, at 82, 83. .

[49] Note, however, that because patent incentives are keyed to markets (and because of the externalities of pollution) patents will provide less incentive to engage in pioneering innovation than is socially desirable. Still, the availability of patents may induce some innovation because consumers do value fuel economy (even if too little from a social perspective), and when redundant with sticks can provide insurance against sticks that are too low. Layering carrots and sticks can also provide protection against the problem of undercompensation, a perhaps more important function in areas, such as fuel economy, where negative externalities are high.

The IP literature is focused exclusively on carrot-based approaches to innovation. This is puzzling in part because the growing "carrots vs. sticks" literature suggests that sticks have potential benefits over carrots.[50] Foundational law and economics work suggests that incentives should be equivalent whether structured as a penalty or reward, so that "any behavioral change induced by promising compliers a $100 reward can also be obtained by threatening violators with a $100 punishment."[51] Recently, Gerrit De Geest and Giuseppe Dari-Mattiacci have, however, called attention to certain systematic differences between carrots and sticks. Most importantly, in equilibrium sticks do not need to be paid. Carrots instead can be used up – if they are paid as a reward to one person, they cannot also be paid to another.[52] The result:

> In a simple setting, in which the principal is benevolent and fully informed, sticks are intrinsically superior to carrots because they do not have to be applied. Sticks incentivize by threatening while carrots incentivize by actually rewarding; in an ideal world, fines are never paid, but prizes are. As a result, sticks yield less transaction costs and less risk for complying agents. Moreover, sticks will usually generate less distributional distortion.[53]

De Geest and Dari-Mattiacci also gesture to possible differences between carrots and sticks in behavioral terms. If actors, for example, are subject to loss aversion, then sticks may be more powerful motivators than carrots, even if the fines and benefits are otherwise equivalent.[54]

These same arguments also suggest a potential role for innovation sticks. The concept of an innovation stick, however, is sufficiently unfamiliar that it is worth spending some time describing some of the ways that such sticks might work. Like innovation carrots, innovation sticks come in many possible forms, and share in common

---

[50] IAN AYRES, CARROTS AND STICKS (2012); De Geest & Dari-Mattiacci, *supra* note ___; Gerrit De Geest & Giuseppe Dari-Mattiacci, *The Rise of Carrots and the Decline of Sticks*, 80 U. Chi. L. Rev. 341, 349 n.27 (2013).

[51] *The Rise of Carrots*, *supra* note ___, at 347. As De Geest and Dari-Mattiacci point out, this is implicit in R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON 1, 7 (1960). *See The Rise of Carrots*, *supra* note ___, at 3.; *see also* Pepin, *supra* note ___, at 3-4 (making the same reference to Coase).

[52] *Carrots Versus Sticks*, *supra* note ___, at 14.. This conclusion relies upon a stylized set of assumptions, for example that sticks do not have any economic or distributional effects. See *id.* at 10. In addition, as the literature on racing makes clear, sometimes carrots clearly induce efforts without having to be paid. Indeed, this is a canonical definition of a race: only the winner receives the reward, but many others exert themselves to try to reach the goal.

[53] *Carrots Versus Sticks*, *supra* note __, at 2.

[54] *Id.* One of us (Ayres) is a co-founder of a website, stickK.com, that leverages loss-aversion by letting users put money at risk if they fail to reach their goals. See Michael Abramowicz & Ian Ayres, *Commitment Bonds*, 100 GEO. L.J. 605, 616 (2012). Sticks, like carrots, may also crowd out intrinsic motivation and thereby dampen innovative efforts. Bruno S. Frey & Jegen, Reto, Motivation Crowding Theory: A Survey of Empirical Evidence, 15 J. Econ. Surveys, 589 (2001). Presumably, wealth effects may also be important in understanding the differential impact of carrots and sticks. In considering various behavioral economic impacts, it may also be important to distinguish between individual and corporate inventors.

only a basic definitional quality: they apply penalties to those who do not innovate, rather than offering rewards to those who do. As with carrots, innovation sticks may be applied to inputs or to outputs, and may use various metrics of success, from the highly technologically specific to the more technologically agnostic.

Table 1 gives examples in each of these areas, and begins to develop a rudimentary typology of innovation sticks. (The table also includes analogous carrots in each case, to help reveal the symmetries and differences between carrots and sticks in this domain.)

Table 1: Typology of Innovation Sticks

		Metric for success	
		Technology specific	Technology agnostic
Punishment [reward] Contingent on	Inputs	Researcher who fails to spend X time on research on electric cars is fined [grants for electric car researchers] Company that fails to spend X$ on research to improve batteries is fined [grants or R&D tax credits for companies that engage in battery research] absolute tort liability for product harms, based on failure to test [grants or R&D tax credits for research on product harms]	Researcher who fails to spend X hours on research is fined. [investigator grants which are agnostic about research domain – e.g. [X] grants in NIH program] Company that fails to spend X amount on general R&D is fined; effectively a regressive tax on R&D expenditures [grants or R&D tax credits for R&D broadly defined]
	Outputs	Researcher who fails to create new battery type is fined [patents or prizes for new batteries] Car companies that fail to market electric cars are fined [patents or prizes for electric cars]	Researcher who fails to produce innovations that diminish emissions are fined [patents or prizes for emissions reducing technologies or strategies] Car company that does not decrease pollution emission in its fleet by X amount is fined [patents or prizes for emissions reducing technologies or strategies]

These different forms of incentives impose distinctive information demands on government. Some of the informational demands that sticks make are also present for non-traditional carrots. For example, for sticks, as well as prizes and grants, government

needs good information on the value of the innovation that it is seeking.[55] Technology-specific incentives likely require better information than more general incentives to innovate – picking a very specific winner (electric cars) may be harder than picking a general aim (reducing pollution). For those carrots and sticks that are keyed to inputs rather than outputs, there is a risk of shirking or waste.[56]

More interesting are the areas where the information requirements of innovation sticks diverge from those of equivalent non-traditional carrots.[57] Innovation sticks would seem for one reason in particular to require more information than do non-traditional carrots. With sticks, the government needs good information about the potential innovator set. But because people will not self-nominate for sticks, governments must do so without their help.[58] Where government awards carrots, individuals will come forward, as occurs when potential innovators apply for government grants. There is a concomitant risk that people will falsely nominate themselves – for example, overstating their potential merit as a researcher, or gaming the definition of a prize.[59] But the costs of detecting lying and cheating, particularly in a repeat player environment, seem plausibly smaller, at least much of the time, than the effort needed to define the potential set of innovators.

Finally, carrots seem to have informational advantages where upper limits to performance are hard to define.[60] Sticks create thresholds below which parties must not fall, so are preferable where the lower limit is known, and clear. For example, sticks are good for enforcing rules about when to get to work (where it is clear that it is best if all get to work by 9am, and there is no value in getting there earlier), but carrots may work

---

[55] Importantly, though it is not often stressed, the government also faces information problems when defining the contours of exclusive rights regimes, such as patent duration or the set of exclusive rights available in copyright. *See, e.g.*, Amy Kapczynski, Intellectual Property's Leviathan, _ Law & Contemporary Problems _ (forthcoming 2014).

[56] Although we don't pursue the issue here, it seems likely that there are differences between carrots and sticks here from a behavioral perspective. For example, loss aversion might make those facing sticks less likely to shirk, but some of the kinds of sticks we identify are so far from the current baseline, and would seem to violate basic liberal commitments (for example, to freedom of research) that their effects on individuals might well be counter-productive.

[57] We focus here on non-traditional carrots, because traditional carrots make use of markets to provide key informational signals, and sticks that would do the same are very difficult to imagine. (Perhaps a government might create a tax on low sales, for example, assuming that companies with low sales are less innovative. But the sales – i.e. markets – would set the level of the fine.) The tradeoffs between sticks and non-traditional carrots, and market-based exclusion rights with respect to information are discussed in some detail above.

[58] Even if the government established a default fine, thus prompting individuals to come forward to claim an exemption, the government still would have to define at the outset the appropriate targets for the fine. With a prize, the government might leave that set open, suggesting that anyone who could build a better mousetrap could come forward to claim the reward. It seems far less plausible to fine everyone who fails to build a better mousetrap, and revoke the fine for the set of individuals who come forward. It also would almost certainly would penalize people with no capacity to innovate in the relevant way, raising a distributional concern that we discuss later.

[59] *Carrots Versus Sticks*, *supra* note ___, at 35.

[60] See Edward P. Lazear, *Labor Economics and the Psychology of Organizations*, 5 J. ECON. PERSP. 89, 102 (1991); De Geest, Rise of Carrots at n. 26.

better where individuals' sales quotas are concerned, if management does not know in advance what possible sales amounts are.[61] Non-obvious innovation is a domain where it may often be difficult to determine upper limits. But many other modes of innovation – including the diffusion of know-how that is required to figure out how to get an idea to work in a different setting – may present domains where the lower limit is more knowable.

Put more generally, as De Geest and Dari-Mattiacci have noted in recent work, sticks may be best in "simple" settings, where "citizens have more or less equal compliance costs and the lawmaker knows these costs and asks for equal efforts from all citizens."[62] In such cases, "sticks are superior because the lawmaker can easily set them high enough so that all citizens comply," reducing costs, and the distortions associated with the need to raise money to pay out carrots. But in more complex circumstances, lawmakers may know little about what to expect from each citizen,[63] and may also presumably have difficulty knowing exactly how to define what they want. It may be relatively easy to determine who should be forbidden to commit assault, and to set the size of the penalty and define the forbidden act. But it may be much more difficult to decide who should build a better light bulb, and difficult to know the costs and precise criteria of success of that light bulb.[64] In addition, where government requires particular efforts from certain citizens, it runs a risk of singling out precisely those whose cooperation is most needed, causing distributional distortions and "artificially impoverishing those from whom much is required."[65] This is one reason why some of the sticks described above – for example, imposing fines on researchers who fail to invent a new form of battery – seem particularly ill-advised. Importantly, though, the government will sometimes have good information about the set of potential innovators, as well as the value of the innovation. The CAFE standards, described below, are a good example, because government understands a great deal about the risks of climate change and the contributions made by the transportation sector.[66]

Innovation sticks also have a second major drawback in the innovation domain: they do not compensate innovators for their investment.[67] One reason that the IP literature focuses so strongly on carrots may be that it assumes that in equilibrium compensation is required to get sufficient levels of investment in innovation. That in turn is because innovation is assumed to be expensive, and to result in discrete goods that can

---

[61] *Rise of Carrots*, *supra* note __, at 349 n.26.
[62] *Rise of Carrots*, *supra* note ___, at 345.
[63] *Id.* (noting, in particular, that "governments may not know which citizens should spend time composing songs").
[64] To refer back to our earlier conversation, these difficulties should be compared to difficulties of the alternative modes of influencing the allocation of inventive effort. For example, if carbon emissions are too cheap, then markets (and so, patents) also have a serious allocative problem. In other words, the information problem question is a comparative one, and not one that obviously can be resolved in favor of markets once we have a more realistic picture of markets in view.
[65] *Id.* at 345.
[66] *See infra* Part II. Notably, the companies affected by CAFE are also free to contract with others to find the cheapest means of meeting their regulatory burden. Where such contracting is possible, the consequences of limited governmental information on innovators is reduced.
[67] *See supra* note _.

be readily copied by competitors and that have a universal (or at least wide-spread) utility. These assumptions drive the conclusion that some form of compensation – whether via exclusion rights or government funding – are needed to produce innovation in adequate amounts under competitive conditions.

One response to this problem will be discussed in a moment – innovation sticks can be applied along with traditional or non-traditional carrots, and where these tools are combined this will help address problems of undercompensation. Importantly, though, innovation sticks may also be useful in other domains, where carrots are either unavailable or ineffective. We have in mind two domains where sticks may be used without associated carrots: in domains where free rider effects are absent (though not, here we assume, because of exclusion rights), and in domains where market disciplines do not apply to actors (and so where exit will not be the result of the application of penalties). We address the two issues in turn.

First, free rider effects do not always accompany innovation. Information is not always expensive, not always readily copied, and not always useful to a broad range of competitors. It is increasingly clear that innovation has many modes, only some of which correlate well to the assumptions of the public goods account of information.[68] For example, there is a growing literature on "social innovation,"[69] a term used, for example, to refer to innovations that restructure relations within organizations or organizations themselves; to process innovations aimed at solving social problems (such as traffic regulation or medical screening); to political innovations (such as ideas for legislation or social programs); and to innovations in "lifestyle" (for example regarding how to express ones values or aspirations, or how to allocate one's resources).[70] Even technological innovation need not have public goods qualities,[71] but these other modes of innovation are still more likely to evade one or more of the requirements of the public goods account. For example, they may be relatively inexpensive, and so be endemic to certain social circumstances, even under conditions of free copying, if the need for such innovation is relatively perceptible and a motive to address it is present. (In this category, for example, would be minor legislative reforms, or simple changes to

[68] This is a corollary to the point about non-excludability above. There we note that different modes of innovation may be differently excludable even in the presence of exclusion rights, with the implication that public goods problems can exist that exceed the power of exclusion rights to remedy. Here we point out that different modes of innovation also may generate greater or fewer public goods problems. Where there are few public goods problems, undercompensation is much less of a risk, and overcompensation may well be a greater concern.

[69] The term social innovation is used in many different disciplines, and is subject to many definitions. Dominik Rüede & Kathrin Lurtz, Mapping the Various Meanings of Social Innovation: Towards a Differentiated Understanding of an Emerging Concept, (EBS Bus. Sch. Research Paper No. 12-03, July 2012), *available at* http://ssrn.com/abstract=2091039.

[70] Wolfgang Zapf, *The Role of Innovations in Modernization Theory*, 1 INT'L REV. SOC. 83, 83–94 (1991). The term is also used in many other ways, for example referring to new modes of "need satisfaction," a category which includes technological innovations such as the personal automobile. *See id.* at 88; *see also* Rüede & Lurtz, *supra* note __, at 5.

[71] For example, technical innovation is not necessarily non-excludable without law if secrecy is effective, and does not face substantial free rider problems if it is useful only to one party, or needs modification before it can be useful for others.

organizational workflow.) Some such innovations may result in goods that have utility only for a small number of people (as when a particular HR department figures out how to resolve a dispute between two employees), or that are difficult to copy, and so not subject in any meaningful way to the problem of non-excludability. Finally, some forms of innovation may be best understood as processes themselves – which is to say, as practices of continual revision that produce not discrete and stable products that may be copied, but an ongoing string of minor innovations that have been revised by the time they might be visible to others.[72]

In this Article, we adopt a broad conception of what it means to innovate. Innovation includes not only the invention of a new technique or mechanism that is expensive and subject to free riding in the absence of exclusion rights, but also the invention of new techniques and mechanisms that are inexpensive, and/or that do not face free rider problems because they are useful only to a few, or because they are rapidly updated in a fashion that leaves natural lead time in place. For us, innovation policy should also appropriately incentivize the diffusion of information, insofar as it may require a kind of innovation for me to learn what you already know, and another kind of innovation for me to learn how to reduce that learning to practice in my particularized setting. Because undercompensation may be less of a risk than overcompensation in these alternative forms of innovation, sticks may here play an important role.

A possible objection arises: If these other modes of innovation lack the indicia associated with the IP and innovation economics literature, are they not therefore uninteresting from a policy perspective, because they are likely to be produced in adequate amounts without any particular social intervention? In some cases, perhaps so.[73] Where the conventional public goods qualities of information are lacking, competitive markets might be expected to perform well. If our local grocery store, for example, internalizes much of the value of improvements in its organizational workflow, *and* if such innovation is cheap, impossible to copy, or not valuable to competitors, then we can assume that such innovation will occur in adequate amounts, without the need for additional policy interventions.

But innovation markets sometimes fail. Innovation sticks can help calibrate incentives where this is so, and may be especially useful precisely where potential innovators face only modest free riding risks, but where existing market conditions generate too little demand for innovation from a social perspective. Similarly, where there are significant barriers to market entry, as in the case of monopsony or monopoly, or where the relevant players are state actors that are insulated from competition, we need not worry as much that undercompensation will lead to exit from an industry.

---

[72] We can think of this domain as one where a first-mover advantage still exists, sufficient to incentivize innovation. *See* J.H. Reichman, *Of Green Tulips and Legal Kudzu: Repackaging Rights in Subpatentable Innovation*, 53 VAND. L. REV. 1743, 1770 (2000)

[73] We set aside here possible interactions between innovation policy and disclosure. While information that can be kept secret may be adequately incentivized, there may be social welfare problems with allowing or encouraging secrecy, insofar as that information is valuable to others (or "nonrival" in conventional terms).

C. The Benefits and Costs of Sticks

To synthesize the foregoing, the case for innovation sticks shares much in common with the case for non-traditional carrots: both sticks and non-traditional carrots may be especially useful where we worry about the deadweight loss associated with exclusive rights in information, and where markets signals diverge in predicable ways from what we desire as a social matter. They are also particularly useful to provide incentives to actors, like states, that do not operate in a competitive market setting or that are precluded from profiting from exclusion rights. In addition, both non-traditional carrots and sticks can be designed to be agnostic as to the form of innovation used, as well as to whether improvements come through new innovations, greater adoption and dissemination of existing innovations, or rediscovery of old innovations. Non-traditional carrots and sticks also have downsides; in particular, they are information intensive.

A further question arises, then: When might we prefer sticks to non-traditional carrots? The central insight that we draw from the above analysis is that if compensation is not required to induce innovation, then sticks will be preferable to non-traditional carrots. "Carrots may distort by overpaying, sticks by underpaying"[74] – but when compensation is not required, the only risk is of distortion by overpaying. Though the existing theoretical account on which the IP and innovation literature is based tends to assume that undercompensation is the chief risk, there is more and more recognition that outside of a few special fields (such as pharmaceuticals) conventional competitive markets in fact may generate sufficient information without additional rewards.[75] In such cases carrots will overcompensate and yield distortions. These distortions stem from the taxes required to fund the reward, and also from the excessive effort or racing that may attend the overcompensation. If markets are otherwise functioning well, no intervention at all may be needed in these cases. But where there are pervasive externalities, for example, or where the targets are non-market actors, sticks are likely to be a better innovation tool than non-traditional carrots.

Put another way, sticks are especially appropriate where we expect that the needed innovations do not have the conventional qualities of public goods (for example, if they stem from forms of social innovation that may be low cost or valuable only to a single entity), but where we are nonetheless concerned that market-based signals will not suffice to induce the innovation we want. This may be, for example, because of pervasive externalities that are practically or politically difficult to address with a general tax, or because the target entities are non-market actors such as states. Non-traditional carrots, in turn, have a comparative advantage where public goods issues (or free rider

---

[74] Carrots Versus Sticks, *supra* note __, at 20.

[75] *See, e.g.*, Richard Posner, *Do Patent and Copyright Law Restrict Competition and Creativity Excessively?*, BECKER-POSNER BLOG (Sept. 30, 2012), *available at* http://www.becker-posner-blog.com/2012/09/do-patent-and-copyright-law-restrict-competition-and-creativity-excessively-posner.html (suggesting that the ostensible need for patents in inventive industries has been overestimated); *see also* MICHELE BOLDRIN & DAVID K. LEVINE, AGAINST INTELLECTUAL MONOPOLY (2010).

problems) are present, but where exclusion rights are inappropriate, for example because they are not effective, are distortive, or generate unacceptable deadweight loss.

Other factors, too, are relevant to the choice between sticks and non-traditional carrots. Both are information intensive, and may for this reason alone be inappropriate in many cases. To implement innovation sticks, the government needs to be able to identify the potential innovators,[76] a verifiable metric of innovation, and value of marginal improvements. If the government knows little about the value of different dishwasher designs, for example, it cannot design a good system to induce innovation of dishwashers. But if it does have good information – for example, if it "knows" better than markets the true long term cost of the energy consumption of a dishwasher – then non-traditional measures may indeed be appropriate as regards this dimension. Whether the information costs of sticks will be higher than of non-traditional carrots will be case-specific, and depend significantly upon whether the government is able reasonably to determine the plausible set of innovators. Also important is whether the aim is to establish a uniform lower bound (favoring sticks), or to direct effort toward an unknown upward bound (favoring non-traditional carrots).[77]

There may also be differences between carrots and sticks with regard to the government's ability to credibly deploy one or the other. As we will see in Part II, the government has in several of our cases stopped short of applying penalties when it became clear that the desired innovations, for example in zero-emissions automobiles, were not forthcoming. This suggests that it may be difficult for government to credibly commit to the deployment of sticks, perhaps more so in the domain of innovation than elsewhere. De Geest and Gneezy, notably, make the opposite point as regards sticks generally: because sticks generate revenue for government rather than require expenditures, they suggest that a downside of sticks is that they may be too easy for governments to deploy, and thus may have more potential for abuse.[78] This may, however, be context specific, and dependent upon the social meaning of the activity in question, as well as the actors who are targeted. It may be easy for the government to overuse sticks as applied to convicted felons, who are easily stigmatized and politically weak (indeed, often disenfranchised). But it may be much more difficult for the government to apply sticks to powerful industries who are being asked to do something perceived as affirmative – innovate – in a context where firms may be able to credibly complain that the task was impossible, and exert political influence to resist the sticks.[79] Non-traditional carrots face less resistance from their targets, but more resistance from

[76] In some settings, the government task is to identify the innovators or the entities who are well placed to serve as Coasean contractors. The threat of CAFE penalties for example gave laggard car manufacturers good incentives to license innovations to improve their fleet's fuel efficiency. See infra at .

[77] Foreshadowing our examples to come, it is perhaps not surprising that sticks have been used widely in the environmental context, because of the feasibility of establishing a uniform threshold, for example for energy use or the use of harmful chemicals, that we wish to apply broadly to all actors.

[78] Carrots and Sticks, *supra* note __, at 28.

[79] *Cf.* Steven L. Puller, *The Strategic Use of Innovation to Influence Regulatory Standards*, 52 J. ENVTL. ECON. & MGMT. 690, 690 (2006) (noting that firms may behave strategically by failing to innovate to meet regulatory standards when they are not "regulation-takers").

those who foot the bill. But non-traditional carrots such as prizes may also face a credibility problem, because governments may have incentives to renege after innovators have sunk their costs.[80] The point about political economy might be generalized this way: sticks may be in general more credible against small and politically diffuse actors, but by the same token, more prone to abuse against these same actors. Carrots may be more credible when applied to large and politically powerful actors, but by the same token, government may be more likely to overuse carrots against these actors and underuse sticks. Whether sticks or non-traditional carrots face greater credibility problems may thus be very context specific, and another relevant consideration for policymakers to consider.

Non-traditional carrots and sticks may also have different implications from a behavioral or distributive perspective. In part because of the aforementioned malleability of baselines,[81] context is likely to be important. But it may not be of trivial importance to policy if, for example, a stick requires that those from who we seek great effort also bear a significant risk of penalty, particularly if penalties are understood, in social more than Coasian fashion, as punishments that generate particular aversion and approbation. In addition, distribution can also affect efficiency, for example if wealth effects are present.[82]

Finally, policymakers can deploy carrots and sticks (whether traditional or non-traditional) together, and may often wish to do so. Some forms of yardsticks employ both carrots and sticks, as described above. And whenever sticks are applied, if patent law applies in relevant ways to the field in question, those sticks will work in conjunction with traditional carrots. In fact, in many cases sticks may be most useful in conjunction with carrots, so that carrots can help incentivize pioneers, and sticks to help discipline laggards or correct market failures that are not addressed in other ways. There are additional complexities raised by the use of these tools together, however. The design of each should be appropriate to the concerns identified above (so that, for example, the carrots are calibrated well to the domain where undercompensation is a concern). We also leave for another day certain questions that arise when these tools are used together, such as the potential anticompetitive effects that may arise where traditional carrots are combined with sticks.[83]

---

[80] *See* Scotchmer, *supra* note __, at 32 n.2 (describing the view and giving examples). Contract law or reputational concerns might help mitigate this problem for carrots. We thank Alan Schwartz for pressing us on this point.

[81] See supra at .

[82] As we will discuss below, if one result of innovation sticks in the educational context were that schools with few resources ended up with still fewer resources, against a backdrop where resources are not justly distributed, this would not be desirable on distributive grounds, and likely also on efficiency grounds.

[83] Requiring every manufacturer to use a new environmentally friendly technology might bestow excessive market power on the technology owner. In such settings, compulsory licenses may be appropriate, *c.f.* 42 U.S.C. 7608 (2012) (allowing the Attorney General to compulsory license any patent that is not "reasonably available" if it is needed to comply with certain aspects of the Clean Air Act, and if "there are no reasonable alternative methods" to comply with the law).

Ultimately, once all of these different tools are brought into view, we face the ordinary – but difficult – questions about efficiency tradeoffs. We do not claim here that innovation sticks are better than alternatives, but rather attempt to establish a set of important (but preliminary, and non-comprehensive) considerations that should inform their use, and that can help us decide between traditional carrots, non-traditional carrots, and sticks – or that might lead us to combine some of the above.[84]

Part II. Existing Examples

The theoretical case for innovation sticks made above is sufficient to suggest under limited circumstances the efficacy of threatening penalties for a failure to innovate. In this section, we show that innovation sticks have already been implemented as a tool of federal policy to induce producers and states to innovate to produce improved performance in a variety of different contexts. We develop several examples from the environmental context because of the importance and prevalence of sticks in this domain, and then develop examples from other settings to illustrate the very diverse contexts in which sticks have been deployed or contemplated.

A. *CAFE and Other Producer Penalties*

i. Environmental Sticks

More than 30 percent of US greenhouse gas emissions are attributable to the transportation sector.[85] Increases in fuel efficiency are thus important to efforts against climate change, and also may help mitigate security and foreign affairs risks associated with the US reliance on fossil fuels. Consumers are not expected to internalize the benefits of the long-term environmental and political gains associated with improved fuel efficiency, making this area one that has long been the subject of regulation.[86]

In 1975, Congress enacted the first Corporate Average Fuel Economy (CAFE) standards in the aftermath of fuel shortages brought about by the Arab Oil Embargo of 1973-1974.[87] These standards set a fuel economy standard in MPG that each car

---

[84] It is also worth noting that innovation sticks generate feedback information, and can be adjusted accordingly. Ideally, the sticks are not applied, or applied rarely. Where sticks are poorly designed and fail to induce effort, or expect too much effort, they will be applied frequently, suggesting a possible need for revision. As this suggests, one important point of comparison between different innovation mechanisms should be their respective openness to feedback, as well as general adaptability and adjustability.

[85] Christopher R. Knittel, *Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector*, 101 AM. ECON. REV. 3368, 3368 (2011).

[86] Mark R. Jacobsen, *Evaluating US Fuel Economy Standards in a Model with Producer and Household Heterogeneity*, 5 AMER. ECON. J.: ECON. POL'Y 148, 148 (2013).

[87] *See* Energy Policy and Conservation Act of 1975, Pub. L. No. 94-163, § 502, 89 Stat. 874, 902 (codified as amended at 49 U.S.C. § 32902 (2012)); David L. Greene, *CAFE or Price?: An Analysis of the Effects of Federal Fuel Economy Regula*tions *and Gasoline Price on New Car MPG*, 11 ENERGY J. 37, 38 (1990) (recounting how the EPCA was a direct response to the fuel price shock caused by the oil embargo). For an overview of the development of the CAFE standards since 1975, see Laura Hall,

manufacturer has to meet for its fleet of new passenger cars in a given model year.[88] The standards were quite stringent in their early years, but effectively stagnated in the 1980s, in part due to increases in the relative sales of light trucks and SUVs (which have generally been subject to more lenient CAFE standards).[89] Very recently, new regulations were promulgated to substantially toughen fuel economy requirements under CAFE: by 2025, manufacturers will be required to nearly double the average fuel economy of new passenger cars and light trucks, which is projected to halve greenhouse gas emissions as compared to the 2010 fleet.[90]

The CAFE standards are a prime example of a regulatory innovation stick. If a car manufacturer fails to comply with the fuel economy requirement in a given model year, it must pay civil penalties.[91] Under current regulations, the penalty totals $55.00 for every one mpg over the set mileage standard, multiplied by the manufacturer's total production for the domestic market.[92] Such penalties are not trivial in real terms, and many manufacturers appear to have treated them as a "binding constraint."[93]

In setting the current CAFE standards, the National Highway Safety Administration Agency (NHSTA) – the agency responsible for implementing the standards via rulemaking – is required by law to mandate "the maximum feasible average fuel economy level that it decides the manufacturers can achieve in that model year," after considering four statutory factors: "technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy."[94]

Note, *The Evolution of CAFE Standards: Fuel Economy Regulation Enters Its Second Act*, 39 TRANSP. L.J. 1, 9 (2011).

[88] *See* Energy Policy and Conservation Act of 1975, §502(a) (codified as amended at 49 U.S.C. § 32902 (2012)).

[89] Knittel, *supra* note ___, at 3368. On the difference between cars and light trucks / SVUs, see COMM. ON THE EFFECTIVENESS & IMPACT OF CORPORATE AVERAGE FUEL ECON. (CAFE) STANDARDS, EFFECTIVENESS AND IMPACT OF CORPORATE AVERAGE FUEL ECONOMY (CAFE) STANDARDS 1 (2002) [hereinafter CAFE REPORT] (noting how in 2002 the CAFE standards were "27.5 mpg for passenger cars and 20.7 mpg for light trucks").

[90] 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 77 Fed. Reg. 62,624, 62,627 (Oct. 15, 2012) (to be codified at 40 C.F.R. pts. 85, 86 & 600); Bill Vlasic, *U.S. Sets Higher Fuel Efficiency Standards*, N.Y. TIMES, Aug. 28, 2012, at B1.

[91] *See* 49 U.S.C. §§ 32911-32912 (2012). CAFE also permits some banking and trading of credits for companies that exceed the standards, so that the central "stick" of the regulation is supplemented with a kind of a carrot. Id. at 62,649.

[92] 49 C.F.R. § 578.6(h)(2) (2012).

[93] Don MacKenzie, *Do Automotive Fuel Economy Standards Increase Rates of Technology Change?*, IAEE N. AMER. CONF. 4 (Oct. 2012), *available at* http://www.usaee.org/usaee2012/submissions/OnlineProceedings/MacKenzie%20CAFE%20Standards%20and%20Technology%20Change%20v3%20Paper.pdf; *see also* Jacobsen, supra note _, at 156. A few companies – such as BMW and Mercedes, which produce relatively small volumes of luxury vehicles – have chosen instead to violate the standard each year since model year 1987 and, in turn, have paid around $500 million in fines; Jacobsen, supra note _, at 156; U.S. GOV'T ACCOUNTABILITY OFFICE, VEHICLE FUEL ECONOMY: REFORMING FUEL ECONOMY STANDARDS COULD HELP REDUCE OIL CONSUMPTION BY CARS AND LIGHT TRUCKS, AND OTHER OPTIONS COULD COMPLEMENT THESE STANDARDS 9-10 (2007).

[94] 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 77 Fed. Reg. at 62,627.. The agency is given discretion to balance these

The CAFE program has long been understood to be "technology-forcing."[95] As the agency sees it, its statutory mandate requires it to set standards that "make it necessary for manufacturers to engage in research and development in order to bring a new technology to market."[96] The agency has also, however, historically been cautious in projecting the pace of change, keying its demands to technologies that have been proven or are close to fruition.[97] The agency does not limit itself to technologies that are already in existence, but in a short rule-making timeframe will look just a few years into the future.[98] The recent increases in CAFE standards were accompanied by a much longer regulatory time-frame (projecting out to the year 2025), so here the agency considered not only "near term" technologies, but also technologies that "that are beyond the initial research phase, and are under development and expected to be in production in the next 5-10 years."[99] As a result, the agency engaged in what it called "augural" projections, "meaning that they represent NHTSA's current best estimate, based on the information available to the agency today, of what levels of stringency might be maximum feasible in those model years."[100] CAFE is thus a particularly interesting example for our purposes, because it is deliberately modeled and understood as a stick-based regime to promote innovation, and because, in its latest iteration, it has relied upon agency efforts explicitly to project and demand technology beyond that which currently exists.[101]

There is also a significant literature evaluating the effects of the CAFE program. It is difficult to decisively distinguish the impact of the regulations from those of other background conditions, and in particular the impact of changes in gasoline price. But many analyses have concluded that the program has had positive effects, in particular,

---

factors. *See* Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1195 (9th Cir. 2008) ("The EPCA clearly requires the agency to consider these four factors, but it gives NHTSA discretion to decide how to balance the statutory factors--as long as NHTSA's balancing does not undermine the fundamental purpose of the EPCA: energy conservation.").

[95] *See e.g.,* Ctr. for Auto Safety v. Nat'l Highway Traffic Safety Admin., 793 F.2d 1322, 1339 (D.C. Cir. 1986) ("Congress created mandatory vehicle fuel economy standards, intended to be technology forcing, with the recognition that 'market forces . . . may not be strong enough to bring about the necessary fuel conservation which a national energy policy demands.'" (quoting S. Rep. No. 94-179, at 2 (1975))).

[96] 77 Fed. Reg. 63,015.

[97] 77 Fed. Reg. at 62,668 (noting that the agency considers "technological feasibility" to exist when "a particular method of improving fuel economy can be available for commercial application in the model year for which a standard is being established").

[98] *Id.*

[99] *Id.* at 62,643. The agency also noted that it did *not* set standards based entirely on conjecture. *See id.* at 63,015 ("[I]t would not be reasonable for the agency to predicate stringency on completely unforeseen future improvements in unknown technologies."). Some believed that the agency should do more, urging it to set standards based on more actuarial estimations. *Id.* (describing the views of the CBD). The agency demurred, citing its additional obligation, under the statute, to consider economic practicability. *Id*.

[100] 77 Fed Reg. at 62,627. Because the statute requires the agency not to set standards more than 5 model years at a time, these standards must be revisited before they come into effect.

[101] *But see* supra note 100 on the fact that the future standards will require new action before they are implemented.

though not only, because it has pushed companies to innovate in the area of fuel economy.[102] A comprehensive evaluation of the program was completed in 2002, when Congress charged a special committee within the National Academy of Sciences to investigate the efficacy of the CAFE standards. That committee noted that fuel economy for passenger cars had nearly doubled and fuel economy for light trucks had improved by fifty percent since CAFE was passed.[103] The two main contributors to this trend, the report concluded, were the CAFE standards and the price of gasoline in the 1970s, with CAFE serving as a backstop for fuel economy when gas prices decreased in the 1990s.[104]

There is also an empirical literature that speaks to how companies have met the challenges of the CAFE standard. Fuel efficiency can be increased in a variety of ways, which are more and less innovation-intensive. For example, companies may design smaller and lighter vehicles, as they did especially within the first decade of the CAFE standards.[105] Such redesign may involve some innovation – for example, innovation in design or innovation that allows a firm to do things that others have done before it. Alternatively, it may involve simple uptake of existing knowledge now that price signals have changed. Several analyses suggest, however, that the CAFE program has induced important technological change.[106] David Greene, in arguing that technological improvements were the key to fuel-economy improvements, notes that a typical 15 mpg passenger car from 1975 equipped with today's technology would get 25 mpg.[107] Technological progress was most rapid in the five years after the passing of the CAFE standards, which lends more support to the causal link between CAFE and innovation.[108]

---

[102] The program has also had costs. For example, increases in fuel efficiency were likely traded off for other things that drivers value (e.g. acceleration speed, reliability). See CAFE REPORT, *supra* note _, at 3. One key strategy used by carmakers to increase fuel efficiency is the downsizing of cars, and many – but not all -- members of the National Academies review committee believed that CAFE "probably resulted in an additional 1,300 to 2,600 car fatalities in 1993." *Id.* Two members dissented from that view, concluding that there may have been no effect on fatalities. Id. at n.2. Clearly, there are possible downsides, and distortive effects, of sticks. In this case, the existence of a CAFE stick could provide an additional argument for a countervailing innovation stick addressing car fatalities. *See* Part III.

[103] CAFE REPORT, *supra* note _, at 14; *see also* David L. Greene, *Why Cafe Worked*, Bureau Transportation Statistics (Nov. 6, 1997), *available at* http://ntl.bts.gov/data/letter_am/cafeornl.pdf. (noting that the average road vehicle in "1994 emitted one-half to one-fourth as much pollution as the average vehicle in 1970" depending on which pollutant you measure)

[104] *Id.* at 15; *see also* David L. Greene, *CAFE or Price?: An Analysis of the Effects of Federal Fuel Economy Regulations and Gasoline Price on New Car MPG*, *supra* note ___, at 37 (1990) (estimating that CAFE had double the effect on fuel economy as gas prices).

[105] Hall, *supra* note _, at 9 (citing OFFICE OF TECH. ASSESSMENT, INCREASED AUTOMOBILE FUEL EFFICIENCY AND SYNTHETIC FUELS 105 (David Sheridan, ed., 1982)). However, lighter cars often prove less safe in accidents, thus leading the National Highway Traffic Safety Administration (NHSTA) to conclude that the "downweighting and downsizing that occurred in the late 1970s and early 1980s . . . probably resulted in an additional 1,300 to 2,600 traffic fatalities in 1993." CAFE REPORT, *supra* note _, at 3.

[106] *Id.* at 18.

[107] Greene, *Why Cafe Worked*, *supra* note _, at 8.

[108] Knittel, *supra* note __, at 3369. This is consistent with other empirical work on other regulatory standards in the environmental area. *See, e.g.*, Richard G. Newell et al.,, *The Induced Innovation Hypothesis and Energy-Saving Technological Change*, 114 Q.J. ECON. 941, 941 (1999) (finding "evidence that both energy prices and government regulations have affected the energy efficiency of

A group of MIT researchers has also concluded that to meet the recent increases in required fuel efficiency, the auto industry will need to increase the deployment of existing technologies *and* to shift the focus of future technological improvement to fuel economy (and away from, for example, increased performance).[109]

The CAFE program thus provides an example of a long-standing, consequential, and apparently at least partially effective innovation stick. Our analysis in Part I can help us understand why the program exists: greenhouse gas emissions represent a significant externality that is not incorporated into the purchasing decisions of consumers. Without another intervention that could correct the market for pollution,[110] car manufacturers face fewer incentives to innovate to improve fuel economy than is socially desirable. Sticks may be preferred to carrots here because government perceives undercompensation to be a relatively small concern. After all, carrots are available for some inventions that would be relevant, such as new battery technologies. Other kinds of innovation – such as innovation in car design or corporate culture – may have few public goods problems, because these may be cheap or unlikely to be afflicted by free riding problems. As regards information costs, it is easy to define the group to be penalized – the car industry – and that group is sufficiently sophisticated that it can presumably contract out where it would save costs to do so. Our analysis also suggests, however, that the program might be still more effective if the agency were to take its "augural" conception further, and deliberately depart from the directly foreseeable horizon of innovation, treating fines as the cost to be paid for failure to innovate at faster pace.[111] After all, if we can model the social costs of pollution, and have good data on the relative responsibility of the transportation sector, then such fines operate as an incentive to improve, and de facto as a tax that should help internalize the harm if the standards cannot be met. While political realities may lead the agency (and Congress) to imposing relatively modest demands on industry, and not to push the innovation envelop via CAFE, a policy case might be made

---

the models of room air conditioners, central air conditioners, and gas water heaters available on the market over the last four decades").

[109] PARISA BASTANI ET AL., U.S. CAFE STANDARDS: POTENTIAL FOR MEETING LIGHT-DUTY VEHICLE FUEL ECONOMY TARGETS, 2016-2025, at 12-13 (2012), *available at* http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/CAFE_2012.pdf.

[110] We in no way here mean to suggest that CAFE standards should be preferred to gas or carbon taxes, but only to point out that in the absence of such tax increases, regulatory standards provide a alternative means to shape manufacturer incentives.

[111] This is especially so if we consider the standards of CAFE-style programs in other countries. Europe and Japan both have regulatory programs like the CAFE program, which are yet more ambitious in their requirements. *See* GLOBAL COMPARISON OF PASSENGER CAR AND LIGHT-COMMERCIAL VEHICLE FUEL ECONOMY/GHG EMISSIONS STANDARDS, INT'L COUNCIL ON CLEAN TRANSP. 5 (May 2014), *available at* http://www.theicct.org/sites/default/files/info-tools/ICCT%20PV%20standard%20May2014.pdf. Although standards are not easy to compare across countries, current standards in Japan appear to be only slightly lower than the CAFE standards projected in the new US regulations for 2025. See *id.* As we note above, fuel economy is affected by many different factors, including the weight and performance of cars, so that carmakers serving the US might nonetheless need to innovate to meet the same standard achieved in Japan if they attempted to keep closer to the profile of the average US fleet rather than simply move to the much smaller profile of the Japanese fleet. *See* Chyi-Ing Lin, *Product Quality, Gasoline Prices, and Japanese Shares in the U.S. Automobile Market*, 2 Int'l J. Bus. 61, 81 n.2 (1997) (noting that Japanese cars' gas mileage exceeded that of U.S. cars because Japanese fleet size is smaller).

for a more aggressive approach which more fully causes manufacturers to internalize the costs of their failures to innovate to what has been shown to be feasible by their peers.

The CAFÉ program (and California's analogous Zero Emission Vehicle mandate, which we analyze at length in an online appendix) may, on balance, be less desirable than a more systematic tax on carbon, or even on more sector-specific tax increases, such as on gasoline. Carbon taxes and effluent taxes more generally can themselves be seen as a kind of innovation stick, albeit of a much more diffuse kind than the ones we review here. Given the political difficulties that such measures face in the US, however, it is worth understanding the potential, and indeed historic importance, of regulatory innovation sticks in reducing the damage associated with our national over-reliance on fossil fuels.

Notably, sticks have also been used in the environmental context to address other pollutants, which might not be reached even by broad taxes on carbon or fuel. Sulfur dioxide emissions became a significant concern in the US when the problem of acid rain was recognized in the 1970s.[112] The problem, which came primarily from power plants burning high-sulfur coal, was addressed with a cap and trade system in the Clean Air Act Amendments of 1990.[113] The law required a permanent overall reduction in SO_2 emissions of about 50% from 1980s levels, phased in over time.[114] Allowances for existing power plants were established based upon their historic emissions that were then scaled down to meet the overall target cap, and plants were permitted to purchase allowances from other sources that outperformed their SO_2 cap.[115] The EPA tracked allowances using an allowance tracking system (ATS), assigning a serial number to each allowance.[116] Fines for exceeding allowances were steep: a fine of $2,000 per ton, increasing with inflation, and a deduction of twice the amount of the excess from the allowance for the next year.[117] The program is widely considered very successful, resulting in 100% compliance,[118] much reduced emissions,[119] and health and benefits estimated in the tens of billions of dollars.[120]

---

[112] JAMES L. REGENS & ROBERT RYCROFT, THE ACID RAIN CONTROVERSY 35-58 (1989). Acid rain damages plant life and aquatic life, and has been a significant concern in the Northeastern US. *See id*.

[113] Clean Air Act Amendments of 1990, Pub. L. No. 101-549, 104 Stat. 2399 (codified at 42 U.S.C. § 7651 (2012)).

[114] Byron Swift, *How Environmental Laws Work: An Analysis of the Utility Sector's Response to the Regulation of Nitrogen Oxides and Sulfur Dioxides Under the Clean Air Act*, 14 TUL. ENVTL. L.J. 309, 315 (2000). The Amendments began the phase out in two stages. Phase I began in 1995 and affected coal-burning utility plants in twenty-one states. Phase II began in 2000 and targeted facilities in 47 states. In 2010, the Amendments capped sulfur dioxide at half of its 1980 levels. *Emission and Compliance Data*, EPA, *available at* http://www.epa.gov/airmarkets/progress/ARP09_1.html (last visited July 7, 2014).

[115] *See* 42 U.S.C. 7651 (2012).

[116] Kanwalroop Kathy Dhanda, A Market-Based Solution to Acid Rain: The Case of the Sulfur Dioxide (SO2) Trading Program, 18 J. Pub. Pol'y & Marketing 258, 260 (1999).

[117] 42 U.S.C. § 7651(j) (2012); Clean Air Act, 40 C.F.R. § 77.6 (2000). The statutory penalty of $2,000 was "significantly higher" than the cost of an allowance. John Schakenbach et al., *Fundamentals of a Successful Monitoring, Reporting, and Verification Under a Cap-and-Trade Program*, 56 J. Air & Waste Mgmt. Ass'n 1576, 1578 (2012).

[118] EPA, 1999 COMPLIANCE REPORT 2 (1999). The program continued to achieve 100 percent compliance in 2009, the year before the statutory cap took effect. *2009 Emission, Compliance, and Market Analyses,* EPA (2010), *available at* http://www.epa.gov/airmarkets/progress/ARP09_2.html.

The 1990 Amendments established a carrot and stick mechanism: heavy fines created a new emissions baseline, and the trade provisions allowed those who could do better than the baseline to profit from that fact. As with the CAFE standards, firms could meet the new standard in a variety of ways. Retrospectively, it is clear that two main strategies were key to the early phase of SO_2 reductions: the use of "scrubbers" that reduced emissions at the smokestack, and more widespread use of lower sulfur coal.[121] Scrubber technology improved significantly in this phase of the program, after stagnating for decades – a result that has been attributed to the cap and trade program, and the incentives it established for more extensive scrubber use.[122] (Notably, the companies that manufacture scrubbers are not those directly affected by the cap.[123] As this illustrates, if contracting is easy, there is less pressure on the government's choice of the regulatory target.) While coal switching would seem to require less innovation, lower sulfur coal had properties that made its industrial use difficult, so switching required both experimentation with new fuel blends and modifications to equipment, both of which were driven by the new standards.[124]

The stick aspect of the cap and trade model plays a role here similar to the above – it helps internalize the externalities associated with pollution. The SO_2 program also helps to illustrate the potential of a cap and trade model that incorporates carrots to push the boundaries for pioneers, and sticks to move the laggards along and change the structure of the market. The sulfur dioxide program has been criticized as too permissive (i.e. as having caps set too high),[125] reflecting the limits of government information about the cost of reductions in SO_2 and the social benefits associated with such reductions. Our analysis suggests that a yardstick model, which allowed firms in competition to establish the appropriate levels of emissions reduction, might have been preferable, because it

---

119 *2009 Emission, Compliance, and Market Analyses,* EPA (2010), *available at* http://www.epa.gov/airmarkets/progress/ARP09_2.html; Swift, *supra* note __, at 323-27; William L. Andreen, *Of Fables and Federalism: A Re-Examination of the Historical Rationale for Federal Environmental Regulation*, 42 ENVTL. L. 627, 676-78 (2012).

120 *See, e.g.*, EPA, PUB. NO. EPA-430/R-95-010, HUMAN HEALTH BENEFITS FROM SULFATE REDUCTIONS UNDER TITLE IV OF THE 1990 CLEAN AIR ACT AMENDMENTS 6-4 (1995) (finding annual benefits of S02 reduction to be $10 billion in Phase I, projected to rise to $40 billion by 2010); CLEAN AIR TASK FORCE, DEATH, DISEASE & DIRTY POWER: MORTALITY AND HEALTH DAMAGE DUE TO AIR POLLUTION FROM POWER PLANTS 4-5 (2000) [hereinafter CLEAN AIR TASK FORCE] (calculating annual social benefits of reducing SO_2 and NO_x emissions from power plants at over $100 billion); Sophia Hamilton, *When Science Palmers Make Policy: The Impact and Future of Cap-and-Trade in the United States*, 4 J. BUS. ENTREPRENEURSHIP & L. 269, 279 (2010) ("[T]he Acid Rain Program accounted for the largest quantifiable human health benefits of any major federal regulatory program implemented in the last ten years, with benefits exceeding costs by more than 40:1.").

121 Swift, *supra* note __, at 328-29 (these two the main drivers for reductions in phase I); *see also* Rico, *supra* note __, at 122 (covering phases I and II).

122 Swift, *supra* note __, at 333-34; Allen Bellas, *Empirical Evidence of Advances in Scrubber Technology*, 20 RESOURCES & ENERGY ECON. 327, 330 (1998) (noting that the sulfur dioxide caps spurred innovation in scrubber technology by offering "improved incentives" to innovate).

123 Swift, *supra* note __, at 330-34.

124 Swift, *supra* note __, at 336-37.

125 Swift, *supra* note ___, at 378; Curtis Carlson et al., Sulfur Dioxide Control by Utilities: What Are the Gains from Trade? 3 (Discussion Paper 98-44-REV Apr. 2000).

could add a dynamic dimension to emissions reduction that was absent in the statutorily chosen cap.[126]

All of these examples are liability rules, but it is worth noting that property rules can also be deployed here. Government can act not by imposing a fine on those who fail to innovate, but by simply banning a particular activity outright. Examples in the environmental domain are easy to come by. The Energy Independence Act of 2007 by banning the manufacturer of certain incandescent light bulbs between 40 and 100 watts created a stick backed by a property rule that "spurred innovation in the light industry."[127] Another successful example is provided by the Montreal Protocol on Substances that Deplete the Ozone Layer.[128] Concluded in 1987, the Protocol banned the production of CFCs in all signatory countries by 2010.[129] The ban has been effective at the national level,[130] and spurred the rapid invention of CFC substitutes.[131]

ii. Medicare's Diagnosis-Related Groups

Another example of using potential penalties to incentivize producer innovation is Medicare's hospital reimbursement scheme for in-patient care where physicians classify patient types into Medicare-established diagnosis-related groups (DRG).[132] Under the DRG system, Medicare reimburses hospitals an amount per patient determined in part by the average cost nationally of treating patients with the same DRG assignment. Specifically, the reimbursement amount is determined by adjusting a standardized base

---

[126] Swift suggests that the government should have established a price floor for the allowance auctions. *Id.* at 380 n.348. Yardsticks might be implemented in a similar way, with reductions in allowances resulting from average prices that drop below a certain level.

[127] 42 U.S.C. ch. 152 § 17001 et seq. & http://thinkprogress.org/climate/2011/07/08/263535/light-bulb-efficiency-standard-will-lower-energy-bills%E2%80%9D/.

[128] Montreal Protocol on Substances that Deplete the Ozone Layer, Jan. 1, 1989, 1522 U.N.T.S. 3.

[129] *Id.* art. 2A.

[130] K. MADHAVA SARMA, COMPLIANCE WITH THE MONTREAL PROTOCOL 308 (2005) (noting that only thirty-five countries failed to comply with the Montreal Protocol by exceeding the cap by relatively low amounts); At the international level, compliance has been "essentially perfect." Cass R. Sunstein, Montreal vs. Kyoto: A Tale of Two Protocols 29 (John M. Olin Law & Econ. Working Paper No. 302 Aug. 2006).

[131] Klaus Rennings, *Redefining Innovation—Eco-Innovation Research and the Contribution from Ecological Economics*, 32 ECOLOGICAL ECON. 319, 328 (2000). Some of these substitutes have been successful, and others have generated their own harms and been the subject of further bans. Industries began producing perfluorocarbons (PFCs) and hydrochlorofluorocarbons (HCFCs) instead of producing CFCs. Timo Goeschl & Grischa Perino, *Innovation Without Magic Bullets: Stock Pollution and R&D Sequences*, 54 J. ENVTL. ECON. & MGMT. 146, 156 (2007). In later years, scientists discovered that HCFCs led to environmental pollution. The Kyoto Protocol currently targets HCFCs, but the United States has not signed the Kyoto Protocol. *Id. See generally* Alan Manne & Richard Richels, *U.S. Rejection of the Kyoto Protocol: The Impact on Compliance Costs and CO_2 Emissions*, 32 ENERGY POL'Y 447 (2004) (noting that the United States did not ratify the Kyoto Protocol). PFCs, however, are not toxic. *Toxicological Profiles of PFCs Perfluorocarbons* EUR. PERFLURORCARBONS TECHNICAL COMM., *available at* http://www.fluorocarbons.org/chemical-families/pfcs/pfc-toxicological-profile (last visited June 29, 2014).

[132] DEP'T OF HEALTH AND HUMAN SERVS., CTRS. FOR MEDICARE & MEDICAID SERVS. ACUTE CARE HOSPITAL INPATIENT PROSPECTIVE PAYMENT SYSTEM: PAYMENT SYSTEM FACT SHEET SERIES 2 (2013), *available at* http://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/downloads/AcutePaymtSysfctsht.pdf.

payment for operating and capitals costs based on a DRG weight—a relative value assigned to each DRG that represents the average resource-intensity of cases within the DRG.[133] These values are derived from national data and updated annually. The base reimbursement amount is also adjusted according to local-level conditions, including wage index, cost of living, proportion of low-income patients the hospital serves, and costly "outlier" cases.[134]

This reimbursement model produces a kind of yardstick incentive with both carrots and sticks.[135] Hospitals are incentivized to reduce patient costs while increasing the volume of patients.[136] If hospitals lower treatment costs below the reimbursement amount, they profit. By the same token, if hospitals' treatment costs are above the DRG reimbursement amount, they face losses.[137] Thus, hospitals competing against the yardstick of average nation costs are incentivized to implement technology and process innovations to produce more cost effective care.[138] Hospitals may consider cost trade-offs—for instance, they might use high-cost antibiotics to reduce to the length of stay, the latter of which can save costs.[139] To reduce the cost of drugs and supplies, hospitals might consider participating in group plans.[140]

Again, our theoretical analysis makes available a fairly simple explanation for why a yardstick carrot-and-stick model was adopted here. Because of the commitment that the government has made to cover certain medical expenses, the difficulty that governments have directly observing the quality of care, and the lack of information and cost-internalization by patients, some cost discipline is needed. Some of the innovations associated with patient care may be affected by undercompensation, but patents will be available for some of these (new technologies, new treatments, or better software to manage patient data). Other innovations are likely more social in nature – better forms of communication in the hospital, for example. These DRG regulations allow the government to remain agnostic about the best methods of reducing Medicare costs. Individual hospitals are allowed discretion to pursue the types of interventions and innovations that will make their treatments most cost effective. Moreover, the hospitals competing against the average annual yardstick will understand that the average is likely to be a moving target—as hospitals producing at the average can increase their profits by reducing their cost of care. The yardstick combination of carrots and sticks thus not only incentivizes cost laggards to reduce their costs to the national average, but it incentivizes leaders in cost effectiveness to continue to improve.

---

133 *Id.*
134 *Id.*
135 Schleifer, *supra* note __, at 319.
136 Francesc Cots et al., *DRG-Based Hospital Payment: Intended and Unintended Consequences*, *in* DIAGNOSIS-RELATED GROUPS IN EUROPE: MOVING TOWARDS TRANSPARENCY, EFFICIENCY AND QUALITY IN HOSPITALS 75, 82 (R. Busse et al eds., 2011).
137 Schleifer, *supra* note __, at 319.. Cots, *supra* note __, at 86.
138 Cots, *supra* note __, at 81.
139 *Id.*
140 *Id.*

The DRG example also illustrates the information problems associated with sticks and non-traditional carrots. Real concerns exist that the DRG yardstick mechanism can also distort incentives on certain margins. Hospitals may develop strategies to reduce consumption of resources by reducing length of stay without improving treatment, increasing hospital admissions for profitable patients, or perhaps not implementing better practices or technologies in favor of cost-savings.[141] In addition, hospitals may "upcode" patients to diagnostic categories that generate larger reimbursements.[142] Whether these incentive distortions outweigh the yardstick benefits derived above is beyond the scope of this paper. But the DRG reimbursement scheme represents another example of an innovation stick already in use, this time deployed in conjunction with carrots, via the yardstick approach.

B. *State Penalties*

While the last section has focused on producer-directed incentives, it is also possible to structure innovation sticks to potentially penalize government entities whose actions impact the rate of innovation. Here we discuss two federal regulations that subjected states to potential innovation stick penalties.

i. Maximum Speed Limit Penalties

In response the OPEC oil crisis, Congress in 1974 passed the National Maximum Speed Law, mandating a 55 miles per hour speed limit on all interstate roads.[143] In the same year, the Federal-Aid Amendments made approval of highway projects funded by federal funds contingent upon state enforcement certification.[144] Although the national speed limit was enacted to conserve fuel, road fatalities fell the very-first year after the limit was imposed by a startling 16 percent, from 54,052 to 45,196.[145]

But many states openly resisted complying with the maximum speed limit. In response to this lack of compliance, the Congress passed the Highway Safety Act of 1978, which incentivized states to abide by the maximum speed limit by withholding federal highway funds for non-compliance and awarding grants for compliance.[146] Federal legislation required states to provide data for the percentage of vehicles that exceeded 55 miles per hour.[147] States collected this data by utilizing monitoring stations that recorded the speed of passing vehicles during set observation periods.[148]

---

[141] Cots, *supra* note __, at 83. OFFICE OF TECHNOLOGY ASSESSMENT, DIAGNOSIS RELATED GROUPS (DRGS) AND THE MEDICARE PROGRAM: IMPLICATIONS FOR MEDICAL TECHNOLOGY 25 (1983).

[142] Leemore S. Dafny, How Do Hospitals Respond to Price Changes? 3 (NBER Working Paper No. 9972 2003); Cots, *supra* note __, at 83

[143] DEP'T OF TRANSP., FED. HIGHWAY ADMIN., SPEED MONITORING PROGRAM PROCEDURAL MANUAL FOR THE NATIONAL MAXIMUM SPEED LIMIT (1980). Lee Friedman et al., *Long-Term Effects of Repealing the National Maximum Speed Limit in the United States*, 99 AM. J. PUB. HEALTH 1626, 1626 (2009).

[144] Speed Monitoring Program Procedural Manual, *supra* note __.

[145] Friedman, *supra* note ___, at 1626.

[146] Speed Monitoring Program Procedural Manual, *supra* note __.

[147] *Id.*

[148] *Id.*

The federal statute conditioned the amount of sanctions and grants on the results of the speed monitoring audits. Just as the proposed tobacco look-back provision conditioned penalties on the results of youth smoking surveys, the Highway Safety Act conditioned funds on the results of passing vehicle speed surveys. In 1979, if more than 70 percent of vehicles in a state exceeded 55 miles per hour, the federal government withheld 5 percent of the state's highway funds; if less than 60 percent of vehicles exceeded 55 miles per hour, the state received a boost of 10 percent in federal-aid highway funds.[149] The statutory level of speed limit compliance for sanctions and grants fell by 10 percent every year until 1983, at which point a state lost 10 percent of federal highway funds if more than 30 percent of its motorists exceeded the maximum speed limit and gained an additional 10 percent grant if less than 20 percent of its drivers exceeded the 55 miles per hour speed limit.[150]

While not based on an evolving yardstick, as with Medicare DRG compensation, the Highway Safety regime did represent a combination of carrots and sticks which became more stringent over time. The potential penalties represented another example of innovation sticks, this time that might be described as an attempt to make more salient for states certain social costs that they have power to affect, but that perhaps are insufficiently salient to drivers (or local voters) to be deployed locally.[151] States that were lagging behind the compliance standard were given financial incentives to take action to come into compliance. And as with our other examples, these incentives were not tied to taking any particular course of action. A state was free to choose the regulatory technology that it believed would be best suited to avoid the increasingly stringent penalties for non-compliance. Again, this serves as a reasonable domain for a stick, given the actors that are targeted (states), and the multi-modality of the innovations that we anticipate would help. Undercompensation here would also appear to be a relatively small risk, with traditional carrots in the background to help prevent free riding on new technologies (such as speed cameras) that the new regulation might help incentivize, and many possible inexpensive measures – perhaps amounting more to adoption than to innovation – that might be deployed by states to reduce speeding rates.

This increasing stringency may, however, have eroded the political viability of the statute.[152] In 1987, Congress permitted states to increase speed limits on rural interstate highways to 65 miles per hour.[153] A study by the Insurance Institute for Highway Safety found that fatalities on rural interstates increased between 25 and 30 percent when states began increasing speed limits on rural highways.[154] Despite the relaxation in regulation,

---

[149] *Id.*

[150] *Id.*.

[151] In contrast, the federal NHTSA apparatus for collecting, reporting and analyzing fatality data might make high safety issues more salient to federal officials.

[152] Q&As, INSURANCE INSTITUTE FOR HIGHWAY SAFETY, *available at* http://www.iihs.org/iihs/topics/t/speed/qanda#cite-text-0-17 (last visited July 7, 2014).

[153] *Id.*.

[154] Herbert M. Baum et al., *The Fatality Consequences of the 65 MPH Speed Limits*, 22 J. SAFETY RES. 171, 171 (1991).

the maximum speed limit law remained unpopular,[155] and in 1995, Congress repealed the maximum speed limit, allowing states to set their own speed limits for the first time in more than two decades.[156] This effectively ended the era of carrot and stick incentives. Although national traffic fatalities have remained relatively stable since the repeal of the maximum speed limit law, many have argued that the number of fatalities caused by increased speed has been offset by improvements in vehicle safety.[157] One study concluded that increased speed limits caused 12,545 deaths between 1995 and 2005.[158]

ii. No Child Left Behind

The No Child Left Behind Act of 2001 (NCLB) represents an additional example of innovation sticks directed at government entities, in this case public schools.[159] NCLB was structured to use federal funds to states to assist and enhance the K-12 education throughout the country. As provided, the law aims to close the achievement gap by having every student proficient in reading and math by 2014.[160] The single largest source of funding, Title I, makes funds available specifically for economically disadvantaged students.[161] At the core of Title I is academic accountability: states that accept funds must establish uniform "challenging academic standards" for public schools in the state and administer annual standardized exams to test whether students are meeting those standards.[162]

Title I is enforced by what amount to failure to innovate penalties directed both at failing schools and failing school districts.[163] Specifically, the law imposes increasingly harsh sanctions on schools that do not make "adequate yearly progress," as determined by test scores.[164] If students fail to meet the standards for two consecutive years, the school

---

[155] *Lawmakers Agree on Measure to End National Speed Limit*, ASSOCIATED PRESS, Nov. 16, 1995, *available at* http://articles.latimes.com/1995-11-16/news/mn-3667_1_speed-limit.

[156] Q&As, *supra* note ___.

[157] Press Release, Governors Highway Safety Association, National Maximum Speed Limit Repeal: Ten Years Later (Dec. 6, 2005), *available at* http://www.ghsa.org/html/media/pressreleases/2005/120605.html.

[158] Friedman, *supra* note __, at 1628.

[159] The No Child Left Behind Act of 2001, Pub. L. 107-110, 115 Stat. 1425 (codified as amended at 20 U.S.C. § 6301); *see generally* U.S. COMM'N ON CIVIL RIGHTS, OFFICE OF GEN. COUNSEL, CLOSING THE ACHIEVEMENT GAP: THE IMPACT OF STANDARDS-BASED EDUCATION REFORM ON STUDENT PERFORMANCE (2004), *available at* http://permanent.access.gpo.gov/www.usccr.gov/pubs/educ/educ0704.pdf; U.S. DEP'T OF EDUC., OFFICE OF ELEMENTARY & SECONDARY EDUC., NO CHILD LEFT BEHIND: A DESKTOP REFERENCE (2002);

[160] *See* 20 U.S.C. § 6311(b)(2)(F) (2012).

[161] U.S. DEP'T OF EDUC., *supra* note __, at 13.

[162] 20 U.S.C. § 6311(b)(1) (2012); James E. Ryan, *The Perverse Incentives of the No Child Left Behind Act*, 79 N.Y.U. L. REV. 932, 937 (2004) (providing background on Title I).

[163] Experts have criticized this sanction-based approach for not properly equipping schools with the resources needed to improve. *See, e.g.*, Robert Manwaring, *Restructuring 'Restructuring'*: *Improving Interventions for Low-Performing Schools and Districts*, EDUC. SECTOR REP. 2 (2010), *available at* http://www.educationsector.org/sites/default/files/publications/Restructuring.pdf.

[164] As with CAFE standards, "adequate yearly progress" is less about ensuring schools improve vis-à-vis past performances than it is about meeting uniform yardsticks, which are applicable to all schools. *See generally* WAYNE RIDDLE, EDUCATION FOR THE DISADVANTAGED: OVERVIEW OF ESEA TITLE I-A AMENDMENTS UNDER THE NO CHILD LEFT BEHIND ACT (Cong. Research Serv., CRS Report for Congress

must implement a two-year improvement plan.[165] Further, that school's students may opt to attend a different public school, including charter schools, within the same district.[166] After three consecutive years, the school must provide students with outside tutoring services.[167] A school that fails for four years in a row must make further such changes as hiring new staff or implementing a new curriculum.[168] And after five years of not making AYP, the school is placed on "restructuring" status cede control to the state, which then has the option of converting that school into a charter school or hiring a private company to manage.[169]

As with our other examples, Congress designed the NCLB-incentives to be technology-agnostic.[170] Specifically, states had broad flexibility in determining how to prepare students for these tests.[171] Indeed, according the U.S. Department of Education the primary purpose of NCLB is to provide increased flexibility and local control.[172]

By 2008-09, 4,580 Title I schools out of approximately 47,000 nationwide were in the restructuring phase.[173] Three-fourths of these schools opted for personnel-neutral reforms, such as implementing a new grading policy or curriculum.[174] With respect to school districts, by 2008-09, 1,735 districts out of roughly 15,000 required "corrective action," the intermediate level of sanctions. As with the schools faced with restructuring, over 75% did not replace personnel, but rather changed the curriculum or allowed students to transfer to other districts.[175] In some instances, NCLB sanctions have lead to school closures; in 2007-08, approximately 3% of schools that had to restructure under the law opted to close down.

In September 2011, President Obama announced that his Administration would waive many of the components of NCLB, including the provisions requiring 100% proficiency in math and reading by 2014 and the increasingly-stringent sanctions for

---

Order Code RL31487, Apr. 6, 2004).

165 20 U.S.C. § 6316(b)(1)(A) (2012).

166 20 U.S.C. § 6316(b)(1)(E)(i) (2012).

167 20 U.S.C. § 6316(b)(5) (2012).

168 20 U.S.C. § 6316(b)(7) (2012).

169 20 U.S.C. § 6316(b)(8) (2012).

170 20 U.S.C. § 6311(b)(2) (2012); *see generally* WAYNE RIDDLE, ADEQUATE YEARLY PROGRESS (AYP): IMPLEMENTATION OF THE NO CHILD LEFT BEHIND ACT (Cong. Research Serv., CRS Report for Congress Order Code RL32495, Feb. 18, 2009). Many have criticized the NCLB as providing incentivizes to states to implement lower educational standards that are easier to meet. *See, e.g.,* Ryan, *supra* note __, 940-41.

171 Horne v. Flores, 557 U.S. 433, 461 (2009) ("[NCLB] reflects Congress' judgment that the best way to raise the level of education nationwide is by granting state and local officials flexibility to develop and implement educational programs that address local needs, while holding them accountable for the results.") States also had discretion to define their own proficiency standards and "adequately year progress" (AYP) benchmarks that measure progress toward attainment of those standards.

172 U.S. DEP'T OF EDUC, *supra* note _, at 10.

173 Manwaring, *supra* note _, at 3.

174 *Id.*

175 *Id.* at 6.

failures to make AYP.[176] As of February 2014, the Administration had granted waivers to 42 of the 45 states that have applied.[177] In one sense, these waivers can be interpreted effectively as the end of innovation sticks. The waivers give states so much more flexibility in setting the agenda for academic improvement (e.g., states can implement standards that focus on achievement growth rather than absolute achievement) that they can reduce the chance that they will fail their own chosen standards. However, another interpretation suggests that a diminished credible threat of sanctions, especially for Title I schools, remains in place: the lowest performance schools must take the most severe remedial action.[178]

Stepping back, we acknowledge that our experience with innovation penalties in these examples (and the additional ones discussed in our online appendix) has been at best a mixed success. Some of the threatened sticks have not been sustained over time. The maximum speed limit penalties were ultimately rescinded after a few years. And the NCLB triggering conditions have been substantially diluted. But both the CAFE and DRG regulations have been shown to be more sustainable and, at least arguably, successful in inducing affirmative incentives to push envelope of human knowledge.

All in all, the experience with innovation penalties suggests that government faces non-trivial problems both in establishing the appropriate innovation goal that would avoid imposition of the penalty and in credibly following through and imposing the penalty on those that fail to meet the goal. The yardstick version of innovation sticks responds to both of these concerns. A yardstick trigger for penalties set at the median success rate is agnostic to the pace of progress. Government need not augur as to what will be feasible, but need only look at what the median was able to achieve. Moreover, a median trigger builds in a natural, sizeable constituency – the 50% that avoided the penalty – to lobby for the ex post imposition of the penalty. From this perspective, it might not be surprising that the DRG implementation and to some extent the CAFE (which has been careful not to move beyond what half of the industry could accomplish) have been two of the more successfully sustained programs. But the purpose of this section hasn't been to argue that these specific innovation penalties are ideally designed, or the best approach in each circumstance. It has instead been to offer examples that show that innovation sticks are not merely a theoretical possibility but are already in use, and in domains that our theoretical analysis can help make sense of.

III. A CAFE Standard for Automobile Fatalities

[176] Sam Dillon, *Obama Turns Some Powers of Education Back to States*, N.Y. TIMES, Sept. 23, 2011, *available at* www.nytimes.com/2011/09/24/education/24educ.html; *Federal Education Budget Project: No Child Left Behind – Overview*, NEW AMERICA FOUNDATION (July 1, 2013), *available at* febp.newamerica.net/background-analysis/no-child-left-behind-overview.

[177] *ESEA Flexibility* U.S. DEP'T EDUC., *available at* www2.ed.gov/policy/elsec/guid/esea-flexibility/index.html>.

[178] WAYNE RIDDLE, CTR ON EDUC. POL'Y, MAJOR ACCOUNTABILITY THEMES OF SECOND-ROUND STATE APPLICATIONS FOR NCLB WAIVERS 3 (2012), *available at* www.cepdc.org/displayDocument.cfm?DocumentID=404.

In this Part, we provide empirical support for the idea that CAFE-like incentives could reduce the prevalence of automobile fatalities that annually claim the lives of 50,000 Americans. More specifically, we imagine a world in which manufacturers were penalized if their fleet produced "above median" fatality rates, and states were penalized if drivers in their jurisdiction produced "above median" fatality rates. Our aim here is to illustrate how the concept of innovation sticks – and more particularly, a yardstick approach – might be applied to a new problem. We have chosen the problem of car fatalities because it is socially important, and because the relevant data is readily available. Also, this problem is plausibly subject to both externalities and diverse modes of innovation, making it, according to our theoretical analysis, an attractive domain for sticks. Moreover, the high sunk costs of automobile manufacturing make it relatively unlikely that undercompensation will induce industry exit. Yardstick carrots (providing rewards for below median fatality manufacturers) might also be effective at spurring the desired safety improvements. But a pure system of yardstick carrots would require ongoing tax dollars to fund the annual rewards. Our yardstick fatality proposal, in contrast, is revenue neutral and combines carrot incentives by transferring the stick revenues from the above-median safety laggards to the below-median safety pioneers.[179] This reward would be in addition to any patent a pioneer was able to secure for a non-obvious improvement in the safety art, illustrating the combined potential of carrots and traditional sticks, where sticks are used to correct market incentives and encourage laggards, and where traditional carrots can help prevent undercompensation.

We begin by identifying particular manufacturers and states that persistently lag behind their peers, providing an empirical basis to think that innovation, whether social or technological, is both needed and possible in this area. As we show, manufacturers like Pontiac and Mitsubishi persistently subject their own drivers and others to "above median" risk of death, while states, like Mississippi and Arkansas, persistently subject their own drivers and others to an increased risk of death.[180] While there have been continual improvements over time in automobile safety, we identify the savings in lives that might be achieved if the laggard states and manufacturers were brought to the median safety rates of their peers.[181] While CAFE has used an augural process of goal setting, negotiated in concert with car manufacturers, our simulations imagine a yardstick trigger for penalties set at the median fatality. The yardstick median is less susceptible to negotiation failure ex ante, and as we argued before,[182] provides a more credible threat of enforcement ex post.

---

[179] The rewards could be made proportional to the amount the pioneer was below the median.

[180] We shared an early draft of this article with manufacturers and states who we identified as persistent laggards and profited from private communications with some who responded.

[181] Our choice to use the median U.S. fatality rate is in many ways conservative as many other developed nations have shown that it is possible to generate substantially lower fatality rates. For example, the World Health Organization estimated in 2013 that the "Estimated Road Traffic Death Rate per 100,000 population" was 67% lower in the United Kingdom (and 40% lower in Canada) than in the United States. WHO, ed. (2013). "Global Status Report on Road Safety 2013: supporting a decade of action" 244–251 (table A2).

[182] See supra note .

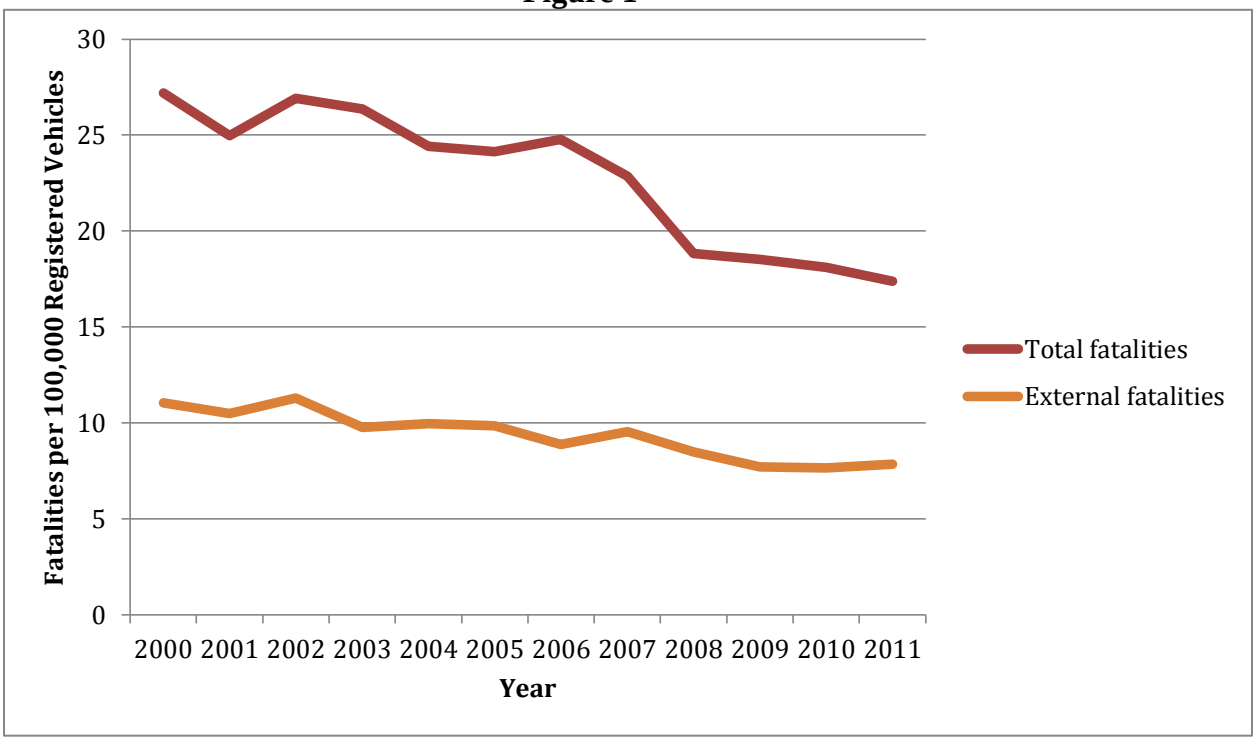
Financial incentives to encourage laggards to innovate toward the median currently achieved by others—even if only partially effective—might save tens of billions of dollars in loss of life. We present our estimated savings as a heuristic upper bound, because we acknowledge that penalizing failures to innovate are unlikely to eliminate all above median fatalities. Then again, fining above median fatality rates creates new incentives for manufacturers and states that are currently at or just below the median to innovate to stay ahead of the game. This new competition to stay ahead of the median – and thus qualify to share in the transfer of the above-median penalties – might lead to an acceleration of innovation and the diffusion of innovation throughout the industry and the states. As a matter of theory, innovation sticks could produce benefits even larger than the "upper bound" estimates suggested here.

A. *Yardstick Penalties for "Above Median" Manufacturers*

To begin, Figure 1 shows using NHTSA Fatality Analysis Reporting System data from 2000-2011 the median manufacturer fatalities rate per 100,000 registered vehicles for two different fatality measures, which we refer to as "total" fatalities and "external" fatalities.[183]

[183] These measures intentionally double count certain types of fatalities in multiple-car accidents. If a Toyota and a G.M.C. are involved in an accident in which a person in the Toyota dies and a pedestrian dies, the data will attribute to Toyota two total fatalities and one "external pedestrian" fatality, and will attribute to G.M.C. two total fatalities, one "external pedestrian" fatality, and one "external in-other-car" fatality. This double counting is appropriate for policy purposes because it captures what Robert Cooter has called the "double responsibility at the margin." Robert Cooter, *Unity in Tort, Contract, and Property: The Model of Precaution*, 73 CALIF. L. REV. 1, 4 (1985). In our example, because both Toyota and G.M.C. cars are involved in the "production" of the accident, both are appropriate targets of policies attempting to internalize the cost of excessive fatalities.

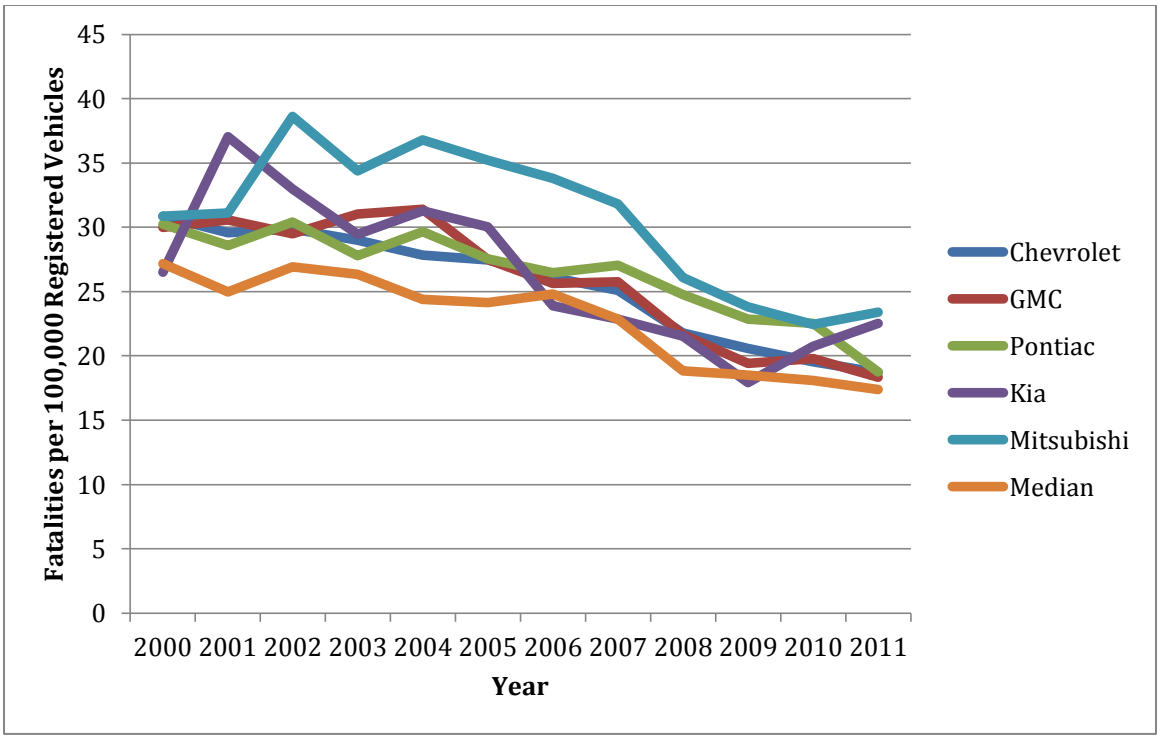
Figure 1



Note: Fatality data is from the National Highway Traffic Safety Administration's Fatality Analysis Reporting System (FARS). Total number of registered vehicles is from the USDOT Federal Highway Administration (FHWA). National fleet proportion data is from the FHWA's Nationwide Household Travel Survey (2001 and 2009). The graph shows a weighted median of 36 passenger vehicle manufacturers' fatality rates per 100,000 registered vehicles where the weight is the manufacturer's national fleet proportion.

Figure 1 shows increasing safety standards over time measured in both the "total" and "external" fatality rates. The median manufacturer fatality rate declined from 26 fatalities per 100,000 registered vehicles in the early years of this century to a rate of less than 18 fatalities per 100,000 registered vehicles in 2011. But there is a marked dispersion in the safety of cars produced across manufacturers. Figure 2, for example, plots the fatality rate of the five manufacturers who averaged the highest total fatality rates across this time period. The figure shows that Chevrolet, GMC, Pontiac, Kia, and Mitsubishi cars experienced total fatality rates that were persistently higher than the median fatality rates for the industry.

Figure 2 : Total Fatality Rates Over Time



Note: The five worst actors and the median for years 2000-2011. Total fatality numbers are the total number of fatalities in crashes involving that manufacturer.

Of course, manufacturers to some extent compete on the safety of their automobiles. Hence manufactures already have some incentive to reduce the likelihood that their cars will kill people, and especially people inside their cars. But manufacturers have imperfect incentives to reduce the fatalities of people outside their cars. Manufacturers are usually not liable when automobiles they produce are involved in accidents, and the same is true for the drivers themselves (and the drivers' insurance companies).[184] The manufacturers who are "total fatality" laggards are detrimental to society from a public health perspective. But even those who are more sanguine about the ability of consumers to make informed decision about their own safety should still be concerned about manufacturers who systemically lag behind in protecting people outside their customer's cars.

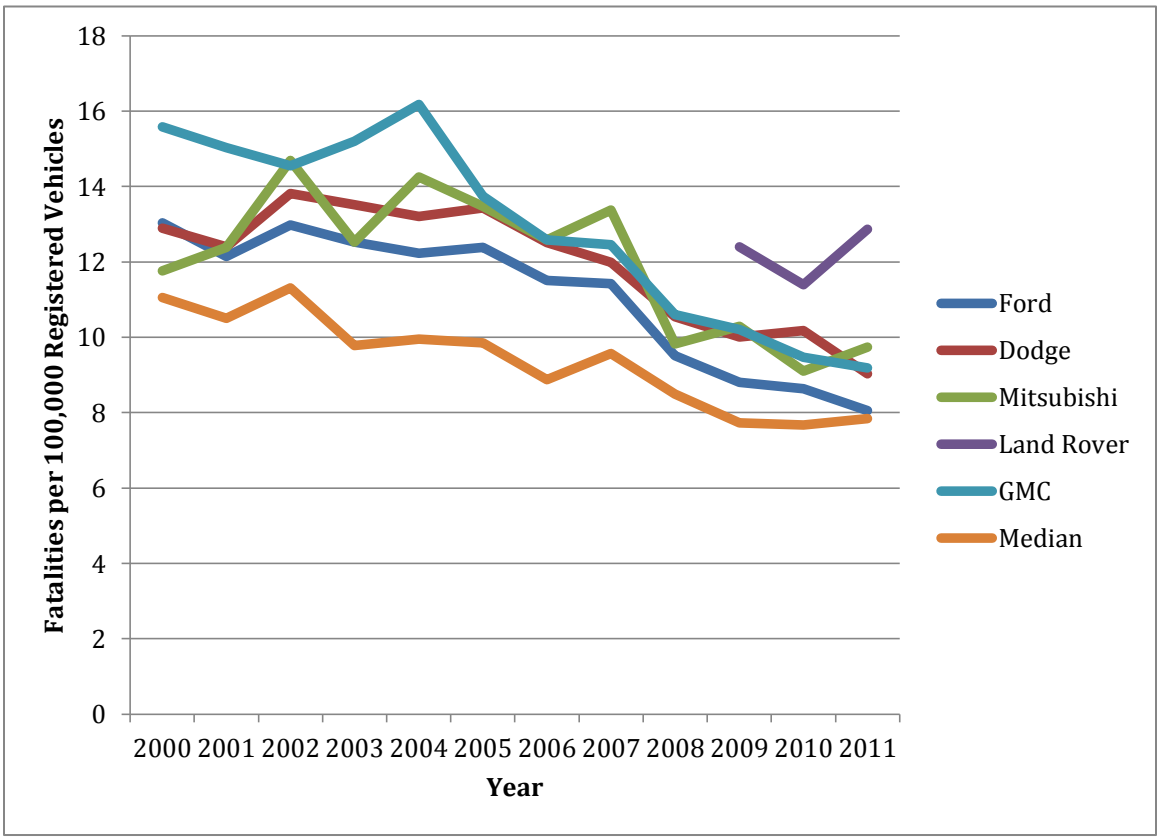
Accordingly, Figure 3 plots the fatality rate of the five manufacturers who averaged the highest external fatality rates across this time period.[185] The figure shows

[184] For the manufacturers, this is an outgrowth of the difficulty of reaching failure to innovate through tort liability, as discussed above. Insurance companies have no incentives to price into their products fatality risks that the company need not pay for under law. Insurance covers accidents where fault is present, rather than all accidents. This, and caps on liability, mean that while insurance companies do have some incentive to learn of, and price in, risks associated with riskier cars, these incentives are highly incomplete.

[185] The external fatality rate is calculated by looking at each car involved in an accident in which there is a fatality and determining whether there was a fatality from someone who was not in the car being considered. For example, if two Toyotas are involved in an accident which kills the drivers of

that Ford, Dodge, Mitsubishi, Land Rover, and GMC cars experienced external fatality rates which were persistently higher than the median external fatality rates for the industry.

Figure 3: External Fatality Rates Over Time



Note: The five manufacturers with the four highest average median external fatality rates for the years 2000-2011. Land Rover only appears from 2009-2011 because the manufacturer was not present in the Nationwide Household Travel Survey's sample until 2009.

The persistently elevated fleet fatality rates of particular manufacturers displayed in Figures 2 and 3 motivate us to ask what would be the impact on fatalities if CAFE-like penalties succeeded at inducing "above median" manufacturers to take actions to reduce their fatality rates down to the median. These penalties would be a kind of innovation stick – but of a less aggressive kind because it would not be requiring manufacturers to innovate toward a level of achievement currently outside the existing realm of possibility. It would only ask manufacturers to achieve the type of safety currently achieved by the median registered car.

---

one of the cars, that accident would increase Toyota's external fatalities by 1 (and Toyota's total fatalities by 2).

Table 2 takes up this challenge by asking how many lives would have been saved on average annually if the intervention succeeded at merely reducing the fatality rates of "above median" manufacturers down to the median industry rate.[186] We take this analysis to likely be an upper bound estimate of the potential savings from a CAFE-like yardstick penalty.[187]

Table 2: "Over Median" Analysis

	Fatalities Over Median	Proportion of Fatalities Over Median	Yearly Cost of Fatalities Over Median ($ billion)
Total fatalities	1690	4.8%	12.9
External fatalities	920	7.1%	7.0

Notes: Fatalities Over Median is calculated by multiplying the difference between each manufacturer's fatality rate and the median fatality rate by the number of cars that the company has on the road. For those manufacturers whose difference is positive, these fatality numbers are then summed by year and averaged over 12 years. The proportion of Fatalities Over Median represents the fraction of fatalities that would be saved if the fatality rate for manufacturers with a fatality rate over median were brought down to the median. The Yearly Cost of Fatalities Over Median was calculated by multiplying the number of Fatalities Over Median by the EPA's estimate of the value of a life, $7.6m. Both the Fatalities Over Median and the costs are deflated by the number of single-counted fatalities divided by the number of double-counted fatalities of each type.

As shown in Table 2, moving laggard manufacturers to the median fatality rates might save close to 1,700 lives annually, a number that represents close to 5 percent of all car fatalities.[188] These saved lives, valued at the EPA's estimate of the value of a life of $7.6 million, would represent an avoided cost of nearly $13 billion. Many of these lost lives come from people who were not riding in the "above median" manufacturer's vehicle. These fatalities are literally, as well as figuratively, not well "internalized." Table 2 calculates that there would have been 920 fewer external fatalities and that

[186] We deflate the numbers to adjust for the double counting mentioned above, *supra* note 209, – so that these estimates of lives lost and social costs (here and below) are not inflated by the double-counting. We create a total number of fatalities over median by summing the fatalities over median for each manufacturer. However, because each manufacturer's number involves double counting, we multiply this fatalities over median number by the ratio (total number of deaths in the US / total number of deaths in the US, double counted). For total fatalities, these numbers are (35,453 / 49,906).

[187] As noted above, it may be beyond the practicable control of some manufacturers to lower the fatality rates, or other manufacturers may lower their rates by shifting high risk drivers to their heretofore below-median competitors. It is theoretically possible though that yardstick competition might produce even faster declines in the industry median rate as below-average manufacturers take additional precautions to assure that they stay below the penalty inducing median fatality rate.

improving laggard fatality rates might avoid 7 percent of all external fatalities, producing $7 billion in savings.

How concretely might a CAFE-like system be applied to internalize these costs of "above median" fatality risks? The online appendix reports estimates of the one-time per-vehicle penalties that might be imposed on nineteen manufacturers if they were held responsible for their above median fatalities. We estimate that Mitsubishi cars are so dangerous that the present value of costs associated with "above median" "total" fatalities is on the order of $4,600 per vehicle. Six other manufacturers (Land Rover, Kia, Pontiac, GMC, Isuzu and Chevrolet) have estimated per vehicle charges of more than $1,500. The threat of imposing potentially crippling fines on these manufacturers would give them strong incentives to bring their fatality rates below (or at least substantially closer) to the industry median rate.[189] Those lagging manufacturers that failed to improve would, by raising their prices, indirectly improve safety by shifting consumers toward the below-median producers.

Alternatively, if one takes the view that manufacturers already have sufficient incentives to protect the drivers and passengers in their own cars, then one might instead focus on estimates of per vehicle charges associated with "above median" external fatalities. Land Rover's excess external fatalities are associated with more than $2,500 of per vehicle costs. Four other manufacturers (in descending order: GMC, Mitsubishi, Dodge and Ford) are estimated to have cost associated with "above median" external fatalities of more than $1,000 per vehicle. It is harder to assert that these manufacturers fully internalize the costs associated with these elevated risk of external fatalities. Moreover, there are known design strategies (beginning with reducing the weight of their cars) that are known to make cars less "aggressive" (i.e. dangerous to people outside the car).

Our appendix shows that some manufacturers (e.g. Plymouth and Oldsmobile) have "above median" total costs but not "above median" external costs, and vice versa (e.g., Lincoln). But we find particular troubling the five manufacturers whose external costs exceeds their total cost estimates by more than $100 per vehicle. In descending order these manufacturers are Dodge, Jeep, Ford, GMC and Infiniti. For example, we estimate that for Dodge the costs from "above median" external deaths is $1,511 while the costs from "above median" total deaths is only $423. This inversion of costs associated with total and external fatalities occurs because Dodge cars are substantially below median with regard to "internal" fatality risk. The policy concern is that Dodge may be designing or promoting its cars in a way that makes them safer to their customers at the expense of outsiders. We estimate that for every internal life Dodge saves by designing or promoting cars to bring the internal fatality rate below the median, there are 2.2 "above median" external lives lost. This creates the possibility that if Dodge

[189] Because the cross-elasticities of demand are high – especially with regard to cars in the same class, a manufacturer who attempted to pass along these substantial penalties would face dramatically restricted demand.

modified its design to be less "aggressive,"[190] it might be able to produce a net reduction in total fatalities by trading off external for internal fatalities.

The final columns also report the per-vehicle costs for above median fatalities after accounting for differences in miles driven by cars made by different manufacturers. A manufacturer might be above median in fatalities per registered vehicle not because of an inferior manufacturer design but merely because the cars for the manufacturer were driven disproportionately more miles per year than the median car. The final columns account for differences in miles driven by manufacturer and reports the re-estimated the implied costs per vehicle that would be charged under an innovation-stick regime.[191] While there are some substantial variations in the two methods of estimating per vehicle cost, the larger picture is that controlling for the differences in the miles driven does not eliminate or even substantially change the order of the above median manufacturers.[192]

Again, we emphasize that many caveats are in order. While the average number of miles driven by cars made by each manufacturer is not controlled for, other unobserved characteristics of vehicle drivers that are correlated with high accident rates—like drivers being drunk or teen males—are not. The location of the cars in a certain state or region will affect accident rates. We take on many of these additional effects in an on-line appendix, and argue that they do not materially alter our results. The purpose of this initial empirical exercise is to make plausible that the project of bring safety of lagging manufacturers in line with the fatality rates already achievable by below-median or median peers has the potential to produce first-order benefits to public safety.

B. *Yardstick Penalties for "Above Median" States*

Among the caveats to the foregoing analysis is the possibility that certain manufacturers may disproportionately sell cars in areas that have different likelihoods of fatal accident.[193] If any geographic accident disparities were beyond the control of the manufacturer, imposing yardstick penalties would be inefficient and inequitable because

---

[190] The fatality literature defines "aggressivity" as a vehicle's propensity to injure or kill someone in another vehicle. Jon S. Vernick et al., *Interventions to Reduce Risks Associated with Vehicle Incompatibility,* 34 EPIDEMIOLOGICAL REV. 57, 57 (2012). It is perverse that Dodge and other manufacturers market their cars as having aggressive exterior designs. See for example *Dodge Avenger*, DODGE www.dodge.com/en/2013/avenger/ (last visited July 7, 2014) ("[T]he Dodge Avenger takes an aggressive stance that's impossible to ignore.").

[191] Estimates for miles driven per year are calculated using the Nationwide Household Travel Survey's data on odometer readings and moths since purchase. Dividing the odometer reading by the number of months since the vehicle was purchased and multiplying by 12 gives a credible number of miles driven per year. Fatality rates are adjusted by calculating a fatality rate per car-mile, determining above-and-below-median rates. By multiplying that number by the average number of miles driven, we return to a fatality rate per vehicle metric.

[192] Controlling for differences in average manufacturer miles driven impacts the size of the implied penalties. The total fatality penalty for Mitsubishi falls from $4595 to $3895 due to the tendency of Mitsubishi driver to drive more miles per year than the average driver (12,400 vs. 10,800). The Oldsmobile total fatality penalty increased from $4 to $846 due to its drivers below average miles driven (of 10,100).

[193] See p _ for evidence of the importance of geography to automobile fatalities.

the foregoing comparison to the national median would be an inappropriate yardstick. Table 3 shows, even after controlling for regional differences in accident rates, that the basic lesson of the foregoing analysis changes very little. The 7th column entitled "Regionally Adjusted Yearly Cost" reports that the regional adjustments only modestly impact estimates for "Yearly Cost of Fatalities Over Median" (reported in the 6th column below). For example after adjusting for regional differences in manufacture sales,[194] the above median cost of total fatalities drops from $12.9 to 12.6 billion, where the above median cost of external fatalities increases from $7.0 to 7.1 billion.

Table 3: "Above Median" Fatality Analysis

	Manufactuer Median Analysis						State Median Analysis				
	St. Dev / Mean	Skew	Fatalities over Median	Proportion of Fatalities over Median	Yearly Cost of Fatalities over Median ($ billion)	Regionally Adjusted Yearly Cost ($ billion)	St. Dev / Mean	Skew	Fatalities over Median	Proportion of Fatalities over Median	Yearly Cost of Fatalities over Median
Total fatalities	0.27	-0.09	1690	4.8%	12.9	12.6	0.38	1.11	8346	20.9%	63.4
External fatalities	0.31	0.08	920	7.1%	7.0	7.1	0.39	0.77	3541	19.2%	26.9
Pedestrian external fatalities	0.22	-0.48	88	3.9%	0.7	0.7	0.42	0.73	1061	15.1%	8.1
Notes:											

But the concern about local differences in accident rates raises the deeper question of whether a CAFE standard might be applied to states themselves instead of (or as well as) to manufacturers. A state-centered system of yardstick penalties would charge states that produced higher fatality rates than the (registration-weighted) median rate found in other states a penalty corresponding to the losses associated with just those "above median" fatalities in the state.

The right hand columns of Table 3, building on estimates presented in the online appendix, compares the difference between an "above median" state and an "above median" manufacturer analysis. While moving "above median" manufacturers to the

[194] 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 regions. See *Census Regions and Divisions of the United States*, U.S. CENSUS BUREAU, *available at* http://www.census.gov/geo/maps-data/maps/pdfs/reference/us_regdiv.pdf (last visited July 7, 2014). Using the fatalities data and the USDOT's state-by-state registration data, we determine how much above or below the weighted mean fatality rate each region is in each year, where the weight is the region's proportion of national registrations. Then, using the NPTS 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 assume does not change. Using these two pieces of information, we can calculate an adjusted rate (fatalities/100,000 registered vehicles) for each car using the formula:
$adjusted\ rate_{iy} = unadjusted\ rate_{iy} - \Sigma\ (share_{ir} * adjustment_{iyr})$
where *i* indexes manufacturer, *y* year, and *r* region, *share* is the proportion of that car manufacturer 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 manufacturer rates down if their cars are more prevalent in high-fatality regions.

median total fatality rate would have saved 4.8 percent of lives, the table shows that move "above median" states to the median would have saved a whopping 21.5 percent of vehicular fatalities.[195] Similarly, the table reports that while "above manufacturer median" external fatalities represent 7.1 percent of all externalities fatalities, 19.2 percent of external fatalities come from "above state median" external fatalities. The substantial proportion of "above state median" deaths raise the possibility that from a public-health perspectives there may be greater gains to changing the behavior of lagging states than in changing the behavior of lagging manufacturers.

Figures 4 and 5 show that particular states have over time been persistently "above median" with regard to both their total and external fatality rates. Thus, Figure 4 shows that Mississippi total fatality rate has not just been above median, but massively above median. Figure 2 showed that Mitsubishi was consistently above the manufacturer median for total fatalities, but Mitsubishi's rate averaged only 34 percent higher. In contrast, Mississippi's rate exceeded the median state rate by 187 percent.

Figure 4: Above Median Total Fatalities

[195] The table also suggests that the reason why the proportion of above state median deaths is so much larger than the proportion of above manufacturer median deaths. The distributions of fatality rates across states are more variable and display more skew upward than the distribution of fatality rates across manufacturers. For example, the manufacture-level total fatality rate distribution exhibits a very slight downward skew (-.09), while the state-level total fatality rate distribution exhibits a substantial upward skew (1.11). These distributional differences mean that the fatality rate conditional on having an above average fatality rate is higher for states than for manufacturers.

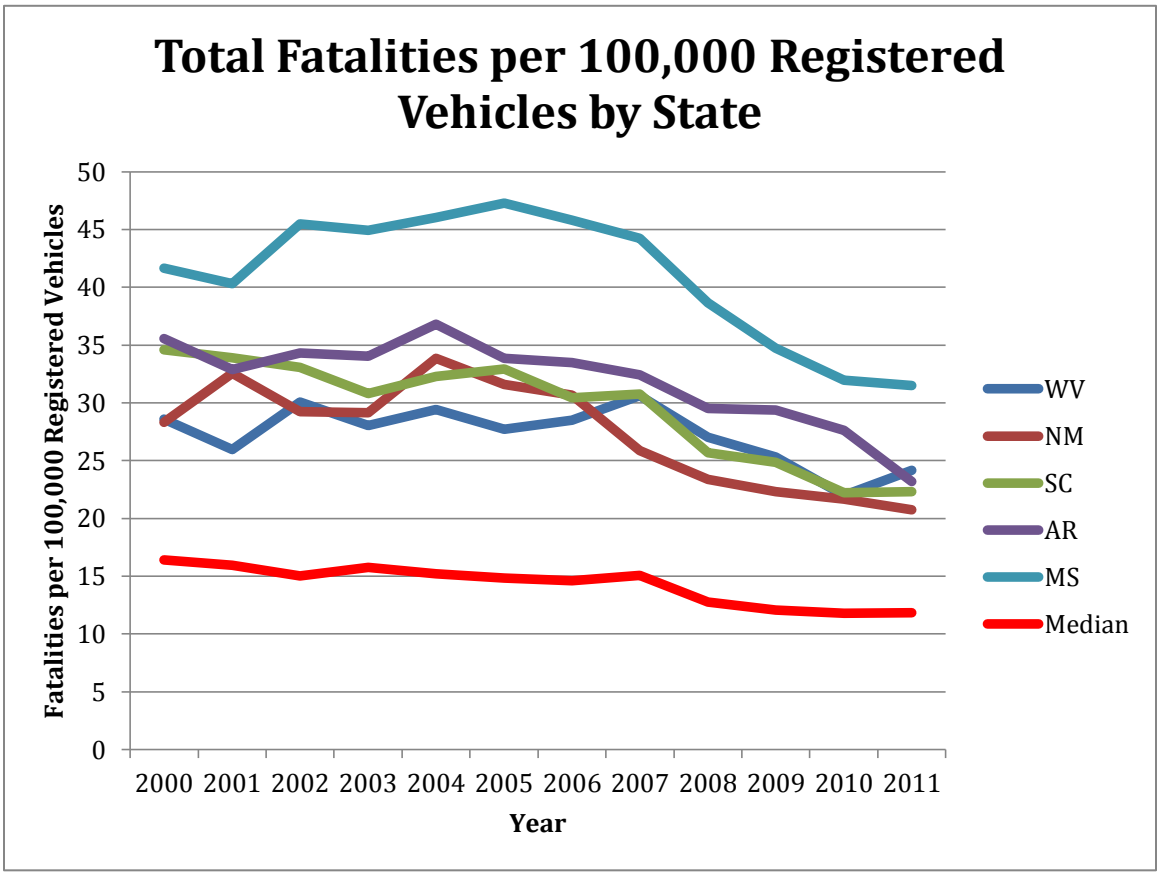
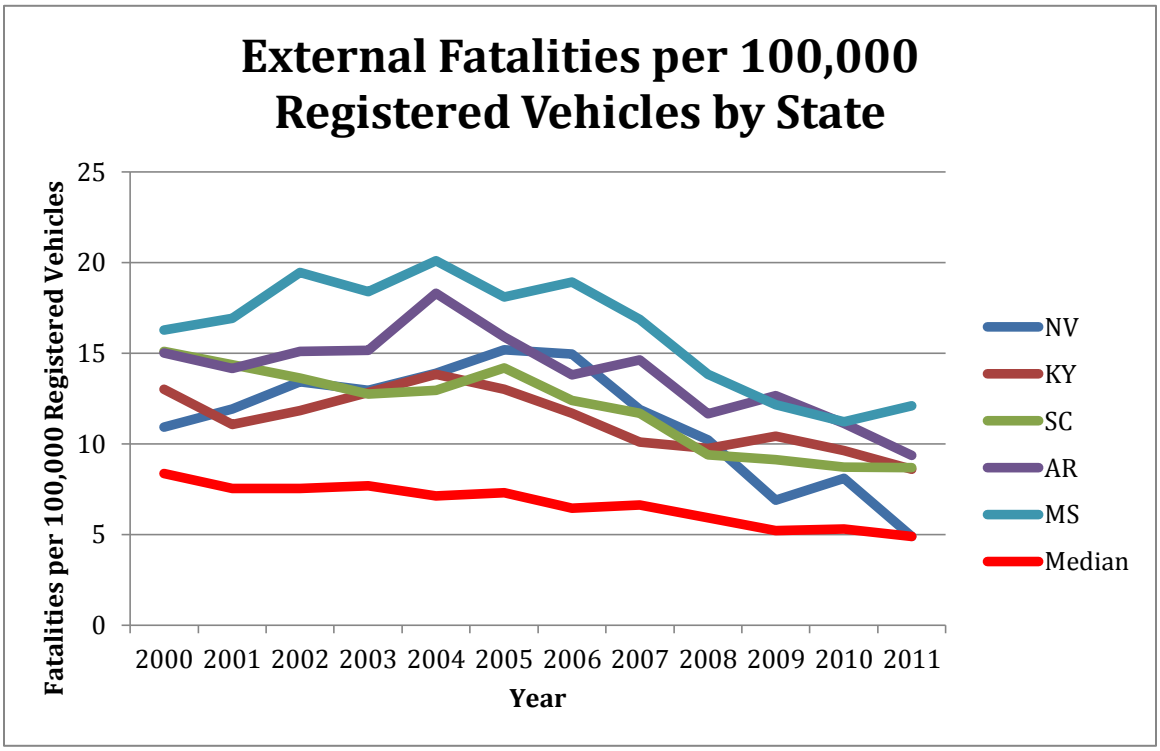


Figure 5 displays a similar story with regard external fatalities. While the median rate of external fatalities has fallen by 35 percent from 7.5 in 2000 to 4.9 in 2011, many states expose their citizens to a hazard per registered car that is more than twice has high.

Figure 5: Above State Median External Fatalities



Our on-line appendix reports estimates of the number of above state median fatalities and the associated per vehicle penalties that would need to be imposed on states to fully internalize the costs associated with these "above median" fatalities

The upward skew of the state fatality distribution has grim impact on our penalty estimates. Mississippi automobiles average 26.77 more deaths per 100,000 registered vehicles than the state median rate of 14.27 fatalities. If we value deaths at the $7.6m EPA-standard valuations, these "above state median deaths" in Mississippi represent a per vehicle cost of more than $15,000. (In contrast, the worst "above manufacturer median" per vehicle costs were only about $4,600). If Mississippi were forced to pay a CAFE-like penalty (for example in terms of lost federal funding) for these above median fatalities, the annual penalty would amount to a crippling annual fee of $4.1 billion (which would equal nearly 80% of the state's current total appropriations).[196] If we instead limited our concern to the "above median" external fatalities, the annual penalty would be on the order of $1.45 billion.[197]

[196] *State of Mississippi Budget FY 2014*, STATE OF MISSISSIPPI, *available at* http://www.dfa.state.ms.us/Offices/OBFM/Forms/FY2014%20Appropriations.pdf (last visited May 20, 2014)

[197] The rationale for focusing on external fatalities is, however, more problematic when analyzing above median state fatalities. A state's voters already, in theory, internalize the risk of both internal and external fatalities. The duly elected state officials may already have sufficient incentives to respond to automobile fatalities occurring in their jurisdiction.

Taking into account state differences in miles driven reduces the implied per vehicle penalty of states like Mississippi from $15,710 to $13,127 because Mississippi vehicles tend to be driven more miles per year than the average vehicle is driven in the United States (14,200 vs. 11,400 miles per year).[198] But the overall lesson is one of continuity. Adjusting the innovation sticks to take account of miles driven does not dramatically change the identity or size of the penalties that would internalize the social costs of above median fatality rates.

Whether it is more appropriate to control for differences in miles driven turns on whether manufacturers or states should be incentivized to take account of how much their cars are driven. We imagine that there are actions that either states or manufacturers might take to reduce the miles driven.[199] But it is not clear that these actions are cost-beneficial. For example, the states with the highest average miles driven per registered car per year are more rural. Forcing these states to internalize more of the costs of driving may inequitably and inefficiently disrupt their economies. Accordingly, we might wish to allow controls for differences in miles driven.

In contrast, we do not think that it is appropriate to control for all intervening variables that might impact the fatality rate. Accidents and fatalities are attributable to driver and environmental factors as well as issues of manufacturer design. A manufacturer who disproportionately sells to teen drivers or drivers who drive while drunk is likely to have higher fatalities than a manufacturer with an equally safe-design who disproportionately sells to safer drivers. In an online appendix, we show that male teen driving and driving under the influence of drugs and alcohol are likely causes of some of our above median results. Nonetheless, we believe it is likely appropriate to hold manufacturers and states financially responsible for these above median deaths because both manufacturers and states can plausibly take cost-effective action to reduce the fatality risk from these disproportionately dangerous driver types. For example, manufacturers might affect teen accident rates by facilitating the use of GPS monitoring to keep insurance companies and parents aware of reckless teen driving patterns.[200] Manufacturers could affect drunk driving accident rates by following Ford's lead and including automated audible warnings that go off inside the car when a driver is caught drifting out of their lane.[201] Existing "driver assist" technologies available in Mercedes and a number over other manufacturers use forward looking radar to detect imminent collision and automatically break the car (utilizing the full distance to the object to reduce likelihood of being hit from behind), while simultaneously flashing brake lights, tightening seat belts, adjusting head rests, closing the windows and roof, and raising the rollbar.[202]

---

[198] The difference between this the miles driven for the average vehicle (11,400) and the number mentioned about, 10,800, is due to error introduced in the sampling methodology of the Nationwide Household Travel Survey. The discrepancy is around 5%.

[199] For example, either might offer a drivers a pre-bate if they agreed to higher gas taxes. See Ian Ayres & Barry Nalebuff, "A Voluntary Gas Tax," FORBES.COM, Feb. 26, 2009, http://www.forbes.com/forbes/2009/0316/098_why_not.html.

State action can also directly affect both teen male and drunk accident rates. Graduated driver's license requirements for teens could be made more stringent in many states.[203] The requirement that teens not drive after 8pm, for example, has been found to lower teen fatality rates by 20 percent.[204] A wide variety of policy interventions are available to states that wish to lower drunk driving accident rates -- including enforcement of seat belt laws, lower speed limits, sobriety check points and speed cameras.[205] Roadway improvements, such as rumble strips both on the edges and in the middle of roads, roadway lighting, and guardrail improvements, are another possibility. . States could lower the legal BAC threshold below .08%, as studies have shown that impairment occurs at a BAC of just .01%.[206] States could require the use of ignition-lock "interlock" breathalyzer systems for driving under-the-influence (DUI) offenders.[207] DUI enforcement could become more high-profile, or states could take away your license or your car if you are caught drunk driving.[208] Given the wide range of plausibly cost-effective interventions that could be undertaken by both manufacturers and states, it is inappropriate to control away for differences in driving under the influences when calculating the size of innovation laggard penalties.

The plausible ability to effectively react to incentives is a necessary, but not a sufficient basis for imposing even partial penalties. We have not here developed a theoretical account explaining *why* we should reduce car fatalities. We have loosely assumed a welfarist approach in the style and manner of our reasoning, but have not done more than that in part because we believe that reductions in such fatalities are likely to be desirable from many different normative perspectives. However, different value perspectives may also generate arguments that should be addressed before adopting such penalties. From a welfarist perspective, for example, there are unaccounted benefits of fast, reckless, and even inebriated driving. A liberal or rights-based perspective might generate additional objections, such as concerns that pressures on manufacturers would lead to technologies with an unacceptable impact on privacy or autonomy, or that pressures on states would lead to problematic surveillance. From a welfarist, liberal, or rights-based approach – among others – one also might question whether it is appropriate for the federal government to shift the incentives of states in the way we suggest here. The politicians of Mississippi and other laggard states already have some incentives (or put in a more deontic frame, responsibility) to protect citizens of their state both inside and outside of automobiles. Before imposing penalties on states, we should have a better account of why local politics does not adequately address the problem.

A few further caveats are in order. Before imposing such a system on the states, we might also want closer study of the reasons for the disparities. A deeper driver of the higher fatality risk in laggard state may be poverty. In the public health literature, poverty

puts people at systematically higher risk for a variety of bad outcomes – including alcoholism and accidents.[209] States with poorer drivers may have fewer cost-effective actions to mitigate their above median fatality rate. Before imposing such a system on manufacturers, we might want to consider the extent to which manufacturer penalties may just cause a reshuffling of high-risk drivers without improving overall safety. At a minimum, our empiricism is a sufficient proof of concept to warrant further consideration. We've shown that particular manufacturers and particular state persistently lag the median levels of safety achieved by their peers, and that penalties that moved these laggards to the median might save thousands of lives a year. Finally, our example has helped to illustrate the potential power of a sticks-based approach to innovation, as well as some of the complexities associated with the design of innovation sticks. While these complexities should be taken seriously, feedback effects can help refine such sticks over time. We also think our empirics help show vividly the high costs of inaction, in an area where innovation can plausibly have very beneficial effects, but is not well incentivized with conventional carrots.

Conclusion: Necessity's Child

Until now, all normative analyses of innovation incentives have implicitly been constrained to alternative kinds of "carrots." To explicitly see this constraint naturally leads us to ask whether "stick" incentives or "carrots and stick" incentive regimes might ever be normatively attractive. Seeing the possibility of stick incentives also allows us to ask the analogous positive question of whether such incentive regimes have ever existed. This article has provided examples where innovation sticks have been used. Moreover, we have provided an argument as to why, in limited circumstances, they are appropriate to use. We have even provided heuristic empiricism on why and how yardstick penalties might be applied to laggard states and automobile manufacturers to improve the incentives of each to innovate to reduce car fatalities.

To see the value of innovation sticks, we must recognize three things that have not yet been fully appreciated in the IP literature. First, innovation comes in many modes, only some of which are well compensated by conventional IPRs, and only some of which generate goods that are public goods in the classic sense of the term. Second, it may be difficult, as a policymaker, to tell whether innovation, or mere adoption of an innovation, is needed. Mechanisms that are agnostic as to the mode of innovation, or even as to whether results are reached with innovation or rote adoption, can therefore also

[209] Kate E. Pickett & Margaret Pearl, Multilevel Analyses Of Neighbourhood Socioeconomic Context And Health Outcomes: A Critical Review, 55 *J. Epidemiol Community Health* 111 (2001). If poverty were a main driver, then sticks that further impoverished laggard states might just exacerbate the issue. In the language we develop above, we would have more of an undercompensation than overcompensation problem, and carrots might in this case be more appropriate than sticks.

be valuable. These first two points advance our appreciation not only of sticks, but also of non-traditional carrots. The third is critical to understanding the possible value of sticks: when setting innovation policy, overcompensation, and not only undercompensation, is a possible risk. Where innovation is possible without major free-rider problems, sticks have advantages over non-traditional carrots, and may make substantial efficiency gains possible.

While most academics in this field think of themselves as "Intellectual Property" scholars, this article's flipping inclination can be implied to ask whether there should also be a category of "Intellectual Anti-Property."[210] If IP is a conditional asset that you acquire by being creative, the Intellectual Anti-Property would be a conditional liability that you could only avoid by being creative.[211]

The aphorism, "Necessity is the mother of invention," implicitly suggests that it is the spur of extreme adverse consequences that breeds creativity. And yet our thinking about innovation incentive policy focuses on bestowing non-necessitous benefits. Enlightened policymaking will rarely embrace Rumpelstiltskin threats – "to figure out how to spin straw into gold or have your head off."[212] But this article has shown that policymakers at times should use and in fact already have used potential penalties as part of their innovation incentives.

[210] For a different usage of the term "anti-property," see Abraham Bell & Gideon Parchomovsky, *Of Property and Anti-Property*, 102 MICH.. L.. REV.. 1, 45 (2003).

[211] Put in option terms, intellectual property regimes grant potential innovator call options, while intellectual anti-property regimes would grant potential innovators something more analogous to a put option. See IAN AYRES, OPTIONAL LAW 45 (2005).

[212] THE GRIMM BROTHERS, RUMPELSTILTSKIN, *available at* http://www.authorama.com/grimms-fairy-tales-25.html (last visited May 20, 2014).