GOVERNING INNOVATION PRIZES

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Innovation prizes have been the focus of significant scholarly and political attention in recent years. The idea behind these prizes is simple: A public or private entity offers a monetary reward for the development of new technology. But their execution is complex. This paper critically evaluates innovation prizes as institutional solutions to the underproduction of technological public goods. We use a detailed case study of a prominent innovation prize – the Progressive Insurance Automotive X Prize – to illuminate that governance challenges that innovation prizes may face, and we argue for a shift in thinking about the comparative merits of innovation incentive mechanisms. Instead of focusing solely on social welfare in economic terms, we suggest that the choice of innovation incentive depends on the appropriate way to organize innovative activity to solve a particular problem.

Innovation prizes have a long historical pedigree.[1] Most famously, the British Crown offered £20,000 in 1714 for the development of a method to calculate longitude at sea. The prize was eventually – though not without some controversy – claimed by John Harrison, who designed and built a chronometer the accuracy of which could not be disrupted by sea travel.[2]

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[1] *See* SUZANNE SCOTCHMER, INNOVATION AND INCENTIVES 8-11 (2004); Fiona Murray et al., *Grand Innovation Prizes: A Theoretical, Normative, and Empirical Evaluation*, 41 RES. POL'Y 1779, 1780-81 (2012). For a detailed catalogue of historical and contemporary innovation prizes, see KNOWLEDGE ECOLOGY INT'L, SELECTED INNOVATION PRIZES AND REWARD PROGRAMS (KEI Research Note 2008:1, 2008), *available at* http://keionline.org/misc-docs/research_notes/kei_rn_2008_1.pdf.

[2] *See generally* DAVA SOBEL, LONGITUDE: THE TRUE STORY OF A LONE GENIUS WHO SOLVED THE GREATEST SCIENTIFIC PROBLEM OF HIS TIME (1995); Jonathan R. Siegel, *Law and Longitude*, 84 TUL. L. REV. 1 (2009).

Although prizes were offered extensively by both government and private entities to stimulate innovation through the 18th and 19th centuries,[3] they fell largely by the wayside in the 20th and early 21st centuries, replaced by patents and procurement (in the form of research grants and contracts) as our principal means of incentivizing innovation.

Prizes have come back into vogue, though, in both the public and the private sectors. Among the most well known contemporary prizes are those offered by the X Prize Foundation. These prizes are offered for grand technological feats – a $10 million prize for the first private team able to successfully to launch a reusable manned spacecraft into space twice within two weeks, for example. That competition attracted 26 teams that collectively invested $100 million into commercial spaceflight research.[4] Netflix famously offered a $1 million prize to design a better matching algorithm for its online recommendations. McKinsey & Company recently estimated the total size of the "prize sector" as $1-2 billion.[5]

And, importantly, the federal government has started using prizes as a tool of innovation policy. This move was tentative at first, with agencies like DARPA and NASA taking the lead under specific statutory authorizations.[6] But in 2010, Congress passed and the President signed the America COMPETES Reauthorization Act, which grants all federal agencies the authority "to award prizes competitively to stimulate innovation that has the potential to advance the

[3] *See* MCKINSEY & COMPANY, "AND THE WINNER IS…": CAPTURING THE PROMISE OF PHILANTHROPIC PRIZES 94-109 (2009); KNOWLEDGE ECOLOGY INTERNATIONAL, *supra* note 2; Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q.J. ECON. 1137, 1144-46 (1998).
[4] *See* X Prize Foundation, *Ansari X Prize*, at http://space.xprize.org/ansari-x-prize (last visited July 5, 2013).
[5] *See* MCKINSEY & CO., *supra* note 3, at 16.
[6] *See, e.g.*, 42 U.S.C. § 2459f-1 (NASA); 10 U.S.C. § 2374a (Dep't of Defense).

mission of the respective agency."[7] The executive branch, through the White House Office of Management and Budget (OMB) and Office of Science and Technology Policy (OSTP), is engaged in the development of government-wide guidelines to implement that authority.[8] And several agencies – notably the Department of Health and Human Services – already are conducting competitions pursuant to this new authority.[9]

Prizes have also been popular objects of scholarly attention in recent years, especially as an alternative to intellectual property and particularly in areas like medical research.[10] But the literature focuses primarily on comparative social welfare analyses of prizes and other innovation incentives and largely ignores issues of implementation. It asks, first, whether and under what conditions prizes might be more socially optimal than other mechanisms for providing incentives to innovate;[11] and, second, how properly to set the amount of the prize award.[12] It all but

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[7] America COMPETES Reauthorization Act of 2010, Pub. L. No. 111-358, § 105(a), 124 Stat. 3982, 3989 (2011) (codified at 15 U.S.C. § 3719(b)).

[8] *See, e.g.*, Memorandum for General Counsels and Chief Information Officers for Executive Departments and Agencies from Boris Bershteyn, General Counsel, Office of Management and Budget, *Prize Authority in the America COMPETES Reauthorization Act* (2011), *available at* http://www.cio.gov/documents/Prize%20Authority%20in%20the%20America%20COMPETES%20Reauthorization%20Act.pdf.

[9] *See* Office of Science & Technology Policy, Implementation of Federal Prize Authority: Progress Report (Mar. 2012), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/competes_report_on_prizes_final.pdf.

[10] *See infra* Part I.

[11] *See, e.g.*, Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY 51 (Adam B. Jaffe et al., eds. 2002); Steven Shavell & Tanguy van Ypersele, *Rewards versus Intellectual Property Rights*, 44 J.L. & ECON. 525 (2001); Brian D. Wright, *The Economics of Invention Incentives: Patents, Prizes, and Research Contracts*, 73 AM. ECON. REV. 691 (1983).

[12] *See, e.g.*, Shavell & van Ypersele, *supra* note 11; Michael Kremer, *Patent Buyouts: A Mechanism for Encouraging Innovation*, 113 Q.J. ECON 1137 (1998); Robert C. Guell & Marvin Fischbaum, *Toward Allocative Efficiency in the Prescription Drug Industry*, 73 MILBANK Q., June 1995, at 213; Douglas Gary Lichtman, *Pricing Prozac: Why the Government Should Subsidize the Purchase of Patented Pharmaceuticals*, 11 HARV. J.L. & TECH. 123 (1997). These

assumes that once a goal has been identified and a welfare-maximizing prize amount has been chosen, the prize sponsor can credibly commit to awarding the prize. In this paper, we argue that that assumption is unwarranted. Governance – the process of establishing and implementing rules and procedures for prize competitions – is a far more significant challenge than most legal and economic analyses suggest.[13]

Take, for example, the longitude prize. The economic operation of the prize was and remains easy to state: an award of £20,000 for the first inventor to develop a sound method of determining longitude at sea. But determining *how* to award the prize proved much more difficult than determining what the prize should be.[14] John Harrison, who history credits with solving the longitude problem by designing a chronometer that could be used at sea, tried numerous times to claim the prize. In hindsight, the Board of Longitude, which was constituted under the 1714 Longitude Act for the purpose of adjudicating the prize, fell victim to numerous administrative pathologies.[15] It was accused of bias and conflict of interest against Harrison, in no small part because Board members often were themselves or were affiliated with competitors

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approaches are critiqued in Michael Abramowicz, *Perfecting Patent Prizes*, 56 VAND. L. REV. 115 (2003).

[13] A few words to clarify our use of the term "governance" may be helpful. We use "governance" to refer generically to the range of operations that prize giving authorities – both public and private – must undertake in order to complete the goal of the program. *See infra* Part II (delineating governance challenges). This is consistent with the distinction sometimes drawn in the legal literature between "governance" and "regulation," where the former is meant to "signif[y] the range of activities, functions, and exercise of control by both public and private actors in the promotion of social, political, and economic ends." Orly Lobel, *The Renew Deal: The Fall of Regulation and the Rise of Governance in Contemporary Legal Thought*, 89 MINN. L. REV. 342, 344 (2004). Our analysis includes activities of both private and public prize making entities. We address the implications of our analysis for broader models of public and private governance in Part III, *infra*.

[14] Assume, for the moment, that £20,000 was at least a reasonable, if not welfare maximizing, estimate of the social value of the invention.

[15] *See* Siegel, *supra* note 2, at 27-57.

for the prize.[16] The Board was charged with implementing a statute that provided ambiguous guidance about the conditions that needed to be met for the prize to be awarded. One section of the Act provided that the prize money would be awarded upon the successful completion of a trial run of the successful method; another section provided that the method had to be "practicable and useful."[17] Despite the successful completion of a trial at sea, the Board required Harrison to submit his chronometer to an ever-expanding array of examinations and further trials in an apparent effort to judge its practicality and utility as against what the Board thought at the outset would be the solution – an astronomical method.[18] Royal intervention ultimately was required for Harrison to claim the prize.[19]

The award of the longitude prize was therefore significantly more complicated than the simple application of an economic formula to a technological problem. Instead, the story of the longitude prize raises a host of questions about the operation of prizes as a means to stimulate innovation: How can prize sponsors establish governance structures that are legitimate in the eyes of the participants? How can they devise and implement rules that provide both the needed flexibility to accommodate novel technological development and reasonable assurance that the prize will be awarded to the winner? How can they manage conflict among the participants?

In this article, we draw upon examples of contemporary and historic innovation prizes – primarily an in-depth case study of the Progressive Automotive X Prize – to articulate and describe the contracting and governance challenges that innovation prize competitions face. Understanding and overcoming the governance challenges in innovation prizes is important to innovation policy for several reasons. Irrespective of the academic debate over whether and

[16] *See* SOBEL, *supra* note 2at __; Siegel, *supra* note 2, at __.
[17] Longitude Act 1714, 12 Ann., c. 15, §§ 3, 4 (Eng.).
[18] *See* SOBEL, *supra* note 2, at __; Siegel, *supra* note 2, at __.
[19] *See id.* at__.

when prizes should be used instead of patents to promote innovation, government is *already* using prizes alongside existing innovation incentive mechanisms.[20] It therefore stands to reason that the policy tool ought to be used well.

More broadly, the governance challenges that innovation prize competitions face are not unlike the governance challenges that confront other institutional arrangements for the promotion of innovation – more commonplace mechanisms like patents or procurement. All of these institutions respond to the uncertainty and asymmetric information that characterize innovation.[21] But they do so in different ways and subject to different institutional constraints. The economic theory literature ultimately does not provide a satisfactory answer to the question when one or another innovation incentive scheme ought to be preferred. Instead, the choice of incentive mechanism depends on a number of context-specific factors. The institutional response to uncertainty and asymmetric information is one such factor. A better understanding of these responses therefore provides an important data point in evaluating which incentive mechanisms might be suited to different innovation environments.

Unlike patents, which rely on administrative processes to adjudicate the validity of the incentive mechanism, and procurement, which requires government to resolve uncertainty (at least in part) prior to making an award of the incentive, innovation prizes approach uncertainty and asymmetric information through a collaborative, iterative process. As we describe, when this process functions well, it allows for innovation to proceed toward a *certain* goal even without resolving the significant *uncertainty* that accompanies technological development. It is

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[20] *See* [Tom Kalil presentation explaining prizes as supplement/complement to existing innovation incentive mechanisms].

[21] *See* 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, 615 (Nat'l Bureau of Econ. Research ed., 1962); Gallini & Scotchmer, *supra* note 11, at 56-62.

an institutional solution that is well suited to innovation environments in which there is a broad technological goal but multiple and competing uncertain paths to reaching that goal.

Our argument proceeds as follows. Part I argues that governance is a critical yet under-studied aspect of innovation prizes. The academic literature to date has focused primarily on the theoretical questions whether and in what circumstances prizes may be preferred to patents or procurement. But although it has yielded some important insights into those questions, its primary conclusion is that the choice of innovation incentive is likely to be highly context-specific and dependent on numerous variables. Meanwhile, governments and private sponsors have been using prizes as innovation policy tools *alongside* more conventional patent and procurement mechanisms. They are voluntary, not mandatory. They complement or supplement rather than replace intellectual property. Although some empirical work suggests that prizes may be effective innovation promotion mechanisms, there is still little understanding of when they ought to be preferred or how their performance can be improved. Similarly, although many have noted some common problems with prizes – potentially high administrative costs and the difficulties of credibly committing to award the prize – institutional analysis of the governance features of these prizes is lacking. But learning about governance is important at least because we want innovation prizes to be run well and, especially, because it provides us with important insights into the situations in which prizes might function well or poorly.

In Part II, we draw on an in-depth, multi-method empirical study of the Progressive Insurance Automotive X Prize to identify and describe the governance challenges that may arise in prize competitions.[22] Those challenges are three-fold. The first is establishing a process to

[22] We choose the Automotive X Prize because the structure of the prize closely resembles the structure of prize competitions contemplated under the America COMPETES Act. *See infra* Part II.A.

design the goals and then the rules of the competition. In so doing, a prize sponsor needs information about technology that is in the private possession of a large number of parties, many of whom are likely to be competitors. The process of rule design must secure participant input but also must remain immune to capture by those participants in order to remain credible. The second challenge is to balance commitment with flexibility in implementing the competition. Because the technology at issue in grand innovation challenges is uncertain, any attempts to set rules or guidelines ex ante are likely to fail to take full account of the range of technological solutions to a given problem. When the technology evolves in unexpected directions, prize organizers must respond flexibly to the changing conditions. The danger, of course, is that such flexibility is adverse to the reliance interests of competitors. Finally, prize organizers must implement the rules in a manner that is consistent and fair.

Part III explains how these findings can help determine when prizes may be effective institutional choices for innovation incentives. It begins by generalizing from our findings to explain why the challenges we describe arise and how they might be resolved. In particular, we argue that innovation prize competitions are subject to two phenomena that are common in the management of technological innovation: significant technological uncertainty and information asymmetries among and between the competitors and the sponsors. Prize competitions operate in an environment marked by persistent non-estimable uncertainty. The particular technological goal may be capable of being stated, but the means to achieving that goal is highly uncertain. The competitions are designed, moreover, not necessarily to resolve the uncertainty, but to take advantage of its presence to drive unpredictable or innovative solutions to a particular problem. Managing technology in such conditions requires the development and communication of private information from multiple parties, each of which experiences the uncertainty in a different way.

Drawing upon the institutional design literature pioneered by Elinor Ostrom and others, we argue that the appropriate response to these phenomena is to build a governance structure that is credible yet allows for significant flexibility as the competition progresses. We then compare this emerging governance model with the responses that the patent and procurement systems offer to the same problems. In so doing, we argue that different governance approaches may be more or less well suited to different innovation environments. Governance ought therefore to be a key variable in determining the choice of institutional arrangements for innovation.

I. INNOVATION PRIZES IN THEORY AND REALITY

Patents and procurement remain the primary institutional mechanisms for promoting innovation in the modern era.[23] Nevertheless, there has been a resurgence of interest in prizes both in the popular press and the academic literature.[24] The academic literature has focused mostly on defining the economic conditions in which one or another innovation incentive regime may be optimal. It has largely elided questions of governance. This Part makes the case for a renewed theoretical and empirical focus on the governance of innovation prizes. The economic literature on innovation incentives does not conclusively establish that one or another mechanism is superior in all circumstances. Instead, it teaches that context is critical. That context must include governance.

A. Economic evaluation of innovation incentives

[23] Consider, for example, that the most generous estimate of the amount of money spent on prizes is about $1-2 billion. *See* MCKINSEY & CO., *supra* note 3, at 16. By comparison, the total amount of federal government spending on research and development (R&D) is around $130 billion per year. *See* NATIONAL SCI. FOUND., FEDERAL FUNDS FOR RESEARCH AND DEVELOPMENT: FISCAL YEARS 2009-11, at 9 tbl.1 (2012).

[24] *See, e.g.*, David Leonhardt, *You Want Innovation? Offer a Prize*, N.Y. TIMES, Jan. 31, 2007, at C1; *And the Winner Is…*, ECONOMIST, Aug. 5, 2010, at 62; Joseph Stiglitz, *Give Prizes, Not Patents*, NEW SCIENTIST, Sept. 16, 2006, at 21. For an overview of the academic literature, see Peter S. Menell & Suzanne Scotchmer, *Intellectual Property*, *in* 2 HANDBOOK OF LAW AND ECONOMICS 1473, 1530-34 (A. Mitchell Polinsky & Steven Shavell eds., 2007).

Economists have long understood that in a competitive market, the incentives for private persons to engage in technological innovation may not be adequate.[25] That is because innovation depends on the production of information goods and such goods have economic characteristics that make them less susceptible of market production than tangible goods. In particular, information is nonrivalrous – that is, one person's use of the information does not limit another person's use of the same information. This means, in turn, that information needs only to be produced once; the marginal cost of subsequent use is zero. As Arrow noted, in a competitive market, goods are optimally priced at marginal cost. "[A]ny information . . . should, from the welfare point of view, be available free of charge. . . . [B]ut, of course, [this] provides no incentive for investment in research."[26] Similarly, information often may be nonexcludable. Because information may be difficult to conceal from others, it is easy for others to appropriate information once created and free ride on the creator's investment.[27] Putting these characteristics together suggests that private actors will have insufficient incentive to engage in R&D. Doing so is costly and there is little assurance that such costs can be recouped.[28]

This analysis suggests that *some* institutional response is necessary to promote innovation, but it does not suggest any particular kind of response. Intellectual property solves the incentive problem by granting an inventor the exclusive right to make, use, or sell her

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[25] *See* Arrow, *supra* note 21, at 616-17; Richard R. Nelson, *The Simple Economics of Basic Scientific Research*, 67 J. POL. ECON. 297 (1959). For a review of the economic literature, see Menell & Scotchmer, *supra* note 24, at 1476-78.
[26] Arrow, *supra* note 21, at 616-17.
[27] *See id.* at 614-15. For a critique of the argument – not made by Arrow, but using his analysis as a starting point – that information is inherently nonexcludable, see Michael J. Burstein, *Exchanging Information Without Intellectual Property*, 91 TEX. L. REV. 227, 248-55 (2012).
[28] *See* Arrow, *supra* note 21, at 619 ("To sum up, we expect a free enterprise economy to underinvest in invention and research (as compared with an ideal) because it is risky, because the product can be appropriated only to a limited extent, and because of increasing returns in use."); *see also* SCOTCHMER, *supra* note 1, at 38 (describing the ex ante incentive problem).

invention.[29] This allows an inventor to exclude others from using the information at the core of her invention, and to place a non-zero price on her invention. Because she can recoup her investment, intellectual property is thought to provide needed ex ante incentives to engage in innovative activity.[30] Indeed, that has come to be its primary justification.[31]

As Arrow recognized, however, intellectual property is socially costly.[32] Because it facilitates pricing information goods above their marginal cost (i.e. zero, or close to it), it leads to deadweight loss. Some users who would otherwise purchase the good at it the competitive price, will not be able to do.[33] In addition to this static inefficiency, intellectual property may lead to dynamic inefficiencies because information is an input into further research and development; exclusion therefore limits the ability of follow-on innovators to create new works.[34] In view of these difficulties, Arrow argued that government financing of R&D was likely to be a less socially costly form of innovation incentive than intellectual property.[35]

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[29] *See* 35 U.S.C. § 271(a).
[30] *See, e.g.*, SCOTCHMER, *supra* note 1, at 38; Menell & Scotchmer, *supra* note 24, at 1477-78.
[31] *See, e.g.*, William Fisher, *Theories of Intellectual Property*, *in* NEW ESSAYS IN THE LEGAL AND POLITICAL THEORY OF PROPERTY 168, 169 (Stephen R. Munzer ed., 2001); Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 83 TEX. L. REV. 1031, 1053-55 (2005).
[32] *See* Arrow, *supra* note 21, at 617. The costs of intellectual property are well summarized in Lemley, *supra* note 31, at 1058-59 ("First, intellectual property rights distort markets away from the competitive norm, and therefore create static inefficiencies in the form of deadweight losses. Second, intellectual property rights interfere with the ability of other creators to work, and therefore create dynamic inefficiencies. Third, the prospect of intellectual property rights encourages rent-seeking behavior that is socially wasteful. Fourth, enforcement of intellectual property rights imposes administrative costs. Finally, overinvestment in research and development is itself distortionary.").
[33] *See* SCOTCHMER, *supra* note 1, at 36-37; Arrow, *supra* note 21, at 617 ("[P]recisely to the extent that [intellectual property] is successful, there is an underutilization of the information.").
[34] *See* Arrow, *supra* note 21, at 618; Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. ECON. PERSP. 29, 29-30 (1991).
[35] *See* Arrow, *supra* note 21, at 623 ("The previous discussion leads to the conclusikno that for optimal allocation to invention it would be necessary for the government or some other agency not governed by profit-and-loss criteria to finance research and invention.").

Arrow's analysis was the subject of an influential critique by Harold Demsetz.[36] Demsetz argued that government funding suffered from a particular flaw: absent some connection with market demand, it would be difficult for the government to determine the appropriate level and direction of investment in research and development.[37] Property rights, he argued, took advantage of the signaling function of price to guide the efficient production of information.[38]

Prizes represent, in some ways, a middle course between the use of property rights and direct government funding as mechanisms to incentivize innovation. In a prize system, the government does not determine the rate and direction of R&D, but neither does the above-market pricing provide the source of incentives to innovate. Instead, in the paradigmatic economic model of a prize, the choice of innovation goals and strategy remains in private hands. But inventions pass into the public domain and the inventors are compensated ex post by the government.[39] In theory, a well-designed prize system can therefore provide the financial incentive of a patent or a procurement system, but can do so (a) without the deadweight loss of a patent;[40] and (b) without the government having to choose which innovations to fund through procurement.

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[36] *See* Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J.L. & ECON. 1 (1969).
[37] *See id.* at 9.
[38] *See id.* at __; *see also* Gallini & Scotchmer, *supra* note 11, at 56-58.
[39] *See, e.g.*, Shavell & van Ypersele, *supra* note 11, at 525; Gallini & Scotchmer, *supra* note 11, at 53-54.
[40] Because most theoretical prize proposals would fund the prizes from general tax revenue, there is still *some* deadweight loss. But the deadweight loss associated with general taxation is thought to be lower than the deadweight loss associated with exclusive rights because the latter operates as a tax on a single market. *See* Heidi Williams, *Innovation Inducement Prizes: Connecting Research to Policy*, 31 J. POL'Y ANALYSIS & MGMT. 752, 757 (2012).

Economic analysis of prizes has focused on two issues: The conditions under which prizes, patents, or procurement is the preferred incentive mechanism; and the challenge of setting the size of the prize. These analyses provide some useful insights into the tradeoffs a policymaker might make among the three incentive mechanisms, but ultimately are inconclusive. In a germinal contribution, Brian Wright modeled how the presence of information asymmetries between inventors and the government affects the choice among mechanisms. He concluded that if the benefits and costs of research were known both to inventors and the government, there would be no reason to favor patents over prizes or procurement.[41] On the other hand, in the presence of such information asymmetries, and at least in the case where the terms of the prize must be fixed before the asymmetry is resolved, then patents might be superior.[42] Each mechanism has positive and negative features, depending on the innovation environment in which it is deployed.[43] The lure of patents and prizes may result in duplication of effort that procurement, by limiting the number of participants, avoids. On the other hand, procurement raises the risk that the government will make poor choices or that ex ante payments to innovators will result in shirking.

Further work has aimed at refining these results but it remains subject to the kinds of qualifications discussed above. Gallini and Scotchmer, for example, conclude that intellectual property may be best when value and cost are not observable to the government, but that neither intellectual property nor prizes do a good job aggregating private information necessary to avoid

[41] *See* Wright, *supra* note 11, at __.
[42] *See id.* at __.
[43] *See id.* at 703-04; *see also* Amy Kapczynski, *The Cost of Price: Why and How to Get Beyond Intellectual Property Internalism*, 59 U.C.L.A. L. REV. 970, 985-86 (2012) (summarizing conclusions from economic literature).

duplication of efforts.[44] Shavell and van Ypersele refine these models to conclude first that "[a]nalysis of patent versus reward does not lead one to think that there exists any general argument favoring the patent system over the reward system,"[45] but second that an "optional reward system" in which an inventor chooses between a patent and a prize may be superior.[46] Others have made similar refinements.[47] Finally, because much of the analysis depends on whether the government can accurately determine the amount of the prize, significant scholarly attention has been devoted to developing methods for a prize sponsor accurately to determine the optimal amount of the prize.[48]

This work, while useful, is largely inconclusive as a policy matter. As Amy Kapczynski summarizes:

> the post-Demsetzian economics literature has proliferated a series of parameters that influence the comparative efficiency of these different systems, including, most importantly, the competitiveness of the research environments; the cost of research as compared to the value of the reward; the riskiness of research or creativity; the importance of private information about the cost of value of creation; the costs of overseeing effort in the context of contracts; and the comparative costs of rent seeking, uncertainty, and the administration of each system. The information economics literature thus offers no general endorsement of any mechanism.[49]

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[44] *See* Gallini & Scotchmer, *supra* note 11, at 70.
[45] Shavell & van Ypersele, *supra* note 11, at 530.
[46] *See id.* at 530-31.
[47] *See, e.g.*, Benjamin N. Roin, *Intellectual Property versus Prizes: Reframing the Debate*, 81 U. CHI. L. REV. (forthcoming 2014) (arguing that static benefits of prizes are usually overstated); V.V. Chari et al., *Prizes and Patents: Using Market Signals to Provide Incentives for Innovations*, 147 J. ECON. THEORY 781 (2012) (examining effects of innovator's ability to manipulate market signals and concluding that prizes are superior to patents where such manipulation is infeasible); Hugo Hopenhayn et al., *Rewarding Sequential Innovators: Prizes, Patents, and Buyouts*, 114 J. POL. ECON. 1041 (2006) (evaluating effects of patents and prizes in a model of cumulative innovation); E. Glen Weyl & Jean Tirole, *Materialistic Genius and Market Power: Uncovering the Best Innovations*, IDEI Working Paper No. 629 (2010).
[48] *See, e.g.*, Kremer, *supra* note 12; Abramowicz, *supra* note 12, Shavell & van Ypersele, *supra* note 11
[49] Kapcyznski, *supra* note 43, at 988; *see also* Williams, *supra* note 40, at 757.

Indeed, as the next section describes, the academic debate has become largely unmoored from the reality of innovation prizes as policy tools.

B. Contemporary innovation prizes as policy tools

The economic debate over whether prizes, patents, or procurement provides the optimal innovation incentive has been resolved as a practical matter. All three mechanisms are used simultaneously. In a stark contrast with the theoretical literature described above, most prizes – whether offered by government or a private sponsor – are voluntary rather than mandatory and do not require participants to give up their claim to intellectual property rights.[50] The advocates of prizes cite a wide variety of rationales for their use.[51] But like those of the academic literature, these rationales are under-specified. They fail to provide much guidance about the conditions in which prizes may be useful policy tools.

Contemporary prizes take a variety of forms. Most of the contemporary focus – and our focus here – is on "inducement" rather than "reward" prizes.[52] The former is an ex ante prize in which a goal is specified and the prize is awarded upon completion of the goal; the latter is a reward for past achievement, like the Nobel Prize. Even within the category of inducement prizes, however, there is still significant variation. Some authors, for example, draw a distinction between demonstration projects and prizes aimed at creating market-ready goods.[53] The COMPETES Act itself specifies three different types of prizes that federal agencies may offer: (1) "[a] point solution prize that rewards and spurs the development of solutions for a particular,

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[50] *See* Michael Kremer & Heidi Williams, *Incentivizing Innovation: Adding to the Toolkit*, *in* 10 INNOVATION POLICY AND THE ECONOMY 1, 10-11 (2010) (describing voluntary prize systems and arguing that such systems be deployed as experiments without disrupting settled expectations of IP-based appropriation of the gains from R&D).
[51] *See* Murray et al., *supra* note 1, at 1783-84.
[52] *See* Thomas Kalil, Prizes for Technological Innovation 5 (Brookings Institution 2006).
[53] *See, e.g.*, Williams, *supra* note 40, at

well-defined problem;" (2) "[a]n exposition prize that helps identify and promote a broad range of ideas and practices that may not otherwise attract attention;" and (3) "[p]articipation prizes that create value during and after the competition by encouraging contestants to change their behavior or develop new skills."[54]

Our focus in this article is on "grand innovation prizes" – "large monetary prizes awarded to the innovator(s) providing the best or first solution to a pre-determined set of significant new performance goals with no path to success known ex ante and believed to require significant commitment and a breakthrough solution."[55] These are the prizes that have captured the most attention in the private sector and that provide a model for the government's early efforts under the COMPETES Act and similar legislation.[56] Although the scale of the prizes may vary,[57] the underlying structure of the prize usually is the same. The sponsor articulates a goal and invites entrants to meet the goal; the overriding characteristic of the competition is that "the objective is clear, but the way to achieve it is not."[58]

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[54] 15 U.S.C. § 3719(c). The statute also authorizes agencies to sponsor "[s]uch other types of prizes as each head of an agency considers appropriate to stimulate innovation that has the potential to advance the mission of the . . . agency." *Id*; *see also* MCKINSEY & CO., *supra* note 3, at 48-51 (categorizing prizes as "exemplar," "exposition," "network," "participation," "market stimulation," and "point solution."

[55] Murray, *supra* note 1, at 1779.

[56] *See, e.g.*, NAT'L ECON. COUNCIL, COUNCIL OF ECON. ADVISERS & OFF. OF SCI. & TECH. POL'Y, A STRATEGY FOR AMERICAN INNOVATION 12 box.2 (2011) (citing Progressive Insurance Automotive X Prize) [hereinafter *2011 National Innovation Strategy*]; OFF. OF SCI. & TECH. POL'Y, IMPLEMENTATION OF FEDERAL PRIZE AUTHORITY: PROGRESS REPORT 7-8 (same) [hereinafter *OSTP Progress Report*].

[57] *See OSTP Progress Report*, *supra* note 56, at

[58] MCKINSEY & CO., *supra* note 3, at 49; *see also* Kalil, *supra* note 52, at 6 ("Prizes are especially suitable when the goal can be defined in concrete terms but the means of achieving that goal are too speculative to be reasonable for a traditional research program or procurement."); *2011 National Innovation Strategy*, *supra* note 56, at 12 box.2 ("Prizes allow the sponsor to set an ambitious goal without selecting the team or approach that is most likely to succeed."). We follow Murray et al, *supra* note 1, at 1779, in drawing a distinction between these prizes and many of the competitions sponsored by platforms such an InnoCentive or

The most famous historical prizes had this structure. The British longitude prize, described above, offered £20,000 for the first discoverer of a method for finding longitude at sea.[59] The Orteig Prize inspired Charles Lindbergh to fly nonstop from New York to Paris. We describe the Progressive Insurance Automotive X Prize in great detail below.[60] It is typical of the prizes sponsored by the X Prize Foundation: the $5 million Ansari X Prize to the first team successfully to launch a reusable manned spacecraft twice in two weeks; and the Google Lunar X Prize, which offers $30 million for the first privately funded team to send a robot to the moon. In a similar vein is the Netflix Prize, which awarded $1 million for the first team to improve the accuracy of Netflix's matching algorithm by 10 percent.

These prizes may make different design choices –about, for example, the degree of technical specification to be made ex ante, the mix of financial and non-financial incentives that constitute the prize, and the requirements for qualification to compete and then to move on from one stage to the next.[61] But the basic structure described above is the most common across the range of contemporary inducement prizes.

The COMPETES Act and its predecessor legislation expressly contemplates prizes of this structure. NASA, for example, was granted the authority to conduct prize competitions in 2005.[62] Pursuant to this authority, the agency conducted, for example, a challenge to build a

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TopCoder that involve significantly less uncertainty and more limited goals. *See, e.g.*, Kevin J. Boudreau, Nicola Lacetera & Karim R. Lakhani, *Incentives and Problem Uncertainty in Innovation Contests: An Empirical Analysis*, 57 MGMT. SCI. 843 (2011).

[59] *See* Longitude Act 1714, 12 Ann., c. 15, § 3, *reprinted in* Siegel, *supra* note 2, at 65.

[60] *See infra* Part II.

[61] *See* Murray, *supra* note 1, at 1781-82, 1784-89; *see also* MCKINSEY & CO., *supra* note 3, at 51-60 (categorizing design elements of prizes, including determining participants, defining participant rights, creating the rules – criteria for winning, staging and timing, and participant interaction – and setting the award(s), including non-monetary incentives and the number and size of monetary prizes).

[62] This authority is currently codified at 42 U.S.C. § 20144.

forecasting algorithm to determine appropriate levels of radiation exposure for astronauts in space, a problem that the agency had long been struggling with.[63] Under the COMPETES Act, the Department of Health and Human Services has launched a $5 million initiative to sponsor up to 15 prize competitions each year in the area of health care information technology. One such competition asked software developers to "create apps to promote healthy behaviors for cancer prevention, aid early detection and screening, inform decision-making, or increase patient adherence to treatment plans."[64]

These prizes differ significantly from those treated in the economic literature described above. For one thing, they are not necessarily a substitute for intellectual property.[65] Indeed, the COMPETES Act prohibits the government from "gain[ing] an interest in intellectual property developed by a participant in a competition without the written consent of the participant."[66] In the view of most prize proponents, the prize is a *supplement* to existing incentives like intellectual property. As the National Research Council wrote in a study that was influential in shaping the COMPETES Act:

> the monetary value of the prize may be of relatively limited consequence; the much greater reward would come from profits earned in the marketplace and from publicity associated with the contest and with winning teams. To enjoy such rewards, these firms need to own or control the commercialization of any intellectual property.[67]

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[63] *See 2011 National Innovation Strategy*, *supra* note 56, at 12 box.2.
[64] *See OSTP Progress Report*, *supra* note 56, at 14-16; *see also id.* at 23-53 (detailing fiscal year 2011 prize activity).
[65] *See* Williams, *supra* note 40, at 765; MCKINSEY & CO., *supra* note 3, at 53-54 (describing range of approaches to allocating intellectual property rights).
[66] 42 U.S.C. § 3719(j)(1).
[67] *See* NATIONAL RESEARCH COUNCIL, INNOVATION INDUCEMENT PRIZES AT THE NATIONAL SCIENCE FOUNDATION 25-26 (2007); *see also id.* at 33-34 (recommending against government control over IP from prize competitions, except where the winner makes no good faith effort to commercialize or license the winning invention) [hereinafter *NRC Report*].

This position underscores the second significant difference between prizes in theory and in practice. Prizes in practice are not meant to provide a socially optimal allocation of inventive resources.[68] Instead, they seek to maximize prize-related activity. Prize sponsors in both the public and the private sector offer prizes to achieve a far broader range of goals than academic prize theorists accommodate. The White House, for example, articulates the following goals for prizes:

> establish an important goal without having to choose the approach or the team that is most likely to succeed; pay only for results; highlight excellent in a particular domain of human endeavor to motivate, inspire, and guide others; increase the number and diversity of the individuals, organization, and teams that are addressing a particular problem or challenge of national or international significance; improve the skills of the participants in the competition; stimulate private sector investment that is many times greater than the cash value of the prize; further a federal agency's mission by attracting more interest and attention to a defined program, activity, or issue of concern; and capture the public imagination and change the public's perception of what is possible.[69]

Private sector prize sponsors similarly place a significant focus not only on technological development but also on education and publicity.[70]

Like the economic literature critiqued above, this broad popular conception of the utility of prizes, under-specificies the conditions in which prizes might be preferred to other innovation incentive mechanisms. Public and private prize sponsors appear mostly to follow "[a] rule of thumb . . . that prizes are useful tools for solving problems for which the objective is clear, but the way to achieve it is not."[71] More specifically, prizes appear to have captured the most

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[68] *See* Murray et al., *supra* note 1, at 1783.
[69] Office of Management & Budget, Guidance on the Use of Challenges and Prizes to Promote Open Government 2 (Mar. 8, 2010), *available at* http://www.whitehouse.gov/sites/default/files/omb/assets/memoranda_2010/m10-11.pdf.
[70] *See* Murray et al., *supra* note 1, at 1784 (describing objectives of Progressive Insurance Automotive X Prize).
[71] MCKINSEY & CO., *supra* note 3, at 36; *see* Kalil, *supra* note 52, at 6; *OSTP Progress Report*, *supra* note 67, at 7. An interested exception is: Daniel Hemel & Lisa Larrimore Ouellette,

attention in fields where patents or procurement appear particularly ineffective – pharmaceuticals for rare diseases or diseases endemic to the developing world,[72] for example, or climate change.[73] These fields are often subject to extensive market failure. The social gains from innovations far exceeds the private gains to the innovators. Indeed, sometimes there is no effective market in which patent rents might be used to recoup investment costs. On the other hand, procurement often does not work because the problem is, by necessity, too under-specified to be the subject of determinate contracting. While these observations do give rise to the useful "rule of thumb" described above, they do not account for the large number of factors that the economic literature identifies as relevant to the determination whether prizes are an optimal incentive mechanism.

C. The importance of governance

The previous two sections demonstrate the divergence between prize theory and practice. Most theoretical prizes are substitutes for intellectual property, and the economics literature asks when their use would be more socially optimal than patents or procurement. But in reality, prizes are used with great frequency as complements or supplements to patents and procurement. The existing literature sheds little light on the operation of prize competitions as they are actually implemented.

Beyond the Patents-Prizes Debate, 92 TEX. L. REV. 303 (2013). *See infra* notes __ - __ and accompanying text.

[72] *See* Kremer, *supra* note 3; Michael Kremer, *Pharmaceuticals and the Developing World*, 16 J. ECON. PERSP. 67 (2002); Marlynn Wei, *Should Prizes Replace Patents? A Critique of the Medical Innovation Prize Act of 2005*, 13 B.U. J. SCI. & TECH. 25 (2007); James Love & Tim Hubbard, *The Big Idea: Prizes to Stimulate R&D for New Medicines*, 82 CHI.-KENT L. REV. 1519 (2007); [others].

[73] *See* Jonathan Adler, *Eyes on a Climate Prize: Rewarding Energy Innovation to Achieve Climate Stabilization*, 35 HARV. ENVTL. L. REV. 1 (2011).

Understanding governance – how prizes operate on the ground – is therefore of great importance if prizes are to become a durable part of the innovation incentive toolkit. If prizes are going to be effective policy tools, they must operate effectively. More particularly, a prize sponsor may find it difficult to make credible commitments to awarding the prize. In order for a prize to serve as an incentive to take certain actions – to invest in technological development – the participants must be reasonably well assured that if they satisfy the prize conditions, the prize will be awarded. After all, it is the ex ante promise of a reward at the end that induces creative effort. The economic literature described above often acknowledges this problem.[74] But it offers no analysis of the nature of the commitment problem under conditions of high uncertainty in the technological domain or of how it may be solved. As Part II explains, this problem is complex and multifaceted. Prizes must work within an overarching governance structure to solve challenges arising from the legitimacy and definition of the initial rules, the need to apply them flexibly, and the need to achieve consensus and resolve disputes. A more refined understanding of how prize competitions manage technological development amidst significant uncertainty and asymmetric information should also serve as an input into policy decisions about which innovation promotion tools to use in which circumstances.

Solutions to both the problem of credible commitment and the puzzle of when prizes are an effective innovation incentive turn on governance. Indeed, the former is almost entirely a governance problem. Credible commitment depends on the participants' faith that the rules and

[74] *See, e.g.*, Kremer, *supra* note 12, at 1137 ("Allowing government officials wide discretion to set payments to inventors ex post may lead to rent seeking and to exproporiation of investros after their research costs are sunk."); 1143 (explaining that prize sponsors "might be tempted to expropriate inventors" "even for prizes ostensibly specified ex ante, if the rules governing prize awards are not clear."); Menell & Scotchmer, *supra* note 24, at 1531 ("Prizes avoid deadweight loss, but prize authorities have two challenges that patents automatically avoid: the problem of choosing the value, and the problem of making it credible that they will, in fact, award the prize."); SCOTCHMER, *supra* note 1, at 32-33 n.2 (citing Longitude Prize).

procedures of an innovation prize will result in the prize being awarded to the deserving innovator. The story of John Harrison's long struggle to claim the Longitude Prize is effectively a story about the failure of the governing legislation and the agency it created to articulate and adhere to a set of rules that provided both flexibility in the face of unexpected technological developments and stability in the management of the competition.[75] Governance can also shed light on the question when prizes will be effective incentive mechanisms. That is because, as we discuss in Part III, different institutional responses to uncertainty and asymmetric information may be better suited to different innovation environments. In other words, understanding how prize competitions can effectively manage those challenges could lead to better understanding of which technological problems are better suited to the prize mechanism.

The existing literature, however, largely ignores governance issues. The theoretical literature often notes that prizes' efficacy depends in part on their administrative costs,[76] but to date there does not appear to be a considered treatment of those costs. Others note that a prize system would likely be subject to rent-seeking behavior, but do not suggest mechanisms to counteract those institutional pathologies.[77] To be sure, Michael Kremer makes several suggestions about balancing credible commitment with flexibility in the context of global health initiatives.[78] And the reports that led to the COMPETES Act grapple with some of the potential governance issues that innovation prizes may face, and emphasize the need to avoid subjectivity in judging and staging criteria.[79] But governance remains understudied, particularly as an

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[75] *See* Siegel, *supra* note 2 (describing Longitude Prize as a problem of administrative law).
[76] *See, e.g.*, Abramowicz, *supra* note 12, at 206-07;
[77] *See, e.g.*, Lee Davis & Jerome Davis, *How Effective Are Prizes as Incentives to Innovation? Evidence from Three 20th Century Contests*, Paper for the Druid Summer Conference on Industrial Dynamics (2004).
[78] *See* Kremer, *supra* note 72, at 84-85.
[79] *See NRC Report*, *supra* note 67, at 5.

empirical matter. Some recent empirical work provides evidence that prizes can be effective in inducing innovation.[80] But understanding governance requires primarily case study analysis. It is that analysis to which we now turn.

II. A CASE STUDY OF INNOVATION PRIZE GOVERNANCE

As Part I describes, prize organizers face a credible commitment problem. They may offer a prize, but so long as the prize is awarded after inventive effort takes place, there is always a risk to participants that the prize organizer will renege or that participants' efforts will not be rewarded properly. Indeed, this is the central theme of modern retellings of the story of the Longitude Prize: that the Board of Longitude could not be trusted to award the prize to John Harrison even after it became clear that his chronometer was superior to the astronomical calculation methods that conventional wisdom held would succeed.[81] Solving this credibility problem is the central governance challenge of modern innovation prizes as well.

In this Part, we describe a case study of the Progressive Insurance Automotive X Prize (PIAXP), a $10 million prize offered by the X Prize Foundation for the development of a car that could achieve a fuel efficiency rating of 100 miles per gallon.[82] This case study suggests that the

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[80] *See* Luciano Kay, *The Effect of Inducement Prizes on Innovation: Evidence from the Ansari X Prize and the Northrup Grumman Lunar Lander Challenge*, 41 R&D MGMT. 360 (2011) (utilizing qualitative data to assess prize effectiveness); Liam Brunt, Josh Lerner & Tom Nicholas, *Inducement Prizes and Innovation*, 60 J. INDUS. ECON. 657 (2012) (using quantitative data from Royal Agricultural Society of England annual competitions to evaluate effects of prizes on market entry and patenting).

[81] *See* SOBEL, *supra* note __; Siegel, *supra* note __.

[82] A note on methodology is appropriate here. Our empirical analysis is based on interviews conducted with the permission of the X Prize Foundation from November 2009 through January 2011, which included the period of active competition and its aftermath. The interviews were semi-structured, focuses on a variety of issues. We interviewed participants and organizers for one to two hours each, recorded the interviews with permission, and transcribed them. We then coded the interviews for different aspects of prize governance. In addition, we collected documentary evidence from the prize organizers including various iterations of the relevant contracts, guidelines, and rules. This research was undertaken as part of a broader project that

credible commitment problem is largely one of governance. Prize organizers must credibly formulate, change, and implement rules in an environment of extreme technological uncertainty and asymmetric information. We describe these challenges in detail below.

A. Overview of the PIAXP

The X Prize Foundation is a non-profit organization that sponsors "grand innovation prizes,"[83] with the goal of "bring[ing] about radical breakthroughs for the benefit of humanity, thereby inspiring the formation of new industries and the revitalization of markets."[84] The X Prize Foundation launched the Automotive X Prize in 2006, and Progressive Insurance signed on as the sponsor of the $10 million prize in 2008. The basic goal of the prize was articulated simply: "A ten million dollar cash purse will be awarded to the teams that win a long-distance stage race for clean, production-capable vehicles that exceed 100 miles-per-gallon energy equivalent."[85] By "production-cable," the organizers meant that the cars had to be "designed to reach the market,"[86] rather than "concept cars."[87] They had to satisfy a wide range of criteria, including safety and emissions requirements,[88] manufacturability (i.e. teams had to demonstrate

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seeks to examine the nature of the prize organization, the incentives provided by the prize and experienced by the participants, and the governance of the prize throughout its implementation. *See* Murray et al., *supra* note __.

[83] Murray, *supra* note __, at 1779 (defining "grand innovation prize" as "large monetary prizes awarded to the innovator(s) providing the best or first solution to a pre-determined set of significant new performance goals with no path to success known ex ante and believed to require significant commitment and a breakthrough solution").

[84] *See* X Prize, http://www.xprize.org (last accessed Mar. 1, 2014).

[85] X Prize Foundation, Progressive Insurance Automotive X Prize Competition Guidelines Version 1.3, at 7 (Dec. 21, 2009) [hereinafter "PIAXP Guidelines v.1.3"].

[86] *Id.* at 8.

[87] *Id.* at 7.

[88] Participants had to demonstrate their compliance with a subset of Federal Motor Vehicle Safety Standards. *See id.* at 49-56.

that their vehicles could be manufactured in quantities of 10,000 per year), features that were desirable to current automobile consumers, and a credible business plan.[89]

Consistent with the X Prize Foundation's broader mission, the PIAXP had goals beyond the development of new automotive technologies. The US Department of Energy contributed $3.5 million to fund an education program for primary and secondary school students that coincided with the various stages of the competition.[90] The prize organizers also sought publicity for the prize with the intention of using it as a way to start a broader national conversation about energy efficiency and to create an industry for fuel efficient vehicles.[91] As to the competitors themselves, the prize organizers expressly recognized that they would be motivated by more than the prospect of the prize – they shought to "[p]rovide many opportunities for recognition so that it's worthwhile to compete, and not just for first place," and to "[m]ake heroes out of the competitors and winner(s) through widespread exposure, media coverage, and a significant cash reward."[92]

The purse was divided between two different classes of vehicles. The "mainstream" class, the winner of which could claim half the prize purse, comprised on "typical existing small, 5-passenger economy mixed use vehicles."[93] Entrants in that class "were required to seat at least four passengers, have four wheels, and have a minimum 200 mile range."[94] Two "alternative"

[89] *See id.* at 8.
[90] *See* X Prize Foundation, Education, at http://www.progressiveautoxprize.org/education (last visited Mar. 2, 2014).
[91] *See* PIAXP Guidelines v.1.3, at 6.
[92] *Id.*
[93] *Id.* at 9.
[94] Progressive Insurance Automotive X Prize Overview & Goals, at http://www.progressiveautoxprize.org/prize-details (last visited Mar. 2, 2010).

classes, "tandem" and "side-by-side" seating, each worth $2.5 million, focused on 2-passenger, non-standard designs.[95]

To award the prize, the organizers conducted the competition in a series of stages, each stage designed to winnow the field. Registration was easy. A team provided an application with basic technical information about the vehicle, paid a $5000 entry fee, and signed the Master Team Agreement. The X Prize administrators applied a light screen to registrations, weeding out only those applicants that were "clearly unqualified."[96] By the February 2009 deadline, 111 teams registered a total of 136 vehicles for judging in the next stage.[97] The registrants were quite diverse, ranging from venture-backed startups to hobbyists to engineering students, and staffed by personnel with a range of automotive industry experience.[98]

The registered teams then a "Design Judging" stage, in which they provided detailed data submissions to demonstrate that their vehicles were production capable. Although the PIAXP provided contestants with broad outlines of the minimal design requirements,[99] panels of experts were convened with broad discretion to determine which cars would qualify for the on track events. These expert panels – judging submissions on safety and emissions, manufacturability and cost, features, and business plan – convened over the course of several days to consider submissions.[100] 43 teams representing 56 vehicles passed the design judging stage in October 2009 and were qualified for the on-track race events held from April 2010 through August 2010 at the Michigan International Speedway. In the weeks between qualification and the start of the

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[95] *See id.*
[96] PIAXP Guidelines v.1.3, *supra* note __, at 15.
[97] *See* Murray et al., *supra* note __, at 1783 tbl.2 for descriptive statistics.
[98] *See* JASON FAGONE, INGENIOUS: A TRUE STORY OF INVENTION, AUTOMOTIVE DARING, AND THE RACE TO REVIVE AMERICA 38-41 (2013).
[99] *See* X Prize Foundation, Progressive Insurance Automotive X Prize Competition Guidelines v.1.2, at 16-20, 23-25 (Jan. 10, 2009) [hereinafter "PIAXP Guidelines v.1.2"].
[100] *See id.* at 54-55.

on track events, the prize organizers provided the competitors with additional technical details and requirements and performed inspections and safety tests, while the teams continued to hone their vehicles. Not all teams made it through this process; only 33 vehicles chose to enter the on-track race events.[101]

Those events were themselves staged. The first stage was a "shakedown" event that took place from April 26-May 7, 2010. In that phase, the teams put their vehicles through a number of long-distance practice races and a rigorous safety inspection to "shake out any problems, make final adjustments, and verify competition readiness."[102] Following the "shakedown" phase, 28 vehicles entered the "knockout" stage, which was the first of the competitive races, held from June 16-30, 2010. To move on from the knockout stage to the finals race stage, vehicles had to achieve at least two thirds of the range and energy efficiency goals – that is, they had to achieve 67 MPGe and a 134 mile range – and had to pass a number of performance tests to "confirm compliance with [the] minimum specifications" for things like acceleration and braking speeds, noise, and speed maintenance on a grade.[103] 28 teams entered the knockout phase, 15 qualified for the finals, and 9 teams ultimately competed in the finals.[104]

The final races were held from July 19-30, 2010. The marquis race was a combined performance and efficiency test over a 200 mile course. The vehicles were then subjected to validation testing at Argonne National Laboratory. The winning vehicle in each class would be the vehicle that achieved the fastest race time in the final stages while still achieving 100 MPGe and meeting all other technical requirements. On September 16, 2010, the X Prize Foundation

[101] *See* Murray et al., *supra* note __, at 1783 tbl.2.
[102] PIAXP Guidelines v.13, *supra* note __, at 37.
[103] *Id.* at 37-38.
[104] *See* Murray et al., *supra* note __, at 1783 tbl.2.

announced the winners of the PIAXP.[105] The mainstream class winner was a team called Edison2, a group of automobile engineers from Charlottesville, VA.[106] The winners in the alternative classes were Li-ion Motors in the side-by-side class, and X-Tracer in the tandem class.[107]

Every innovation prize competition has unique features and circumstances. Nevertheless, we believe the PIAXP is a good model for studying innovation prizes for several reasons. First, it closely resembles the prizes contemplated by the COMPETES Act. It utilizes a similar structure, positing a well-defined problem without a clear path to a solution.[108] The participants in the PIAXP, like those in the nascent government prizes, are incentivized not only by the prize award, but by the ability to keep their intellectual property.[109] And the prize was structured with a view toward not only the development of a particular new technology, but also to publicizing the results and engaging the broader public with the problem to be solved.[110] Second, because the PIAXP is privately run and voluntary, it offers a good example of private ordering to facilitate collaborative research.[111]

B. Governance challenges in the PIAXP

Most broadly, governance of the PIAXP was determined by contract. Each participating team and the prize organizers were parties to a "Master Team Agreement." That agreement set

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[105] *See* X Prize Foundation, Three Teams Awarded Share of $10 Million Purse in Progressive Insurance Automotive X Prize for Super Fuel-Efficient Vehicles (Sept. 16, 2010), *available at* http://www.progressiveautoxprize.org/news-events/press-releases/.
[106] *See* Edison2, at http://www.progressiveautoxprize.org/teams/edison2?carId=144 (last visited Mar. 2, 2014).
[107] *See supra* note 105.
[108] *See* 15 U.S.C. § 3719(c)(1) ("A point solution prize that rewards and spurs the development of solutions for a particular, well-defined problem."); [administrative sources].
[109] See PIAXP Master Team Agreement art. IX; 15 U.S.C. § 3719(j)(1).
[110] *See supra* notes __ - __ and accompanying text; Kalil, *supra* note __, at __.
[111] *See infra* Part III.B.

forth what might be called the "constitutional" rules of the competition; a set of rules that defined the broad obligations of the parties toward one another and that were exceedingly difficult, if not impossible, to change.[112] In particular, the Master Team Agreement governed the relationship between the prize organizers and the teams, including such topics as indemnification and insurance, sponsorship and advertising, media rights, intellectual property, and the like.[113] Importantly, the Master Team Agreement incorporated by reference a set of further guidelines and rules that were significantly easier to change, and that are subject to change at the will of the prize organizers. The agreement provided that "[t]eams agree to comply with Competition Guidelines, Technical Specifications, plus revisions and other competition-related documents."[114] Pursuant to the authority granted in the Agreement, the PIAXP organizers promulgated a series of documents throughout the course of the prize that elaborated upon the rules and requirements. The "Competition Guidelines" laid out most of the rules of the competition – the various stages and the requirements for teams to move from one stage to the next. These Guidelines reminded participants that they "are binding as references in the overall Master Team Agreement."[115] In addition to the Competition Guidelines, the organizers articulated more precise rules and technical requirements in a periodic series of bulletins that issued to participants and in a series of in-person briefings at the start of the on-track race events.[116] Given this structure, the organizers relied heavily on concepts of good faith borrowed

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[112] In public settings, the equivalent framework might be set forth in, say, legislation. The COMPETES Act or the Longitude Act, for example, similarly set the broad framework within which the prize sponsors and the participants in the competition relate to one another.
[113] *See* PIAXP Master Team Agreement.
[114] *Id.* art. V.
[115] PIAXP Guidelines v.1.3, *supra* note __, at 5.
[116] *See* X Prize Foundation, Technical Information, at http://www.progressiveautoxprize.org/prize-details/technical-information (last visited Mar. 2, 2014).

from commercial law. The Guidelines expressly stated, for example, that "[t]he [PIAXP] organizers and sponsors are entering into this competition in good faith. We expect and require the same attitude from all competitors and participants, so that together we can provide the most favorable experience for all."[117]

Several features therefore emerge at the outset: the initial contracting with highly incomplete; it delegated authority to the organizers to fill in the gaps as the competition progressed; and even then it relied on the good faith of the participants to help overcome necessary incompleteness. This highly contingent structure led to three central governance challenges, which we consider in turn: making the rules, changing the rules, and implementing the rules. These challenges arose from the interaction of the basic structure described above and the technological characteristics of the project.

1. Making the rules

The first challenge was establishing a process for the development of the rules of the competition. As others have noted, the rules for prize competitions are a complex balancing act.[118] They must set goals that are technologically ambitious but not impossible. They must be clear enough to implement without too much subjectivity and litigation but flexible enough to accommodate the demands of fast-developing technology. Sometimes, it involves a surprising amount of guesswork. One journalistic account of the PIAXP describes the process of settling on the 100 MPGe goal – the fundamental goal of the competition: "Instead of a target of 250 or 500 MPGe," which the team had originally considered, "the new team settled on 100 MPGe—

[117] PIAXP Guidelines v.1.3, *supra* note __, at 7.
[118] *See* Kalil, *supra* note __, at

hard, but doable. 'Five hundred would have been impossible,' Shore recalls. 'And one hundred is a lovely nice round number.'"[119]

Moving beyond this guesswork, the PIAXP put into place several mechanisms to develop the rules that would eventually come to govern the prize. First, they sought input from a wide variety of sources:

> We went to a range of advisors….and had to sort out what was bias and what were actual facts when it came to establishing core metrics of competitions …..wanted to make sure our matrix was objective not subjective…you want the public to agree with you…We knew they had to be clear and easily explained to the consumers and the public. (CL, p.2)

To this end, the PIAXP appointed a "Prize Development Advisory Board" made up of representatives from government, the automotive industry, environmental groups, academia, and finance.[120] When this board completed a draft of the guidelines for the prize, the organizers released these guidelines for public comment:

> The first time we showed the public in detail what we were aiming for was when we published draft guidelines….we got a 1000 comments or so. (JS p.2)[121]

They sought opinions not only on the technical specifications that would be most appropriate, but also on the prize's media and public relations attractiveness. For example,

> One of the versions was a sales race…it's a proxy for is there a market……but we abandoned it….one reason the media advisors said it was boring (JS p.2).

[119] FAGONE, *supra* note __, at 37.
[120] *See* X Prize Foundation, Prize Development Advisory Board, at http://static.progressiveautoxprize.org/about/advisors (last visited Mar. 2, 2014).
[121] *See also* PIAXP Guidelines v.1.3, at 47 ("We solicited input and feedback directly, and we also published Draft Guidelines for public comment. We received well over 1000 comments from the general public, and a number of substantial changes included in these Guidelines are the result of the public's input.").

This was particularly important to the prize organizers because, as described above, publicity was a key part of building awareness of the need for efficient vehicles and a further non-monetary inducement for participation.

Second, the organizers engaged in an iterative process of rule development:

> Developing the criteria was one of the early things that we did….we realized we needed to take a step back and have some meta-criteria….then we went through an iterative process of developing draft guildelines…we went through five different versions before we honed in on the one that became the automotive X prize. (JS p.2)

This iteration took place within a smaller group of experts on the Prize Development Advisory Board and then again after receiving public comments.

Finally, the prize organizers sought to build consensus among various stakeholders:

> We held a series of working groups….auto industry reps, regulatory agencies and more….helping us to compare fairly those various fuel sources. (CL, p3)

These working groups were organized by topic area: Energy and emissions, race structure and course design, and production capability. Each was staffed with representatives from government, academia, and the private sector, and each was charged with achieving consensus before moving forward.[122]

Taken together, these methods appear to have been successful in lending credibility to the guidelines and securing buy in from most of the parties. Nevertheless, the development process was not free of problems. The prize organizers acknowledged that members of the development team included potential competitors:

> We recognize that some of those advising on AXP Guidelines may end up competing, but that is an unavoidable result of engaging with so many experts who have real-world knowledge of the automotive industry. We believe that the Guidelines published here are balanced and credible, and that this would not have been possible without seeking as much feedback as possible from diverse parties,

[122] *See* PIAXP Draft Competition Guidelines v.6.0, at 33-35 (Apr. 2, 2007).

> without regard for future possible conflicts. Had we only sought input from those unlikely to have a future interest in the AXP, the result would have been poor Guidelines. Our process has been open and we do not hide our involvement with any party.[123]

At least one team angrily withdrew from the competition, in part because "in our opinion, a problematic conflict of interest occurred when X Prize allowed one of the accepted letter of intent contenders to be part of the rule setting and ultimate team evaluation processes."[124]

2. Changing the rules

One problem with establishing rules for a prize competition is that they may be overtaken by events. That is, the original rules may prove to be technologically infeasible or inappropriate given the development of the technology. The PIAXP organizers expressly acknowledged this possibility, providing in the Guidelines that: "There may also be unanticipated issues that arise and require modifications to these Guidelines; thus, we reserve the right to revise as appropriate. In all cases, we will endeavor to remain true to the spirit of these Guidelines."[125] The PIAXP organizers emphasized the importance of flexibility. Commenting, for example, of a change in the format of the race events from street to closed track, one organizer said:

> It has been a very natural evolution given the external circumstances – ranging from economc crisis and what is facing cities. Most teams understand the change of format (CL p. 5).

Similarly, another organizer emphasized the importance of being able to define milestones as the competition progressed:

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[123] *Id.* at 25.

[124] Sebastian Blanco, "HP2G Acrimoniously Drops Out of Auto X Prize," AUTOBLOGGREEN, June 5, 2009, *at* http://green.autoblog.com/2009/06/05/hp2g-acrimoniously-drops-out-of-auto-x-prize/ (last visited Mar. 2, 2014). The PIAXP organizers disputed this team's characterization of the process, noting that competitors could be involved in rule development but not in any actual evaluation of one another. *See id.*

[125] PIAXP Guidelines v.1.3, *supra* note __, at 5.

> A lot of milestones were NOT defined at the beginning but certain things had been decided e.g. basic structure. (JZ p.4)

Changes were made both to the overall structure of the competition and to the detailed technical requirements. In late 2009, for example, entrants in the alternative class complained that the vehicle being entered were too diverse to be compared using the same technical specifications. Following consultation with experts and teams, the PIAXP organizers decided to split the alternative class into two separate classes: one for cars with side-by-side seating, and one for cars with tandem seating. The $5 million purse was similarly split in half; the winner in each class would take home $2.5 million. Other changes were more technical in nature. For example, between the first and second iterations of the Guidelines, the prize organizers eliminated the top speed requirement, replacing it with a more flexible "highway-capable" requirement, reduced acceleration specifications, and reduced the amount of space that had to be allocated to the back seat in the mainstream class.[126] The organizers tried to keep the changes reasonable:

Most teams look at it as reasonable changes [the change from a cross country race] and in many cases they have benefited our teams……[less] expensive for teams in terms of time required of them (CL p.6)

But they nevertheless received mixed reviews from participants. Some were understanding of the need:

> I think as those rules get solidified and more things are written down than verbally I think it will be run a little better. I think they're doing a good job. I think they are feeling their way trying not to knock anybody out because of a rule that was written a year ago when it turns out maybe nobody can pass that. So things are in a state of flux. (AMP3 p.19)

[126] *See* PIAXP Guidelines v.1.2, *supra* note __, at 5.

But a more commonly voiced sentiment was frustration with what seemed to be a moving target. One participant complained that "the rules for the events have been changing all the time." Similarly, another explained that:

> [We are] competing for real money in real events. But you don't know what they are until you get there… There has to be a goal. And the goal here is really fuzzy. You have to go on trust and be willing to gamble because you just don't know. The truth is, you don't. The rules have changed many times.

Participant complaints seemed most directed at the lack of an established process for making these changes. As one team described:

> We'll quite often get a rule change or a schedule change or something a week before we are leaving. I think…….we got a 60 page document that was what our technical spec was going to be and there were lots of differences between that and the original rules, so that last week before we had to leave was like triage…..like these large changes to the car….you feel like 'oh by the way…" (FVT5 p.23)

This lack of process also created problems with respect to the teams' reliance interests in the stability of the rules. Because engineering automobiles is a difficult process, teams that come to rely upon the old rules may find themselves facing significant hardship in re-engineering their cars to meet the new rules. The costs of changes at a late stage once many design and technical choices became irreversible were high. One team explained:

> I was around to comment on the rules before they were final….[I'm] jaded because [changes] were stuff that affected me directly but I know why they made the decision. The problem is some of the decisions they didn't make soon enough so once it was welded in steel in our car we couldn't change it….. I had to bite my tongue…there have been critical [rules] that have changed or they have allowed leniency on but it hurt us, too. (ILL p.73)

3. Implementing the rules

Finally, the implementation of the stated rules during the course of the competition proved to be somewhat contentious. There were two potential sources of trouble. One is that broadly written, flexible rules give judges discretion in implementation. Given the conflict of

interest issues that the PIAXP encountered during the period of rule development,[127] the organizers implemented a "strict no-conflict policy" once the competition was underway.[128] They disbanded the Prize Development Advisory Board, and replaced it with "a conflict-free Prize Administration Advisory Board."[129] For the design judging phase, which appears to have been the most discretionary, the prize organizer put into place a set of procedures designed to incorporate as many viewpoints and possible and to achieve consensus among the judges where possible.[130] The judging criteria stated that members of judging panels "may not have a direct conflict of interest,"[131] but it is unclear what constitutes "direct" or "indirect," leaving the possibility of bias intact.

The second problem is that even where the rules were stated with clarity and in such a way that discretion was not lodged in the judges, they were not applied uniformly across the competitors. This was partly a matter of design. As one of the organizers explained,

> The earlier rounds were also more lenient towards teams. Rather than eliminating teams for not hitting milestones, they provided detailed feedback, technical support and time to improve between rounds (in the earlier stages). Furthermore, workshops and webinars were offered upfront to provide additional support to teams that were not well versed in running a business.

But this generated complaints that the rules were not applied fairly: "Enforcement of those rules, not fair." (FVT5, p.27). Another team explained:

> Flexibility in the rules has its advantages, especially during the earlier rounds to allow less experienced teams to catch up, however it resulted in the rules being unclear and potentially bias" and "actually, I think there's been quite a bit slipping in the rules for some things. I don't know why. But it seems to me that their rules aren't that strict. You can go under the fence somewhere.

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[127] *See supra* notes __ - __ and accompanying text.
[128] PIAXP Guidelines v.1.3, *supra* note __, at 47.
[129] *Id.*
[130] *See id.* at 57-59.
[131] *Id.* at 58.

These charges of unfairness or bias were compounded by a lack of transparency. One team believed that there were secret agreements in place between certain competitors and the organizers:

> There was a super secret probation which some of the other teams were on….but we were not…..but it was another week off work and X couldn't make it. (ILL p. 57)

Here again, there seems to be a balancing. One the one hand, the organizers, in the of the overall goals of the prize competition, could reasonably choose to be inclusive and help teams to achieve the goal. On the other hand, to the extent that such help was doled out unfairly or without any process, it called into question the legitimacy of the prize. These difficulties highlight the importance of a mechanism by which teams can surface issues in the implementation of the rules and bring them to a fair resolution.

PART III – PRIZES AS INSTITUTIONS

The previous part described the myriad governance challenges that innovation prize competitions may face. Making the rules of the competition, changing those rules as the competition progresses, and implementing the rules fairly all are aspects of a central problem facing prize organizers: how to credibly commit to awarding the innovation prize. Prizes are an effective method of organizing intellectual production only if innovators are sufficiently confident that they may claim the prize if they are successful. Otherwise, they will not participate. In this Part, we explain first that the problem of credible commitment arises because of two underlying characteristics of innovative environments: uncertainty and information asymmetry. We then cast prizes as institutional responses to those two potential obstacles to innovative activity. Prize competitions like the PIAXP and those being designed and implemented under the American COMPETES Act are efforts to organize collective innovative

behavior. As such, the optimal design of and choice among such mechanisms depends not only on the economic incentive they may provide to innovators, but also on the manner in which they organize activity to overcome uncertainty and information asymmetry. This change in perspective has implications both for the design of innovation prize competitions and for the analysis of their effectiveness as policy tools.

A. Uncertainty and information asymmetry in innovation prizes

The challenges described in Part II are attributable to two characteristics of innovation that plague efforts to organize collective action: uncertainty and information asymmetry.

1. Uncertainty

Innovation is an inherently uncertain activity.[132] Most basically, an innovator experiences uncertainty when she cannot determine ahead of time whether – or how – her innovative activities will succeed in solving a particular problem. "Producers have to make a decision on inputs at the present moment, but the outputs are not completely predictable from the inputs."[133] She also may be uncertain about the economic value of her innovation, even if it is successful. From the perspective of a social planner, the uncertainties associated with innovation proliferate. That is because the course of technological development is nearly impossible to predict ex ante. As Richard Nelson writes, "[i]t is very easy to make choices which, ex post, turn out to be the wrong ones."[134] At the outset of a project, it is easy enough to state a goal: curing

[132] Following Knight, we distinguish here between uncertainty and risk. The latter is quantifiable, while the former is not. *See* FRANK. H. KNIGHT, RISK, UNCERTAINTY AND PROFIT 192-237 (1921); *cf.* Ronald J. Gilson, Charles F. Sabel & Robert E. Scott, *Contracting for Innovation: Vertical Distintegration and Interfirm Collaboration*, 109 COLUM. L. REV. 431, 433 n.2 (2009) (drawing similar distinction in the context of supply chain contracting).
[133] Arrow, *supra* note __, at 610.
[134] Richard R. Nelson, *Uncertainty, Learning, and the Economics of Parallel Research and Development Efforts*, 43 REV. ECON. & STAT. 351, 352 (1961). Nelson advocates for parallel research efforts to overcome the uncertainty of technological development. *See id.* at

cancer, say, or landing a man on the moon. But from an ex ante perspective, the technology that will accomplish that goal is uncertain. So too is the time it will take and, of course, the cost.[135] No one hearing President Kennedy's 1961 speech setting a national goal of landing a man on the moon could have predicted the mix of technologies that would ultimately achieve that goal – the Saturn V rocket, the Apollo spacecraft, and so forth.[136] Instead, those technologies emerged from a process of development; the ultimate outcome was entirely path dependent.

Of course, during the process of technological development, it is possible for some uncertainties to be resolved. Information gleaned through experimentation can help to refine estimates about the right technological approach, its characteristics, and its costs.[137] But the process itself involves what Gilson et al. call "continuous uncertainty."[138] Technological development is ongoing and dynamic. The resolution of one particular aspect of uncertainty often raises others. Imagine, for example, a binary choice between two technologies to accomplish a single problem at the outset of development. Choosing one or the other likely results in two different subsequent technological choices. That second order decision then yields a third set of choices. And so on. As Gilson et al. explain, "operational decisions must be continually updated and refined" in light of decisions made during development.[139]

One can see this process of innovation under continuous uncertainty in the PIAXP. The prize sponsors had a clear enough technological goal: the production of a car capable of

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[135] *See id.* at 353 ("[A]t the start of a development program, estimates of the cost, time, and performance of

[136] Indeed, Kennedy himself acknowledged this uncertainty in his speech. *See* John F. Kennedy, *Address Before a Joint Session of Congress*, May 25, 1961 ("We propose to develop alternate liquid and solid fuel boosters, much larger than any now being developed, *until certain which is superior*.") (emphasis added)

[137] *See* Nelson, *supra* note 134, at 252 ("[E]stimates of cost, performance, and development time tend to improve as development proceeds and information accumulates.").

[138] *See* Gilson et al., *supra* note 132, at 448.

[139] *Id.* at 449.

achieving 100 mpg fuel efficiency. But the technological path to that goal was highly uncertain at the outset. It was impossible to predict the technological characteristics that would achieve the goal. As the competition went on, information about which technologies were likely to be more successful than others emerged. But in the meantime, decisions had to be made about the rules of the competition amidst this uncertainty. Hence the need to change the rules in midstream. As described above, in one case the prize organizers initially set a staging goal – a criterion that had to be met for a team to move from one stage of the competition to the next – too high. [140] Although the goal may have seemed reasonable ex ante, it turned out to be technologically too difficult for any team to meet. The rules set under conditions of uncertainty therefore needed to be revisited when at least one aspect of that uncertainty – whether a technological threshold was reasonable – was resolved. Similarly, the PIAXP changed its structure when two different technological paths toward the 100 mpg car proved to be non-comparable.[141] Although the competition organizers initially envisioned a singular "alternative class" for unusual vehicle designs, the divergence of the designs from one another – which could not have been predicted ex ante – necessitated splitting the class in two.

The need to change the rules can be seen as a direct consequence of the continuous uncertainty of the technological innovation. Uncertainty makes it impossible to specify ex ante the precise rules of the game. A prize sponsor can make an educated guess based on presently available information. (To the extent that information can even be gleaned in the first place; see below.) But that guess may turn out to be wrong in any number of ways, some or none of which may be predictable. When new facts make the old rules obsolete, a change is necessary. The

[140] *See supra* notes __ - __ and accompanying text.
[141] *See supra* notes __ - __ and accompanying text.

fact that the PIAXP had to change the rules and, indeed, had to do so throughout the competition, should be unsurprising in light of the uncertainty of the technology.[142]

2. Information asymmetry

Organizing innovation also requires aggregating technological information that might be highly dispersed among different parties. Economists since Demsetz have pointed out the difficulty involved in doing this.[143] Demsetz argued that it was difficult for any single actor – such as the government -- to "produce information on the desired directions of investment and on the quantities of resources that should be committed to invention."[144] Indeed, the economic case for prizes over patents depends upon individual researchers and the government having *identical* information.[145] When that is the case, prizes dominate patents because they offer lower deadweight loss.[146] But when information asymmetry is introduced and the terms of the prize must be fixed before the asymmetry is resolved, the result is less clear.[147] Demsetz and his successors have argued that because the government cannot adequately amass enough

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[142] In a similar vein, most accounts of the British longitude prize suggest that the difficulty Harrison had in claiming the prize was due in no small part to the fact that the rules of the competition were not adapted to the unexpected success of his chronometer. Instead, the prize sponsors believed that an astronomical solution would be most likely and built the competition around that ultimately erroneous presumption. *See* SOBEL, *supra* note __, at __; Siegel, *supra* note __, at __.

[143] *See* Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J.L. & ECON. 1, 11-12 (1969).

[144] *Id.* at 12.

[145] *See* Wright, *supra* note __, at 691; Shavell & Van Ypersele, *supra* note __, at __; Williams, *supra* note __, at 756 ("If the government knew how much it would cost to develop technologies, and what the value of the technologies were, then it would be relatively easy to design an appropriate compensation scheme for inventors; however, in practice there is asymmetric information about both the costs and values of new technologies, and different individuals may substantially disagree about one or both.").

[146] *See* Wright, *supra* note __, at 692-95.

[147] Notably, it is not certain that patents dominate prizes under conditions of information asymmetry. *See id.* at __. Much of the economic literature on prizes attempts to solve the asymmetry through a variety of mechanisms. *See supra* notes __ - __ and accompanying text.

information to determine the costs and benefits of any particular research program, it is better to let the market determine the social value of R&D through a patent system.[148]

More precisely, Gallini and Scotchmer model the difficulty a central authority might have in aggregating highly dispersed technological information.[149] Their central insight is that different inventors pursuing a similar goal may have different cost or value signals that are unobservable to others engaged in the activity. This makes the firms' individual investment choices inefficient, and also makes it difficult for a central authority to determine the appropriate rate and direction of investment.[150]

That said, the fact that aggregating information may be difficult and imperfect does not suggest that *some* aggregation of information is impossible in all circumstances. Even Demsetz acknowledged that "[t]here are ways, of course," for a system to produce information about the optimal allocation of inventive resources, citing, for example, "[s]urveys of scientists and managers" that could be taken and weighed in some manner.[151] The PIAXP provides an illustration of one of these mechanisms. As described above, the PIAXP organizers used a process akin to administrative notice-and-comment rulemaking to gather information sufficient to set the overall goal of the prize and the initial set of rules.[152] Developing the rules of the competition required integrating technical knowledge that was highly dispersed among a large number of actors. The PIAXP appears to have orchestrated a method to do that. It is of course true that information asymmetries will pervade collective efforts at innovation. But the presence of these information asymmetries need not stifle that activity altogether.

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[148] *See* Demsetz, *supra* note 143, at 12; *see also* [others].
[149] *See* Gallini & Scotchmer, *supra* note __, at 56-58.
[150] *See id.*
[151] Demsetz, *supra* note 143, at 12.
[152] *See supra* notes __ - __ and accompanying text.

3. Uncertainty, information asymmetry, and credible commitment

Uncertainty and asymmetric information require that prize organizers take action in suboptimal conditions. That in turn may make it difficult to credibly commit to awarding the prize. Return, for example, to the process of making the rules. Developing the rules of the competition requires the integration of technical knowledge that may be highly dispersed among a large number of people. A problem arises, however, when the sources of knowledge needed to articulate the goals and rules of a prize competition may themselves be future competitors. Or consider the need for changes to the rules. Continuous uncertainty requires constant adjustment and adaptation. But any time the rules change, those who have acted in reliance upon the old rules will be upset. And because there will always be winners and losers when the rules change, charges of bias can follow easily.

This leads to the central challenge innovation prize competitions face: how to navigate uncertainty and information asymmetry while maintaining legitimacy. Credible commitment is difficult when the rulemaking process requires that those who make the rules also abide by them. Credible commitment is difficult when the rules can change, particularly in a way that can be seen to benefit one or another party. And credible commitment is difficult when ambiguous criteria are applied to highly variable technologies. In order for prizes to be effective at incentivizing innovation, they must be effective at marshaling participation. They must convince potential participants that it is worth their effort because – notwithstanding the problems of information asymmetry and continuous uncertainty – there may still be a prize awarded at the end to the most deserving party.

B. Innovation Incentives as Institutional Design Problems

The central challenge for innovation prizes, then, is to encourage participants to work towards the prize goal despite the pervasive difficulties of uncertainty and asymmetric information. The economic incentive offered by an innovation prize is meaningless if no one steps forward to attempt to claim it. Prize organizers therefore face a management challenge. And prizes represent an institutional mechanism through which participants can manage the challenges associated with technological innovation. In this section, we argue that "innovation incentives" are a problem not only of economic analysis, but also of institutional design. Indeed, *any* innovation incentive must confront the problems of uncertainty and asymmetric information. We then draw from the institutional design literature pioneered by Elinor Ostrom, and adapted to the study of information production by a number of scholars in recent years, to suggest that uncertainty and asymmetric information need not be *resolved* in order for innovation incentives to function well. Instead, they must be *managed*. That management calls for an institutional solution. We conclude this section by casting several more common innovation incentives as institutional solutions to the same set of problems. This analysis lays the groundwork for our suggestions that follow.

1. The role for institutional design

Innovation incentives are usually modeled as black boxes. As described earlier,[153] the rationale for providing incentives is that the market ordinarily will under-produce scientific and technological goods. The various innovation incentive mechanisms are meant, in one way or another, to provide the producers of those goods with enough additional surplus to make up the gap. Patents do this by allowing inventors to charge super-competitive prices for their goods for a limited period of time. Prizes (at least as they are usually modeled in theory) do this by

[153] *See supra* Part I.A.

rewarding inventors after they have invented. Grants do this by providing a direct payment to innovators to fund their efforts.

Innovation incentives work, however, only insofar as innovators are willing to take them. They are not black boxes. To the contrary, any incentive mechanism is an inherently social institution.[154] It is subject to a range of performance issues by which it might fail to achieve its objective. This is often noted in the prize literature, when critics argue that it may be difficult for the prize sponsor credibly to commit to awarding the prize.[155] To the extent that potential participants do not have faith that their successful efforts will bear fruit, they will not take the incentive. This is no less true, however, of other innovation incentives. Take, for example, the patent system. Patents are effective innovation incentives only so long as people continue to apply for and enforce them rather than turning to other methods of protecting freely appropriable goods, such as trade secrecy.[156] It may only be worthwhile to inventors to avail themselves of the patent system if they can be reasonably certain they will be issued an effective patent if they fulfill the statutory requirements. So too even for outright research grants. Applications cost time and money; they are only worth undertaking if there is a reasonable likelihood that the grants will be awarded fairly.

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[154] *See* SCOTCHMER, *supra* note __, at

[155] *See, e.g.*, Menell & Scotchmer, *supra* note __, at 1532 ("Prizes can only work if the prize giver can commit not to renege . . .."); Roin, *supra* note __, at 29; Abramowicz, *supra* note __, at

[156] One increasingly common critique of the patent system is that its dysfunctions are becoming serious enough that from the perspective of an individual inventor, it may not be worthwhile to apply for or enforce patents. [citations]. As discussed below, these dysfunctions are closely related to the institutional structure of the system. *See infra* notes __ - __ and accompanying text.

The previous section explained that uncertainty and information asymmetries lie at the roots of prizes' credible commitment problem. But uncertainty and information asymmetries are pervasive features of innovation. They are not confined merely to prizes.

Consider uncertainty. Continuous uncertainty poses a barrier to innovation quite apart from the potential lack of financial incentives. Indeed, the uncertainty of the technological innovation is itself a disincentive. Would-be innovators have no assurance of success. And because the contingencies in technological innovation are so great, it is difficult ex ante for an innovator to quantify the risk she faces.[157] It is well understood that technological innovation requires the investment of significant resources, but the return on those resources, if any, is highly uncertain. We do not mean to overstate the case. Individuals have different risk profiles, and technological innovation tends to be carried out by those who are risk-loving rather than those who are risk-averse. For individuals who fall into the former category, uncertainty is not an absolute barrier. But on the margin, it is reasonable to conclude that the overall output of innovation may lower under conditions of extreme uncertainty than it would be otherwise. Asymmetric information poses a different kind of barrier to innovation. It prevents collective action to solve technological problems. Any single innovator may not have all of the resources at her disposal to solve a particular technological problem. But unless innovators can effectively share and aggregate information, it may be, at the least, inefficient and, at the worst, impossible to achieve any given technological goal.

This is where institutions come in. In their pioneering work on commons-based resources, Elinor Ostrom and her collaborators explained the persistence of self-governing institutions that could manage natural resources in the absence of state-based property or

[157] *See supra* note 132 (distinguishing between risk and uncertainty).

regulatory regimes.[158] Her examples of the management of "common pool resources" range from Spanish irrigation districts, to the lobster gangs of Maine, to Japanese fisheries. These (mostly) natural resources are of the type that we would ordinarily think subject to the "tragedy of the commons."[159] They are too large to facilitate inexpensive exclusion, the resources are not subject to joint use, and improvement efforts are shared among all users.[160] Ostrom found that collective action to manage these resources sustainably could and did in fact occur. The key to facilitating such collective action was the development of institutions – "sets of working rules that are used to determine who is eligible to make decisions in some arena, what actions are allowed or constrained, what aggregation rules will be used, what procedures must be followed, what information must or must not be provided, and what payoffs will be assigned to individuals dependent on their actions."[161] The Spanish *huerta* irrigation districts could be sustained because of a detailed set of governance practices that were established and followed by the community even in the absence of formal law.[162] These practices are necessarily highly context specific. They are tailored to the particular local conditions, geographies, and demographics. Among the most lasting of Ostrom's contributions, therefore, is a framework for studying the institutional arrangements that allow for self-governance of complex collective action.

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[158] *See* ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION (1990); *see also* Yochai Benkler, *Commons and Growth: The Essential Role of Open Commons in Market Economies*, 80 U. CHI. L. REV. 1499, 1508 (2013) (distinguishing between state-based and cooperative "proprietary claims of exclusion, use, and disposition).

[159] Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968); *see* OSTROM, *supra* note 158, at 2-7 (describing the dynamic of resource overuse in a commons as a "tragedy of the commons," a "prisoner's dilemma," and a problem of "collective action").

[160] *See* OSTROM, *supra* note 158, at 30-31.

[161] *Id.* at 51.

[162] *See id.* at 69-82.

In recent years, a number of scholars have demonstrated that Ostrom's work can be adapted to study the production of information-based goods.[163] Noting that "cultural production is an inherently social phenomenon, taking place over a wide range of scales and within a complex, overlapping variety of formal and informal institutional structures,"[164] Madison, Frischmann and Strandburg advocate for detailed, contextual, and empirical studies of the mechanisms by which cultural production – including innovation – takes place.[165] To be sure, Ostrom's framework for research into collective action to manage natural resource communities does not map perfectly onto innovation environments. This is particularly so because such environments involve not only management of resources, but the *production* of intellectual goods.[166] Nevertheless, the analogy remains a good one. Collective action problems in the natural environment may lead to overuse of resources in the absence of a governance structure; so too in the cultural or innovative environment may collective action problems lead to underproduction.[167] Barriers to collective action for the production of innovation can be lowered through governance mechanisms.

Return now to the problems of uncertainty and information asymmetry. We argued above that these are the principal barriers to collective action in innovation. The literature on institutional design suggests that even if these problems cannot be *solved*, they can be *managed*

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[163] *See* Michael J. Madison, Brett M. Frischmann & Katherine J. Strandburg, *Constructing Commons in the Cultural Environment*, 95 CORNELL L. REV. 657 (2010). Ostrom and Charlotte Hess recognized the links between natural resource and information commons as well. *See, e.g.*, Charlotte Hess & Elinor Ostrom, *Ideas, Artifacts, and Facilities: Information as a Common Pool Resource*, 66 L. & CONTEMP. PROBS. 111 (2003). For an application, see, e.g., Timothy Simcoe, *Governing the Anti-Commons: Institutional Design for Standard-Setting Organizations*, *in* 14 INNOVATION POLICY AND THE ECONOMY (Josh Lerner & Scott Stern eds., 2014).
[164] Madison, Frischmann & Strandburg, *supra* note 163, at 669.
[165] *See id.* at 670-71.
[166] *See id.* at 680.
[167] *See id.* at 691-92.

through institutional arrangements. Indeed, Ostrom herself identified uncertainty as a critical driver of the institutional response to resource management needs.[168] Importantly, Ostrom observed that although "[u]ncertainties stemming from lack of knowledge may be reduced over time," "[u]ncertainty reduction is costly and never fully accomplished."[169] More recently, Benkler placed uncertainty at the center of his argument for open commons in infrastructural goods.[170] In Benkler's view, the key to enabling collective action in the face of pervasive uncertainty is a "feedback and correction mechanism."[171] "In the face of persistent uncertainty," he writes, "freedom of action in the commons provides room for experimentation not only in productive, material, and intellectual innovation, but in social relations and political action."[172] Similarly, Ostrom recognized the problem of asymmetric information when she noted that a central dilemma in common pool resources was that it presented "an interdependent situation" in which each actor nevertheless "must act independently."[173]

How do institutions solve these problems? Although Ostrom's work does not expressly address this question, it offers several clues. Ostrom articulates a set of design principles for successful commons governance, some of which are highly relevant to the management of uncertainty and information asymmetry.[174] Successful natural resource commons put in place

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[168] *See* OSTROM, *supra* note 158, at 33.
[169] *Id.* at 34; *see also id.* at 88 ("One similarity is that all [successful common pool resource settings] face uncertain and complex environments.").
[170] *See* Benkler, *supra* note 158, at 1539 ("In a highly uncertain, changing environment, with needs and plans that call for continuously updating the required resources, the freedom to operate provided by commons has important, valuable attributes relative to the security of holdings and the power to appropriate of property.").
[171] *Id.* at 1546.
[172] *Id.*
[173] OSTROM, *supra* note 158, at 39; *see also* Benkler, *supra* note 158, at 1542 (noting information failures in a variety of governance systems).
[174] *See* OSTROM, *supra* note 158, at 90 tbl.3.1; *cf.* Simcoe, *supra* note 163, at 15 tbl.2 (adapting design principles for shared technology platforms).

mechanisms for collective choice, such that "individuals affected by the operational rules can participate in modifying the operational rules."[175] They implement monitoring in which the monitors are accountable to the participants.[176] And they often are organized as nested structures, in which higher order rules are harder to change than lower-order rules.[177]

The next section explores the governance structures utilized by more well developed and studied innovation incentive mechanisms. We then draw lessons for innovation prizes.

2. Innovation incentives through an institutional lens

Viewed through the lens of institutional design, the choices made to structure innovation incentives become richer and more diverse than traditional economic analysis suggests. Patents are not merely rights to exclude; the *patent system* is a mechanism for granting, maintaining, and enforcing those rights. So too, scientific grantmaking is not merely a source of funds to make up for the absence of appropriability of the products of scientific research. It is a system for collective determinations about the direction and funding of research and development. Even procurement – the process of contracting for innovation – can be seen as a self-governing mechanism to enable collective action among innovators. In the vignettes below, we briefly describe how these three institutions manage uncertainty and asymmetric information, and how they therefore enable collective action.

a. Patents. A patent entitles its holder to the exclude others from making, using, or selling the subject matter covered by the patent for, in the United States, a period of 20 years from the date of application.[178] This allows the holder to earn a super-competitive return on her investment in producing the good that is claimed in the patent. Nevertheless, invention is a

[175] OSTROM, *supra* note 158, at 90 tbl.3.1; *see also id.* at 93-94
[176] *See id.* at 94-100.
[177] *See id.* at 101-02, 51-52.
[178] *See* 35 U.S.C. §§ 154(a)(2), 271(a).

highly uncertain endeavor. The inventor usually cannot know ex ante whether her invention will be successful in the marketplace. Of course, no governance mechanism can remove that uncertainty. But assuming that an inventor is willing to invent notwithstanding market uncertainty, she may still be unwilling to make the investment if she cannot be reasonably assured that she could obtain a patent if she meets the requirements for one. In other words, the government (which grants patents) faces a problem of credible commitment. The inventor may be willing to tolerate uncertainty in *outcome* (i.e. the value of the invention) if there is certainty as to the *process* of obtaining the innovation incentive.

The patent system solves this credible commitment problem through a highly regulated scheme of administrative and judicial review, undergirded by the constitutional value of due process. Patent applications are examined at the United States Patent and Trademark Office, and applicants have a right to administrative appeal of the denial of their applications.[179] If the denial is upheld on appeal, applicants have a further avenue of judicial review available to them. Throughout the process, the applicant has the opportunity to present evidence supporting her argument for patentability. Once the patent issues, it enjoys a presumption of validity.[180] Though it remains subject to challenge, such challenges must be proven by clear and convincing evidence in a fully litigated judicial setting in which the applicant may put on a robust defense of her patent.[181] This system is not without flaws.[182] Indeed, one set of critiques of the patent system is that it has become unreliable for inventors in recent years. But putting aside recent developments, the system has for many years provided inventors with assurance that so long as

[179] *See* 35 U.S.C. § 134.
[180] *See* 35 U.S.C. § 282(a).
[181] *See Microsoft Corp. v. i4i*.
[182] For example, some argue that various judicial doctrines make it too easy to challenge the validity of patents and therefore undermine the stability that we describe here. *See, e.g.*, Dreyfuss & Pope on *Lear*.

they meet a set of criteria defined ex ante, they will get a patent. Then, *if* there is a market for their product, they will be able to take advantage of that market. Security in the former enables risk taking in the latter.

The patent system helps to overcome information asymmetry much differently. Here, as Demsetz first pointed out, the system relies on market signals to aggregate information about the value of inventions.[183] As to the decision whether or not to grant a patent, the system similarly utilizes the market. Information relevant to the determination whether a patent is valid may be held by multiple, dispersed parties. Those parties bring the information forward in litigation over patent validity when they are incentivized to do so. Then the adversarial process of litigation before the PTO or a court provides the mechanism by which such information is aggregated.

b. *Grants*. The federal government funds a significant amount of basic research through grants administered by the National Institutes of Health (NIH), the National Science Foundation (NSF), and similar agencies.[184] Unlike patents, which address uncertainty through a process that enables inventors to *potentially* recoup their investments in innovation, grants provide the risk capital up front. The government nevertheless faces a credible commitment problem, this time in the form of public choice dynamics. The risk is that the process for awarding grants will become captured by concentrated interests or subject to bias and whim.[185] Because applying for grants is costly and time consuming, potential innovators will only undertake the process if they can be reasonably certain that grants will be awarded in a manner that at least roughly correlates with merit. In a similar vein, the classic objection to this funding mechanism is that it requires the

[183] *See* Demsetz, *supra* note __, at __.
[184] [Footnote with latest funding numbers.]
[185] *See* Roin, *supra* note __, at __.

government to pick winners and losers, a task for which the government (or, really, any grant sponsor), will always have inadequate information.[186]

Grantmaking institutions manage the dual problems of uncertainty and asymmetric information through a mix of high-level policymaking and lower-level peer review.[187] Overall funding priorities and policies are set by high-level officials, often political appointees.[188] These appointees are, at least in theory, politically accountable. Once funding priorities are set, the implementation of those priorities through individual decisions to grant or deny applications is made through rigorous peer review.[189] Again, as with the patent system, the peer review system for awarding grants is not without its faults.[190] But it is a reasonably successful attempt to mitigate the problems of both uncertainty and asymmetric information. As to the former, peer review is an accepted part of scientific norms and discourse.[191] The utilization of processes internal to the scientific endeavor for the purpose of validating an external authorities choices help to give legitimacy to those choices. It also allows for a form of collective decisionmaking, at least insofar as the relevant community of decisionmakers is construed broadly.[192] The likelihood that a particular scientist may find herself of the giving or receiving ends of the grantmaking process throughout her career helps to encourage robust decisionmaking. Peer review also helps to facilitate the aggregation of information for the purpose of making informed decisions. Although no aggregation mechanism can be perfect, peer review is a mechanism by which private information in the hands of individual scientists can be shared for the purpose of

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[186] *See supra* notes __ - __ and accompanying text.
[187] *See* Benkler, *supra* note 158, at 1552-53
[188] *See, e.g.*, [citation for stem cell funding case].
[189] *See, e.g.*, [NSF, NIH guidelines].
[190] [cite literature on bias, etc.]
[191] *See, e.g.*, Rai.
[192] *Cf.* OSTROM, *supra* note 158, at __.

collective decisionmaking. The reality of grantmaking is far from Demsetz's simple model by which a unitary institution is tasked with picking winners and losers. Instead, mechanisms for collective choice are well established.

c. Contracts. Parties often contract for the development of new technologies. These contracting environments can take a great variety of forms, and can differ as between government and market settings. But to take one example, Gilson et al. have studied supply contracts in highly innovative industries.[193] In these agreements, a one company contracts with another for the development of a critical part or service. The challenge lies in the fact that the part has not yet been developed. It is not, therefore, a simple supply contract. It is, instead, a contract for the production of a new innovation. Because the parties are subject to continuous uncertainty, however, the parties have ample chance to act opportunistically.[194] The problem these contracts attempt to solve is how to ensure credible commitment. And the mechanism they utilize is purely institutional. The contracts do not specify fixed prices or products, nor do they specify particular designs. Instead, they erect a governance structure by which the parties can collaborate towards the development of the needed technology. Elements of these governance structures include committees for routine knowledge sharing, dispute resolution mechanisms, and continuous iteration of designs and plans among the parties.[195] In this way, the parties develop trust over time, which enables deeper exchanges of information, all within a contractual setting in which the broad outlines of the shared goal are understood but the precise mechanisms by which that goal can be achieved are not.

C. Lessons for innovation prizes

[193] *See* Gilson, Sabel & Scott, *supra* note __, at 458-71.
[194] *See id.* at 455-58.
[195] *See id.* at 476-81.

The institutional design literature suggests that well managed institutions can overcome the problems of uncertainty and asymmetric information by providing a governance structure within which collective activity can take place notwithstanding those barriers. It also suggests that the institutional response to uncertainty and asymmetric information will vary with the precise context in which innovation takes place.

We draw here two sets of lessons for the implementation of innovation prizes by government and private entities. The first is a set of design principles consistent with the successful self-governing institutions described above. The second is a suggestion that policy debates over the appropriate mix of innovation incentives should be sensitive to the institutional context of those incentives. The choice of mechanism may depend at least in part upon the desired response to the challenges of innovation.

1. Designing well-governed innovation prizes

The governance mechanisms described above have several features in common. First, they incentivize innovative activity – notwithstanding continuous uncertainty – by substituting certainty in process for uncertainty in outcome. The institutional processes for managing innovation become *standardized* and participants can therefore rely on them. Uncertainty and persists throughout the innovation process, but a stable structure within which they can be managed provides innovators with enough security to prevent defection from the sphere of collective action. This is most readily seen in the patent system and the emerging model of innovation-by-contract. The judicial and administrative processes of patent prosecution and litigation provide inventors with certainty regarding their ability to procure a patent. Likewise, the contractual governance mechanisms in disaggregated supply chains that Gilson and his collaborators describe offer a process for resolving disputes that enables the trust required to

make asset-specific investments in innovation. This stability then allows for the development of mechanisms for information sharing. The government grantmaking process, for example, involves peer review in which experts in the field are asked to evaluate the merit of grant applications. Many contractual innovation environments expressly provide mechanisms for information sharing.

To be sure, none of the mechanisms are perfect. Innovation prizes, moreover, will vary significantly from one another in terms of their goals and structures. Nevertheless, to the extent that our case study is representative of the challenges that innovation prizes with similar structures may face,[196] a comparison of the challenges we describe in Part II with some of the successful mechanisms for overcoming similar challenges suggests that innovation prizes should incorporate several principles to achieve greater standardization:

a. Collaboration and transparency. In the PIAXP, the initial rule design stage appears to have been successful in engaging multiple constituencies to pool information and develop a reasonable initial set of design criteria for the prize. But subsequent efforts to change the rules became problematic when there was insufficient participation by the affected parties. A failure to institutionalize the process of rule change led to a loss of credibility on the part of the sponsors. Institutional mechanisms that facilitate collaboration and do so in a transparent manner are likely to encourage the trust and information sharing that is critical to decision making.

b. *Iteration*. Continuous uncertainty requires parties engaging in collective action to consistently revisit the assumptions under which they are acting in light of new data. Consistently evaluating decision criteria and the rules of prize competitions allows for frequent

[196] And we have reason to believe that it is. *See supra* notes __ - __ and accompanying text.

incorporation of new data that emerges as the competition progresses. This in turn provides an institutional hedge against uncertainty by allowing the organization to adapt to the changing innovation environment.

c. Tiered decision making. As Part II describes, uncertainty and asymmetric information plague innovation prizes at multiple levels of decision making, including the development of the prize objective, the drafting of rules, and the implementation of those rules through judging as the competition progresses. Processes of collaboration and iteration should take place at each of those levels and should incorporate a mechanism by which governance decisions at lower levels should inform revisions at higher levels.

2. Choosing among innovation incentives

Much of the focus of the scholarly literature on innovation prizes has been on determining when a social planner interested in incentivizing innovation should choose prizes over patents and procurement. As described in Part I, this analysis is largely indeterminate when confined to questions of welfare economics.[197] The range of factors about which economic knowledge is required is simply too great to draw definitive conclusions.

A number of scholars have recently expanded the analysis of innovation institutions in productive ways. Daniel Hemel and Lisa Larrimore Ouellette classify innovation incentives along three dimensions: whether the financial incentive is provided by the government or the market; whether it is provided ex ante or ex post (that is, before or after the innovative activity has taken place); and whether the incentive is paid for by users or by the general public.[198] This taxonomy, while helpful, is still highly stylized and focuses mostly (though, to be sure, not

[197] *See supra* notes __ - __ and accompanying text.
[198] *See* Daniel J. Hemel & Lisa Larrimore Ouellette, *Beyond the Patents-Prizes Debate*, 92 TEX. L. REV. 303, 326-52 (2013).

entirely) on the characteristic of the incentive mechanism rather than the underlying problem to be solved.[199] It posits a fixed set of solutions and asks which solution is likely to be optimal based on the three dimensions of policy choice described above.[200]

Brett Frischmann argues that "[c]hoosing between institutions rests on subtle differences in the manner in which they target innovation market failures, rely on information processing, and have dynamic effects on incentives and other institutions."[201] He considers a somewhat broader range of factors based on the precise market failure that the intervention seeks to remedy and the economic characteristics of the innovation good that is sought.[202] He calls instead for deeper "comparative institutional analysis."[203]

Our analysis suggests a somewhat different answer to the question when one mechanism ought to be preferred over another. The institutional perspective that we develop in this Part suggests that the starting point ought to be the organizational challenges inherent in a particular socially desirable project. Innovation incentives do not function only to provide an economic

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[199] *See id.* at 375-81.

[200] *See id.* Hemel and Ouellette conclude, for example, that "government grants are most effective when the government has a comparative advantage relative to the private sector in evaluating the costs and benefits of potential projects," and "where market signals are poor proxies for the social benefits of new products, where potential innovators encounter significant capital constraints, and where cross-subsidization of product users by nonusers is desirable." *Id.* at 375. Government-sponsored prizes "may be most effective when government officials are capable of setting a clear goal and an appropriate prize size, but where government officials are at a disadvantage in identifying the most promising potential projects ex ante." *Id.* at 376. And patents "are most effective where potential innovators have ready access to the requisite financial capital and where the negative effects of risk aversion on innovators' incentives are limited." *Id.*

[201] Brett Frischmann, *Innovation and Institutions: Rethinking the Economics of U.S. Science and Technology Policy*, 24 VT. L. REV. 347, 392 (2000).

[202] *See id.* at 392-95.

[203] *Id.* at 395. This work presages Frischmann's later work on commons-based management of infrastructural resources; and that latter work has some resonance with our conclusions. *See* BRETT M. FRISCHMANN, INFRASTRUCTURE: THE SOCIAL VALUE OF SHARED RESOURCES 91-95 (2012) (arguing that benefits of commons as a management strategy vary with context).

inducement to innovative activity. They also serve to *organize* that activity. The choice of organizational form depends on the nature of the problem to be solved.

To be sure, there are significant overlaps between our approach and those attempts at sorting out which incentives ought to go with which projects described above. For instance, the more specific the project goal, the more likely it is that direct contracting can solve the problem, while for innovation without a particular desired endpoint, patents are likely to provide a reasonable organization form. But if a sponsor has a particular goal in mind, the sponsor can organize collective activity aimed at achieving that goal in a number of ways. The precise organization form that an innovative project takes will depends on the norms of the scientific field, the complexity of the problem, and other such factors.

We leave to future work more detailed delineation of those choices.