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GOVERNMENT CHOICES IN INNOVATION FUNDING (WITH REFERENCE TO CLIMATE CHANGE)

Joshua D. Sarnoff[*]

ABSTRACT

Huge amounts of money will soon be spent by governments and private entities to develop technology to reduce the costs of climate change mitigation and adaptation, and to deploy new energy and transportation infrastructures. Incredibly, we still lack any good idea of the best means of providing massive amounts of government or private money so as to promote the most innovation and technology diffusion at the lowest cost. This Article seeks to support better analyses of, and decision making regarding, the choices of government innovation-funding mechanisms by discussing the limits of current analyses and providing a taxonomy of such measures. It also proposes future work to better analyze what we know about these choices and their relative effectiveness, and it discusses new measures to expand our knowledge base, which include: (1) better tracking of government innovation-funding inputs and outputs; (2) better documentation of and self-conscious decision making regarding funding choices; and (3) creating experiments that go beyond existing natural experiments.

INTRODUCTION

Huge amounts of money will soon be spent by governments (including government agencies, laboratories, corporations, and other public actors) and private entities (including corporations, foundations, nonprofit entities, universities, and others) to develop technology to reduce the costs of climate change mitigation and adaptation, and to deploy new energy and transportation infrastructures. As a matter of international law, developed country members

[*] Professor, DePaul University College of Law, Chicago, IL. The author thanks the Emory Law School, the Thrower Symposium, and the *Emory Law Journal* for inviting my participation and this Article; the many people who contributed to this Article, including participants in various conferences in the United States and around the world where aspects of the work were presented at different stages; the chapter authors for RESEARCH HANDBOOK ON INTELLECTUAL PROPERTY AND CLIMATE CHANGE (Joshua D. Sarnoff ed., forthcoming 2013); Dean Gregory Mark for editorial suggestions; and Michael Comeau, Jesse Dyer, Rachel Schweers, and librarians Michael Schiffer and Daniel Ursini for research assistance.

of the United Nations Framework Convention on Climate Change (UNFCCC)[1] committed in the 2010 Cancun Agreement[2] to transfer public and private funds and technology for mitigation measures to developing countries. The agreed funding was at least $30 billion per year, rising to at least $100 billion per year by 2020. In the 2011 Durban Platform,[3] the UNFCCC reaffirmed that commitment and created the framework institutional structure for implementing it. Recent analyses suggest that number is low by an order of magnitude, as developing countries may need at least $1 trillion per year to meet mitigation and adaptation needs.[4] As a matter of market economics, tens (and perhaps hundreds) of trillions of dollars will soon flow to develop and disseminate a wide range of new technologies to upgrade energy, transportation, and other infrastructure; to develop low greenhouse gas-emitting consumer and industrial products; and to mitigate and adapt to the effects of climate change (collectively referred to as *climate change technologies*).[5] These funds will come either from governments or, by default,

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1 United Nations Framework Convention on Climate Change, S. TREATY DOC. No. 102-38, 1771 U.N.T.S. 107 [hereinafter UNFCCC].

2 *See* United Nations Framework Convention on Climate Change Conference of the Parties, 16th Sess., Cancun, Mex., Nov. 29 to Dec. 10, 2010, *Report of the Conference of the Parties*, ¶¶ 98–99, U.N. Doc. FCCC/CP/2010/7/Add.1 (Mar. 15, 2011) [hereinafter UNFCCC Cancun Agreement], *available at* http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2.

3 United Nations Framework Convention on Climate Change Conference of the Parties, 17th Sess., Durban, S. Afr., Nov. 28 to Dec. 9, 2011, *Establishment of an Ad Hoc Working Group on the Durban Platform for Enhanced Action*, ¶ 5, U.N. Doc. FCCC/CP/2011/L.10 (Dec. 10, 2011) [hereinafter UNFCCC Durban Platform], *available at* http://unfccc.int/resource/docs/2011/cop17/eng/l10.pdf; *see also* United Nations Framework Convention on Climate Change Conference of the Parties, 17th Sess., Durban, S. Afr., Nov. 28 to Dec. 11, 2011, *Report of the Conference of the Parties*, ¶¶ 126–43, U.N. Doc. FCCC/CP/2011/9 (Mar. 15, 2012) [hereinafter UNFCCC Durban WG-LCA Decisions], *available at* http://unfccc.int/resource/docs/2011/cop17/eng/09.pdf.

4 *See* Meena Raman, *Trillions of Dollars Needed for Climate Finance*, SOUTH CENTRE (Aug. 17, 2012), http://www.southcentre.org/index.php?option=com_content&view=article&id=1818%3Atrillions-of-dollars-needed-for-climate-finance-17-august-2012&catid=149%3Asouthnews&Itemid=355&lang=en (discussing converging estimates based on published studies by the World Bank, the United Nations, and the International Energy Administration); *see also* WORLD BANK, WORLD DEVELOPMENT REPORT 2010: DEVELOPMENT AND CLIMATE CHANGE 257–85 (2010) (estimating cost-effective mitigation measures between $4 and $25 trillion over the next century for a 420–425 ppm CO_2e stabilization scenario, and discussing the funding needed for both mitigation and adaptation technology development and deployment).

5 *See, e.g.*, BERNICE LEE ET AL., WHO OWNS OUR LOW CARBON FUTURE?: INTELLECTUAL PROPERTY AND ENERGY TECHNOLOGIES 3 (2009) (discussing International Energy Agency (IEA) and Intergovernmental Panel on Climate Change (IPCC) studies); WORLD BANK, *supra* note 4, at 261 (discussing anticipated transportation and other investments); Lawrence H. Goulder & William A. Pizer, *The Economics of Climate Change* 13 (Res. for the Future, Discussion Paper No. 06-06, 2006) (discussing anticipated investments in energy infrastructure); Raman, *supra* note 4 (referencing an IEA 2012 study of energy technology that predicted $370 billion annual investments by 2020 in power generation infrastructure in a two-degree Celsius

from private sources subject to government incentives and regulation of market behaviors.

Incredibly, after centuries of experience, we still lack any clear theory or good comparative empirical analyses from which to determine the best *form* of deploying such massive amounts of government money, inducing private money, or creating public–private partnerships (PPPs) to promote the most innovation, technology development, and diffusion at the lowest cost.[6] The most relevant theoretical analyses stress the general advantages of public financing and public-domain treatment of innovations over private financing and intellectual property rights, based on the economic theories that such rights lead to reduced consumer welfare (deadweight losses) in the absence of perfect price discrimination, and that single-market taxation is less efficient than broad-based taxation.[7] They also identify a number of superior features of government funding, including: the ability to shift resources to the most promising investments when the initial approach to innovation is uncertain, and better coordination of funding levels or parties to avoid inefficiently low entry levels or duplication of efforts.[8] They recognize, however, that intellectual property rights sometimes have superior features to alternatives such as prizes and subsidies.[9] Overlapping ("hybrid") approaches may

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temperature-rise scenario, increasing to $630 billion between 2020 and 2030 and $760 billion between 2030 and 2050).

6 *See, e.g.*, 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, 624 (1962) ("There is clear need for further study of alternative methods of compensation [for inventions]."); *cf., e.g.*, Ger Klaassen et al., *The Impact of R&D on Innovation for Wind Energy in Denmark, Germany and the United Kingdom*, 54 ECOLOGICAL ECON. 227 (2005) (discussing how governments should address infrastructure challenges and manage associated fiscal and macroeconomic risks); Gerd Schwartz et al., *Introduction* to PUBLIC INVESTMENT AND PUBLIC-PRIVATE PARTNERSHIPS: ADDRESSING INFRASTRUCTURE CHALLENGES AND MANAGING FISCAL RISKS 1, 1 (Gerd Schwartz et al. eds., 2008) (same). *See generally* GER KLAASSEN ET AL., INT'L INST. FOR APPLIED SYS. ANALYSIS, IR-03-011, PUBLIC R&D AND INNOVATION: THE CASE OF WIND ENERGY IN DENMARK, GERMANY AND THE UNITED KINGDOM (2003) (providing a comparative analysis of one technology across three countries), *available at* http://webarchive.iiasa.ac.at/Admin/PUB/Documents/IR-03-011.pdf; TECHNOLOGY TRANSFER AND PUBLIC POLICY (Yong S. Lee ed., 1997) (discussing different collaborative interactions among research universities, federal laboratories, and industries in the United States).

7 *See, e.g.*, Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY 51, 54 (Adam B. Jaffe et al. eds., 2002); Stephen M. Maurer & Suzanne Scotchmer, *Procuring Knowledge*, *in* 15 INTELLECTUAL PROPERTY AND ENTREPRENEURSHIP: ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION AND ECONOMIC GROWTH 1, 2, 27 (Gary D. Libecap ed., 2004).

8 *See, e.g.*, Maurer & Scotchmer, *supra* note 7, at 21–23 (also noting the assumption that ideas for development and approaches to problem solving are common knowledge).

9 *See, e.g.*, Gallini & Scotchmer, *supra* note 7, at 54–55 (noting potentially superior knowledge of costs and benefits of R&D for screening investments; the potential to elicit higher levels of effort—like a lottery

sometimes be needed to correct perverse incentives of providing either public or private financing. Public or private financing choices may depend on whether and when the social value and costs of developing ideas are known, observable, and able to be aggregated.[10] This is particularly true where private firms possess information on value or costs that needs to be aggregated for efficient decision making, and when only the government can compel such information to be disclosed.[11] Accordingly, these analyses highlight the importance of comparative analysis of public and private institutions and of their innovation-relevant features.[12]

There are many types of innovation, moreover, including: product and process, institutional, complementary, and marketing. It is commonplace to distinguish innovation—understood as reduction of ideas to practice—from invention—understood as the conception of ideas (although not limited to functional ideas that are the subject of patent rights).[13] However, the boundaries of these categories are not conceptually distinct, and the categories may hide rather than reveal important intersections of different kinds of activities.[14] Innovation is also often equated with commercialization—or applied research (as distinguished from basic research)—although achieving practical applications does not always involve commercial activity for the applications to become widespread.[15]

Further, scientific and technological developments do not usually follow a linear path. Given this heterogeneity, it is intuitively unlikely that there are

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compared to a certain, fixed lower sum; and the ability to avoid taxpayer revolts for certain kinds of investments).

10 Maurer & Scotchmer, *supra* note 7, at 1, 4–6, 21–23; Gallini & Scotchmer, *supra* note 7, at 54–55, 57–61, 65–69.

11 *See, e.g.*, Gallini & Scotchmer, *supra* note 7, at 57, 58 & n.3.

12 *See generally* Daron Acemoglu et al., *The Rise of Europe: Atlantic Trade, Institutional Change and Economic Growth* (Nat'l Bureau of Econ. Research, Working Paper No. 9378, 2002); Edward L. Glaeser et al., *An Economic Approach to Social Capital*, 112 ECON. J. F437 (2002); Douglass C. North, *Institutions*, J. ECON. PERSP., Winter 1991, at 97.

13 *See, e.g.*, Kenneth J. Arrow, *The Macro-Context of the Microeconomics of Innovation*, *in* ENTREPRENEURSHIP, INNOVATION, AND THE GROWTH MECHANISM OF THE FREE-ENTERPRISE ECONOMIES 20, 22 (Eytan Sheshinski et al. eds., 2007) (citing JOSEPH A. SCHUMPETER, THE THEORY OF ECONOMIC DEVELOPMENT (1983); 1 JOSEPH A. SCHUMPETER, BUSINESS CYCLES: A THEORETICAL, HISTORICAL, AND STATISTICAL ANALYSIS OF THE CAPITALIST PROCESS (1939)).

14 *See, e.g.*, Brett Frischmann, *Innovation and Institutions: Rethinking the Economics of U.S. Science and Technology Policy*, 24 VT. L. REV. 347, 348–49 (2000).

15 *See, e.g.*, *id.* at 349–51; Thomas Brzustowski, Government Assistance to and Policy Toward Innovation, Remarks at the Proceedings of the Canada–United States Law Institute Conference on Comparative Aspects of Innovation in Canada and the United States (Apr. 7–8, 2006), *in* 32 CAN.-U.S. L.J. 39, 39, 41 (2006) [hereinafter Can.–U.S. Proceedings 2006].

simple or necessary answers to what works best, when, and why. Recent (and long-standing) comparative institutional and country analyses suggest that effective government choices concerning the form of innovation funding are contingent and contextual, rather than necessary and invariant.[16] Theoretical analyses suggest that the most efficient incentive mechanism may be context-specific, path-dependent (considering, *inter alia*, historic patterns of trade), and reliant on the efficiency of licensing markets.[17] The fundamental assumptions driving decision making also may require additional justification, but analyses to identify when the assumptions hold may be lacking.[18] Further, theoretical or institutional analyses may not evaluate all relevant potential alternatives,[19] or analyze the comparative abilities *and potential abilities* of private- and public-sector decision makers.

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16 *See, e.g.*, DAN BREZNITZ, INNOVATION AND THE STATE: POLITICAL CHOICE AND STRATEGIES FOR GROWTH IN ISRAEL, TAIWAN, AND IRELAND 17 (2007) ("There are many ways by which state and industry can interlink, and each one of them necessitates a different division of labor and gives rise to different industrial capabilities. . . . [W]e no longer can view the state as a unitary actor."); VANNEVAR BUSH, SCIENCE: THE ENDLESS FRONTIER 14–17 (1945) (discussing relative abilities and limitations of university-based, government-agency-based, and industry-based research); *id.* at 26–27 (discussing "five fundamentals" of government support for scientific R&D promoted by a national science foundation: (1) funding stability; (2) employee knowledge, capabilities, and interests; (3) support for external not intramural research; (4) internal control over the research by university fundees; and (5) budgetary controls and political accountability); MARK DODGSON & JOHN BESSANT, EFFECTIVE INNOVATION POLICY: A NEW APPROACH 3–4 (1996) (noting the diversity in government policies and needs of firms, particularly with regard to resources, competencies, and innovative capabilities).

17 Maurer & Scotchmer, *supra* note 7, at 1–2; Philippe Aghion et al., *Carbon Taxes, Path Dependency and Directed Technical Change: Evidence from the Auto Industry* 2–5 (Fondazione Eni Enrico Mattei, Working Paper No. 99.2012, 2012), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2202047.

18 For example, economists tend to assume that innovation will be maximized and investment will reach efficient levels if private returns on investment are equated with the social value of the innovations. Economists also note that intellectual property may be inefficient where social value is not appropriable or the rewards are too low to cover R&D costs, whereas prize rewards should be set below social value where the costs are expected to be lower than the social value. *See, e.g.*, Gallini & Scotchmer, *supra* note 7, at 60–62; Maurer & Scotchmer, *supra* note 7, at 2, 10. *See generally* Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, J. ECON. PERSP., Winter 1991, at 29, 31. However, these analyses may fail to adequately account for positive externalities (social-welfare-enhancing spillovers) that are generated when lower private returns are sufficient to induce investments in making innovations. *See, e.g.*, Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 83 TEX. L. REV. 1031, 1032, 1044 (2005). When this will occur, however, is not always clear. These conflicting analyses also may reflect differing views about whether innovation is a continuous or discontinuous function of investments.

19 For example, the economics literature focuses on intellectual property, government procurement, government grants, and other subsidies, and somewhat less frequently on "intramural" government research (i.e., direct development), but it typically does not address government creation of commons. Maurer & Scotchmer, *supra* note 7, at 17; *see infra* Part II (classifying measures).

This Article seeks to provide a better understanding of these choices.[20] Part I summarizes some basic insights regarding government innovation funding choices that do not take us very far, some analytic approaches that have been developing, and suggestions for their expansion that might get us much farther.[21] Part II provides a taxonomy of the government innovation funding choices that demonstrates similarities and differences among the choices and identifies some interrelationships among them. The taxonomy may provide some immediate assistance to decision makers and analysts by highlighting the possibilities, and by denaturalizing the existing choices to counteract the gravitational pull toward path dependence.

I. BASIC INSIGHTS AND NEW APPROACHES TO UNDERSTANDING GOVERNMENT INNOVATION CHOICES

Research and development (R&D), particularly basic R&D, are public goods with substantial positive spillovers. They require government funding or other inducements to reach social-welfare-maximizing levels because commercial markets will otherwise underproduce them.[22] Similarly, infrastructure is a public good that private commercial markets are expected to underproduce. Infrastructure thus requires public investment, whether through (1) direct government provision; (2) government subsidization of fixed costs; (3) some form of nonprofit-sector supply (which may imply government tax subsidies); or (4) commercial provision by charging above marginal costs (which may imply antitrust or sectoral market regulation, intellectual property rights, or other government action).[23]

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[20] *Cf.* Stuart Minor Benjamin & Arti K. Rai, *Fixing Innovation Policy: A Structural Perspective*, 77 GEO. WASH. L. REV. 1, 6 (2008) (proposing a new executive entity that would focus on cross-agency innovation policies).

[21] I hope in future articles to expand on the insights provided here and to provide more refined suggestions for better tracking of inputs to and outputs of innovation funding, for mandatory documentation of decision making, and for creation of innovation experiments across jurisdictions.

[22] *See, e.g.*, EDWIN S. MILLS, THE BURDEN OF GOVERNMENT 40 (1986); *see also* DOMINIQUE FORAY, ECONOMICS OF KNOWLEDGE 8, 16 (2004) (citing Kenneth J. Arrow, *The Economic Implications of Learning by Doing*, 29 REV. ECON. STUD. 155 (1962); Nathan Rosenberg, *Learning by Using*, *in* INSIDE THE BLACK BOX: TECHNOLOGY AND ECONOMICS 120 (Nathan Rosenberg ed., 1982)) (noting the public-good character of knowledge and differences between private and social returns, as well as the claim that knowledge production may occur even if it is not the immediate goal, in light of learning by doing and learning by using).

[23] *See, e.g.*, FRITZ MACHLUP, SUBCOMM. ON PATENTS, TRADEMARKS, & COPYRIGHTS OF THE SENATE COMM. ON THE JUDICIARY, 85th CONG., AN ECONOMIC REVIEW OF THE PATENT SYSTEM 16–17 (Comm. Print 1958) (discussing "expenses beyond the means of private concerns" and noting four government alternatives to promote additional R&D beyond what the private sector would provide: research grants or subsidies; prizes or bonuses; monopoly grants through patents; and government research agencies); BRETT M. FRISCHMANN,

Government decision making may dramatically affect R&D markets.[24] For example, government decision makers use a mix of mechanisms to promote innovation,[25] and they tend to rely more heavily on particular forms of funding choices for technology development and economic growth in different industrial sectors. Government procurement has predominated for R&D in national defense (given the government's historic monopoly on military activity), whereas subsidies to universities (and to some private firms) for basic R&D—combined with intellectual property rights and private funding for applied R&D—have predominated for pharmaceuticals and biotechnology.[26] Further, it is often and inappropriately assumed[27] that we need to rely on private industry expertise and intellectual property rights to perform applied research and to commercialize innovations that derive from basic research, at least for research that is already subsidized by the government.[28]

Beyond these basic and important (but sometimes wrong) insights, we know far too little to intelligently guide our choices of the form of government funding to best promote innovation. As noted over a decade ago, "Despite wide recognition that socially efficient production of innovation (of all types) requires a comprehensive, complicated 'mix' of federal institutions, comparative institutional analysis is lacking, particularly in terms of mixed systems that rely on multiple institutions."[29] Further, a wide range of

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INFRASTRUCTURE: THE SOCIAL VALUE OF SHARED RESOURCES 5–6, 12–15 (2012) (describing infrastructure as an "impure public good" because of capacity limits).

24 *See, e.g.*, BREZNITZ, *supra* note 16, at 26–28 (discussing "systems-of-innovation" theories that seek to explain R&D by reference to location within the industrial system, financing, and industrial opportunities, all of which are affected by state decisions).

25 *See, e.g.*, Frischmann, *supra* note 14, at 350.

26 *See, e.g.*, FORAY, *supra* note 22, at 225–27 (citing Iain M. Cockburn, *The Changing Structure of the Pharmaceutical Industry*, HEALTH AFF., Jan./Feb. 2004, at 10); VERNON W. RUTTAN, IS WAR NECESSARY FOR ECONOMIC GROWTH?: MILITARY PROCUREMENT AND TECHNOLOGY DEVELOPMENT 108–09 (2006) (contrasting defense-related research funding for computers and semiconductors with defense-related research funding for software, and noting declines in defense-related funding of academic institutions and shifts of such funding toward applied R&D in the 1980s); *see also* Frischmann, *supra* note 14, at 380 (noting that subsidies or procurement are needed for areas such as national defense because intellectual property exclusive rights are ineffective in markets for products with non-rivalrous consumption); Rebecca Henderson & Iain Cockburn, *Scale, Scope, and Spillovers: The Determinants of Research Productivity in Drug Discovery*, 27 RAND J. ECON. 32, 56 (1996) (finding substantial inter-firm spillovers of R&D knowledge in the pharmaceutical industry).

27 *See* Frischmann, *supra* note 14, at 347 n.2 (citing Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA. L. REV. 1663 (1996)) (discussing problems with justifications for the approach chosen, and noting that economic theory suggests adoption of non-uniform approaches); *infra* notes 64–76 and accompanying text.

28 *See, e.g.*, Frischmann, *supra* note 14, at 395–413.

29 *Id.* at 350.

government decision making that is not directly targeted at innovation can affect the markets for which innovation is desired.[30] Globalization of production[31] and cultural and historical differences among nations[32] only multiply the questions that are unanswered.

A. Limits to Existing Input–Output Analyses, and Institution-Based and Creativity-Based Approaches

Some past analytic efforts to get at these issues have examined the proportion of government R&D spending on activities undertaken directly by the government compared to those undertaken by the private and nonprofit sectors. These studies noted the difficulty of determining how much R&D—even for basic science—*should* be undertaken or sponsored by the public sector.[33] The outputs of such innovation funding, moreover, typically are not tracked, much less analyzed to determine how the outputs relate to the various types of spending inputs.[34] Even if the outputs were tracked and analyzed, there would be substantial difficulties in determining which inputs and outputs to measure and how far downstream to look.[35] Further, in comparing the inputs and outputs across different technological fields, the market structures may be affected by the innovations themselves.[36]

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30 *See, e.g.*, BREZNITZ, *supra* note 16, at 26–28; Frischmann, *supra* note 14, at 351–52 (discussing "costly distortions" of markets by "poorly targeted" government interventions).

31 *See, e.g.*, BREZNITZ, *supra* note 16, at 20–25 (noting the growth of worldwide production networks and increasing fragmentation of the production process and research into "global production networks").

32 *See, e.g.*, *id.* at 6 (noting the existence of multiple, but very different, successful national models of technology development in the information technology sector, and identifying three factors that affect state–industry relations and international and financial interactions: (1) state acquisition of knowledge and skills; (2) states addressing research market failures by lowering private entry risks; and (3) states acting to link local industry with multinational corporations and financial markets).

33 *See, e.g.*, KEITH NORRIS & JOHN VAIZEY, THE ECONOMICS OF RESEARCH AND TECHNOLOGY 104–20 (1973).

34 *See, e.g.*, Alan Nymark, Canadian Governmental Support for Innovation, Remarks at the Proceedings of the Canada–United States Law Institute Conference on Promoting and Protecting Innovation in a Changing World (Apr. 21–23, 1995), *in* 21 CAN.-U.S. L.J. 37, 42 (1995); *cf.* LAURA ANADON ET AL., BELFER CTR. FOR SCI. & INT'L AFFAIRS, U.S. PUBLIC ENERGY INNOVATION INSTITUTIONS AND MECHANISMS: STATUS AND DEFICIENCIES 1 (2010) (stating that "all initiatives and institutions [should be] required to consistently collect metrics on relevant outputs and outcomes and information about projects").

35 *See, e.g.*, Zoltan J. Acs & David B. Audretsch, *Innovation and Technological Change: An Overview*, *in* INNOVATION AND TECHNOLOGICAL CHANGE: AN INTERNATIONAL COMPARISON 1, 3–6 (Zoltan J. Acs & David B. Audretsch eds., 1991) (noting typical measures of research expenditure inputs, intermediate outputs—such as the number of inventions and patent counts, and direct measures of output—such as databases of innovations, and discussing problems with these measures).

36 *See, e.g.*, F. M. SCHERER, INNOVATION AND GROWTH: SCHUMPETERIAN PERSPECTIVES 1 (1984); Acs & Audretsch, *supra* note 35, at 3, 15–16 (citing Simon Kuznets, *Inventive Activity: Problems of Definition and*

Notwithstanding these difficulties, there are very good reasons to try to understand these issues better so as to improve innovation policy. This is particularly true regarding climate change mitigation and adaptation technologies, and infrastructure investments—given the importance of the needs and magnitude of the social and fiscal costs to be borne by the world, or more parochially by particular countries. Among these reasons are: improving competitive trade position; reducing adverse impacts of climate change more effectively and quickly; reducing burdens to the economy of effectuating climate policy; and reducing foreign aid and treaty compliance costs.

In contrast to the paucity of our macrounderstanding of these innovation funding choices,[37] substantial microanalyses have been developing regarding invention and innovation and their promotion. These analyses address, *inter alia*: the economics of intellectual property;[38] the variety of innovation paradigms beyond mass-market sellers of products (and particularly the development of user-innovation and user-generated content);[39] and the determinants of invention- and innovation-creation behaviors. These determinants include, but are not limited to: whether innovation inputs and outputs are recognized as property rights or use other control mechanisms, such as access and employee mobility restraints; and whether the inputs and

Measurement, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY, *supra* note 6, at 19); Wesley M. Cohen & Richard C. Levin, *Empirical Studies of Innovation and Market Structure*, *in* 2 HANDBOOK OF INDUSTRIAL ORGANIZATION 1059 (Richard Schmalensee & Robert Willig eds., 1989); Partha Dasgupta, *The Theory of Technological Competition*, *in* NEW DEVELOPMENTS IN THE ANALYSIS OF MARKET STRUCTURE 519 (Joseph E. Stiglitz & G. Frank Mathewson eds., 1986); P. Dasgupta & J. Stiglitz, *Industrial Structure and the Nature of Innovative Activity*, 90 ECON. J. 266 (1980); *see also* Uwe Cantner & Marco Guerzoni, *Innovation and the Evolution of Industries: A Tale of Incentives, Knowledge and Needs*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP 382, 382–98 (David B. Audretsch et al., 2011); Wesley M. Cohen, Richard C. Levin & David C. Mowery, *Firm Size and R&D Intensity: A Re-Examination*, 35 J. INDUS. ECON. 543 (1987) (finding that overall firm size has an insignificant effect on business unit R&D intensity); *cf.* RICHARD D. ROBINSON, THE INTERNATIONAL TRANSFER OF TECHNOLOGY: THEORY, ISSUES, AND PRACTICE 3 (1988) (noting the difficulty of defining units of technology, particularly for disembodied technology, i.e., human skill).

37 An excellent summary of research on the relationship between innovation and environmental regulation is provided in David Popp et al., *Energy, the Environment, and Technological Change* 4–6 (Nat'l Bureau of Econ. Research, Working Paper No. 14832, 2009).

38 An excellent, short summary is provided in Peter S. Menell & Suzanne Scotchmer, *Intellectual Property Law*, *in* 2 HANDBOOK OF LAW AND ECONOMICS 1475 (A. Mitchell Polinsky & Steven Shavell eds., 2007). Another summary may be found in Joseph E. Stiglitz, Lecture, *Economic Foundations of Intellectual Property Rights*, 57 DUKE L.J. 1693 (2008).

39 *See, e.g.*, Katherine J. Strandburg, *Evolving Innovation Paradigms and the Global Intellectual Property Regime*, 41 CONN. L. REV. 861, 884–89 (2009); Katherine J. Strandburg, *Users as Innovators: Implications for Patent Doctrine*, 79 U. COLO. L. REV. 467 (2008); Rebecca Tushnet, *User-Generated Discontent: Transformation in Practice*, 31 COLUM. J.L. & ARTS 497 (2008).

outputs are developed within firms, traded in markets, or subject to cross-firm collaborations that defy expectations of vertical integration or rely on unusual contract structures to deal with uncertainties.[40] Comparatively little attention, by contrast, has been devoted to problems of valuation and bilateral contracting resulting in the illiquidity of markets for property rights in innovations. This has resulted in the consequent need to facilitate the development of such rights markets through trading exchanges (such as the recently created Intellectual Property Exchange International, IPXI) to better promote innovation and technology development and diffusion.[41]

Substantial analyses now exist regarding the personal and organizational determinants of various forms of innovative "creativity" (i.e., "new," "appropriate," and—arguably—not "readily identifiable" outcomes) for people located in different settings, fields, and geographies.[42] These determinants

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40 *See, e.g.*, Ashish Arora & Robert P. Merges, *Specialized Supply Firms, Property Rights and Firm Boundaries*, 13 INDUS. & CORP. CHANGE 451 (2004); Oren Bar-Gill & Gideon Parchomovsky, *Law and the Boundaries of Technology-Intensive Firms*, 157 U. PA. L. REV. 1649, 1650–54 (2009) (citing, *inter alia*, OLIVER E. WILLIAMSON, MARKETS AND HIERARCHIES: ANALYSIS AND ANTITRUST IMPLICATIONS (1975); Philippe Aghion & Jean Tirole, *The Management of Innovation*, 109 Q.J. ECON. 1185 (1994)); Dan L. Burk, *Intellectual Property and the Firm*, 71 U. CHI. L. REV. 3, 3–4 (2004); Dan L. Burk & Brett H. McDonnell, *The Goldilocks Hypothesis: Balancing Intellectual Property Rights at the Boundary of the Firm*, 2007 U. ILL. L. REV. 575, 576–78; Ronald J. Gilson et al., *Contracting for Innovation: Vertical Disintegration and Interfirm Collaboration*, 109 COLUM. L. REV. 431, 435–36 (2009); Érica Gorga & Michael Halberstam, *Knowledge Inputs, Legal Institutions and Firm Structure: Towards a Knowledge-Based Theory of the Firm*, 101 NW. U. L. REV. 1123 (2007); Nicholas J. Houpt, *Financing Innovation: Braiding, Monitoring, and Uncertainty*, 62 SYRACUSE L. REV. 337, 338–42 (2012); *see also* Anthony J. Casey, *Mind Control: Firms and the Production of Ideas*, 35 SEATTLE U. L. REV. 1061, 1062–64, 1070 (2012) (noting the failure of theory-of-the-firm literature to address the "how" of "idea production," discussing the inability of property theories to explain such production given the difficulty of observing and controlling the products of individuals' minds, identifying as relevant variables things like types of production inputs, need for collaboration, and reputational effects on disclosures, and suggesting that such factors may have more influence than the strength of property rights); David J. Teece, *Business Models, Business Strategy and Innovation*, 43 LONG RANGE PLAN. 172 (2010) (identifying various methods that firms can use to capture value from innovations, such as bundling innovative technology into consumer-oriented products and naked licensing, and noting the dependence of such choices on relative perfection and enforceability of property rights).

41 *See, e.g.*, Dietmar Harhoff, *The Role of Patents and Licenses in Securing External Finance for Innovation*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 55; James E. Malackowski, *The Next Big Thing in Monetizing IP: A Natural Progression to Exchange-Traded Units*, LANDSLIDE, May/June 2011, at 32; Gerard Pannekoek, Emerging IP Monetization Solutions: The Institutionalization of an IP Exchange 4–8 (May 25, 2011) (unpublished manuscript), *available at* http://www.ipxi.com/system/files/Oxford%20IP%20Research%20Centre1.pdf; *cf.* Richard Bis, *Financing Innovation: A Project Finance Approach to Funding Patentable Innovation*, INTELL. PROP. & TECH. L.J., Nov. 2009, at 14, 14–17 (discussing growth in patent markets that make an invention company feasible and project finance desirable). *See generally* IPX INT'L, www.ipxi.com (last visited May, 12, 2013).

42 Gregory N. Mandel, *To Promote the Creative Process: Intellectual Property Law and the Psychology of Creativity*, 86 NOTRE DAME L. REV. 1999, 2002–04 (2011); *see also* David J. Teece, *Knowledge and*

include intrinsic and extrinsic motivations (and their interactions);[43] different forms of collaboration, including widespread "peer production" (i.e., dispersed contributions);[44] and convergent and divergent thinking (i.e., analytic and intuitive reasoning)[45] for identifying and solving different kinds of problems.[46] The psychological determinants include rhetoric (principally regarding the "origins" of our intellectual property system) that is used to justify or challenge the existing norms and legal conditions for different forms of creativity, for example, by "valu[ing] . . . group-oriented productivity over individual creation."[47]

But so far these promising avenues of organizational, market, and psychological research regarding factors affecting innovation have not been developed to carefully address the questions of whether, when, and how particular types of creativity and innovation are promoted by the different

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Competence as Strategic Assets, *in* 1 HANDBOOK ON KNOWLEDGE MANAGEMENT 129 (Clyde W. Holsapple ed., 2003) (discussing different forms of knowledge that firms may exploit for value generation, and differential abilities to replicate, imitate, and appropriate value from such knowledge).

43 *Cf.* Rebecca Tushnet, *Naming Rights: Attribution and Law*, 2007 UTAH L. REV. 789, 794–98 (discussing problems of determining when the moral right of attribution should be required based on the relationship between authors and their works or on cultural conceptions of audiences).

44 *See, e.g.*, Greg Elmer, *Research Overview: Collaboration-Led Research*, 37 CANADIAN J. COMM., no. 1, 2012, at 189, 189; Georg von Krogh & Sebastian Spaeth, *The Open Source Software Phenomenon: Characteristics That Promote Research*, 16 J. STRATEGIC INFO. SYS. 236 (2007); Mandel, *supra* note 42, at 2001 ("Open and collaborative peer production involves widely dispersed contributions to a project by vast networks of individuals working towards a common goal. These individuals may be spread across the globe, may rarely interact, and may not even know each other."); Fred Gault & Eric von Hippel, *The Prevalence of User Innovation and Free Innovation Transfers: Implications for Statistical Indicators and Innovation Policy* (MIT Sloan Sch. of Mgmt., Working Paper No. 4722-09, 2009), *available at* http://dspace.mit.edu/bitstream/handle/1721.1/65619/Fred%20and%20Eric%202009%20%202-2-09%20FDG.pdf?sequence=1. *See generally* ERIC VON HIPPEL, DEMOCRATIZING INNOVATION (2005); LAWRENCE LESSIG, REMIX: MAKING ART AND COMMERCE THRIVE IN THE HYBRID ECONOMY (2008).

45 *See* Mandel, *supra* note 42, at 2004 ("Originality often requires divergent thought processes, which involve significantly intuitive cognitive function, while appropriateness often requires convergent evaluation, a more analytic thought process. . . . Divergent ideation itself can involve either or both of two different types of creative thought: problem-finding and problem-solving." (footnotes omitted)).

46 *Id.* at 2000–04; Jessica Silbey, *Harvesting Intellectual Property: Inspired Beginnings and "Work-Makes-Work," Two Stages in the Creative Processes of Artists and Innovators*, 86 NOTRE DAME L. REV. 2091, 2093–94 (2011).

47 *See, e.g.*, Jessica Silbey, *Comparative Tales of Origins and Access: Intellectual Property and the Rhetoric of Social Change*, 61 CASE W. RES. L. REV. 195, 201 (2010). *See generally* James Boyle, *The Second Enclosure Movement and the Construction of the Public Domain*, LAW & CONTEMP. PROBS., Winter/Spring 2003, at 33; Amy Kapczynski, *The Access to Knowledge Mobilization and the New Politics of Intellectual Property*, 117 YALE L.J. 804 (2008). The described deployed narratives may be inaccurate in light of historical analyses of the effects of intellectual property on innovation, which suggest that creating or enhancing patent rights does not always promote innovation. *See, e.g.*, Petra Moser, *Patents and Innovation: Evidence from Economic History*, J. ECON. PERSP., Winter 2013, at 23, 39–40.

forms of *government* funding that can occur. These analyses would have to address the nature, kind, and degree of innovative creativity of actors in different government institutions and in private or nonprofit institutions operating in different market structures under different regulatory regimes (e.g., regulated and unregulated natural and intellectual-property-created monopolies, oligopolies, and competitive markets; complex or simple product markets; and markets subject to significant or few intellectual property rights).[48] This absence of detailed, comparative institutional evaluations is notable in light of the developing literature on the "new institutional economics."[49]

Unlike in some of my other work,[50] I take no position here on whether and what kinds of intellectual property rights the government should create, grant, allow, retain, and control through these different types of funding and regulatory mechanisms. Intellectual property rights are not incompatible with most of the other government funding choices, such as direct subsidies or prizes, and usually are present along with them.[51] Conversely, some subsidies that distort markets dramatically by making alternative desired innovation technologies more or less economical—and thus more or less viable

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48 *Cf.* Robert M. Solow, *On Macroeconomic Models of Free-Market Innovation and Growth*, *in* ENTREPRENEURSHIP, INNOVATION, AND THE GROWTH MECHANISM OF THE FREE-ENTERPRISE ECONOMIES, *supra* note 13, at 15, 15 (noting the lack of joint research between macroeconomic technical-change-model builders and those who study behavioral economics and the history of particular innovations). *See generally* Kuznets, *supra* note 36, at 19 (discussing problems with performing such analyses); Fritz Machlup, *The Supply of Inventors and Inventions*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY, *supra* note 6, at 143 (discussing the non-fungibility of inventions).

49 *See, e.g.*, Erik Stam & Bart Nooteboom, *Entrepreneurship, Innovation and Institutions*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 421, 421–22; *cf.* Douglass C. North, *Institutional Bases for Capitalist Growth*, *in* ENTREPRENEURSHIP, INNOVATION, AND THE GROWTH MECHANISM OF THE FREE-ENTERPRISE ECONOMIES, *supra* note 13, at 35, 39 (noting the difficulty of understanding where "beliefs, norms, and institutions come from"). *See generally* WILLIAMSON, *supra* note 40; Douglass C. North, *The New Institutional Economics and Third World Development*, *in* THE NEW INSTITUTIONAL ECONOMICS AND THIRD WORLD DEVELOPMENT 17 (John Harriss et al. eds., 1995); Elinor Ostrom, *Doing Institutional Analysis: Digging Deeper than Markets and Hierarchies*, *in* HANDBOOK OF NEW INSTITUTIONAL ECONOMICS 819 (Claude Menard & Mary M. Shirley eds., 2005); Edward L. Rubin, Commentary, *The New Legal Process, the Synthesis of Discourse, and the Microanalysis of Institutions*, 109 HARV. L. REV. 1393 (1996); Oliver E. Williamson, *The New Institutional Economics: Taking Stock, Looking Ahead*, 38 J. ECON. LITERATURE 595 (2000).

50 *See, e.g.*, Joshua D. Sarnoff, *Patent-Eligible Inventions After* Bilski*: History and Theory*, 63 HASTINGS L.J. 53 (2011–2012); Joshua D. Sarnoff, Bilcare, KSR, *Presumptions of Validity, Preliminary Relief, and Obviousness in Patent Law*, 25 CARDOZO ARTS & ENT. L.J. 995 (2008); Joshua D. Sarnoff, *Abolishing the Doctrine of Equivalents and Claiming the Future After* Festo, 19 BERKELEY TECH. L.J. 1157 (2004).

51 *See* Frischmann, *supra* note 14, at 376 (noting the need for simultaneous institutional arrangements to address different types of market failures in research).

substitutes—may result in intellectual property rights that are wholly orthogonal to development or use of the innovations that are sought to be promoted. For one important example, consider that fossil-fuel R&D and consumption and production subsidies may lead to intellectual property rights that have no bearing on the development of renewable energy technologies, except regarding competitive market pricing for energy (and thus incentives to invest in renewable energy technology development). But eliminating fossil fuel subsidies and internalizing the carbon externalities imposed on society from fossil fuel consumption[52] would reduce the creation of such intellectual property. More importantly, it could likely lead to more rapid greenhouse gas (GHG) emission reductions and development of renewable energy technologies than the subsidization of such alternatives directly.[53]

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52 Many social harms from productive activities are not reflected in the market. *See, e.g.*, Kenneth J. Arrow, *The Organization of Economic Activity: Issues Pertinent to the Choice of Market Versus Nonmarket Allocation*, *in* JOINT ECON. COMM., 91ST CONG., THE ANALYSIS AND EVALUATION OF PUBLIC EXPENDITURES: THE PPB SYSTEM 47 (Comm. Print 1969) (explaining externalities as a subset of market failures, principally based on an inability to exclude small numbers of buyers and sellers in the relevant market). Given these "negative externalities," liability, regulation, or taxes must be imposed on the sources of the harms to reduce the activity levels to more socially efficient degrees, and taxes (or marketable permits) can do so at less cost than direct regulation. *See, e.g.*, WILLIAM J. BAUMOL & WALLACE E. OATES, THE THEORY OF ENVIRONMENTAL POLICY: EXTERNALITIES, PUBLIC OUTLAYS, AND THE QUALITY OF LIFE 178–81 (1975); William J. Baumol, *On Taxation and the Control of Externalities*, 62 AM. ECON. REV. 307, 308–12, 319 (1972) (citing, *inter alia*, JH DALES, POLLUTION, PROPERTY & PRICES (1968); R. H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960); A. C. PIGOU, THE ECONOMICS OF WELFARE (2d ed. 1924)). Note that taxation to internalize carbon externalities may also have substantial revenue-raising potential, which could then contribute to additional innovation subsidies, particularly as it may be easier to justify expenditures related to the purposes of the tax. *See, e.g.*, William D. Nordhaus, *Carbon Taxes to Move Toward Fiscal Sustainability*, ECONOMISTS' VOICE, Sept. 2010, at 1, 1–4 (proposing a carbon tax to raise revenue and noting numerous benefits, including moving toward meeting climate-reduction goals).

53 *See, e.g.*, UNITED NATIONS ENV'T PROGRAMME, REFORMING ENERGY SUBSIDIES: OPPORTUNITIES TO CONTRIBUTE TO THE CLIMATE CHANGE AGENDA 19 (2008), *available at* http://www.unep.ch/etb/publications/Energy%20subsidies/EnergySubsidiesFinalReport.pdf; Doug Koplow & John Dernbach, *Federal Fossil Fuel Subsidies and Greenhouse Gas Emissions: A Case Study of Increasing Transparency for Fiscal Policy*, 26 ANN. REV. ENERGY & ENV'T 361, 372–73 (2001); Joseph P. Tomain, *"Our Generation's Sputnik Moment": Regulating Energy Innovation*, 31 UTAH ENVTL. L. REV. 389, 396–97, 402 (2011) (discussing the negative externality of dirty energy from carbon emissions and the positive externalities of clean energy as reasons to regulate innovation in the energy sector, and also noting the potential to divert money from fossil fuel subsidies to clean energy development); Michael Barrett, Finding the Money: Securing Capital for Energy Innovation, Remarks at the Proceedings of the Canada–United States Law Institute Henry T. King, Jr. Annual Conference on Energy Security and Climate Change: A Canada–United States Common Approach? (Apr. 14–16, 2011), *in* 36 CAN.-U.S. L.J. 277, 293 (2012) ("Once you start building those costs [of hydrocarbon externalities] in [to conventional electric power projects], suddenly the economics of renewable projects start to look not so bad."). *See generally* CEES VAN BEERS & ANDRÉ DE MOOR, PUBLIC SUBSIDIES AND POLICY FAILURES: HOW SUBSIDIES DISTORT THE NATURAL ENVIRONMENT, EQUITY AND TRADE, AND HOW TO REFORM THEM (2001); Bjorn Larsen & Anwar Shah, *World Fossil Fuel Subsidies and Global Carbon Emissions* (World Bank Policy Research Working Paper Series, Working Paper No. 1002, 1992).

Significantly, although there are many choices of government funding for technology innovation and diffusion, the legal-academic literature tends to focus on only one set from the many possible approaches, even when comparing that set to some of the alternatives. That set of choices is: reliance on private investments, creation of intellectual property rights, and market production with associated intellectual property rights and other forms of market regulation. Similarly, without much detailed analysis, governments around the world appear intent to make private investments, intellectual property rights, and ex post market production and competition regulation the primary approaches to developing and deploying the needed climate change mitigation, adaptation technologies, and energy and transportation infrastructure.[54] Over the past few decades, the government's focus on private investment has been evidenced by the relative percentage of government expenditures for R&D, relying on private-sector substitution.[55] Nevertheless, government-funded R&D remains important, as reflected in recent increases in budget authority for it.[56]

Reliance on the private sector may be based on political constraints to raising sufficient revenue through taxation, auctioning marketable permits, and creating new or expanded federal bureaucracies.[57] Alternatively, such reliance

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[54] *See, e.g.*, Joshua D. Sarnoff, *The Patent System and Climate Change*, 16 VA. J.L. & TECH. 301, 307 n.30 (2011).

[55] *See, e.g.*, MICHAEL YAMANER, NAT'L SCI. FOUND., FEDERAL R&D SUPPORT SHOWS LITTLE CHANGE IN FY 2008, at 2 tbl.1 (2009); Patrick J. Clemins, *Historical Trends in Federal R&D*, *in* RESEARCH AND DEVELOPMENT FY 2010, at 21 (Am. Ass'n for the Advancement of Sci. ed., 2009).

[56] *See, e.g.*, OFFICE OF MGMT. & BUDGET, EXEC. OFFICE OF THE PRESIDENT, FISCAL YEAR 2013 BUDGET OF THE U.S. GOVERNMENT: ANALYTICAL PERSPECTIVES 365–71 (2012) [hereinafter OMB 2013 BUDGET REPORT], *available at* http://www.whitehouse.gov/sites/default/files/omb/budget/fy2013/assets/spec.pdf (noting that the FY2013 budget provides $141 billion for R&D, representing a 1% overall increase and 5% increase for nondefense R&D compared to FY2012).

[57] *See, e.g.*, Keith E. Maskus, *Intellectual Property and the Transfer of Green Technologies: An Essay on Economic Perspectives*, 1 WIPO J. 133, 136 (2009); Lawrence H. Goulder & William A. Pizer, *The Economics of Climate Change* 6–7 (Nat'l Bureau of Econ. Research, Working Paper No. 11923, 2006); *see also* Frischmann, *supra* note 14, at 352 (noting scarcity of government funds as justifying more careful analysis of reasons to fund basic commercial research); Menell & Scotchmer, *supra* note 38, at 1477 ("Probably the greatest virtue [of intellectual property] is that . . . . [n]o one is taxed more than his willingness to pay for any unit he buys; else he would not buy it. In contrast, funding out of general revenue runs the risk of imposing greater burdens on individual taxpayers than the benefits they receive."); *cf.* Joshua D. Sarnoff, *Cooperative Federalism, the Delegation of Federal Power, and the Constitution*, 39 ARIZ. L. REV. 205, 213 n.37 (1997) (citing Evan H. Caminker, *State Sovereignty and Subordinacy: May Congress Commandeer State Officers to Implement Federal Law?*, 95 COLUM. L. REV. 1001, 1044 (1995)) (noting historic political obstacles to raising federal revenue and to creating a national police force, which then required default to state regulation); Joshua D. Sarnoff, *The Continuing Imperative (but Only from a National Perspective) for Federal Environmental Protection*, 7 DUKE ENVTL. L. & POL'Y F. 225, 253–54 (1997) [hereinafter Sarnoff, *Continuing*

may reflect developing public preferences for private markets over government involvement in directing the economy, either by direct development of factors of production or by picking private "winners and losers" through subsidies and regulation.[58]

Reliance on private funding, property rights, and markets that are subject to government regulation to produce the desired innovation goals may arguably be justified in some cases by theoretical concerns. Professor Brett Frischmann suggested that tax mechanisms, unlike grants, should generally be used for commercial projects because they leave specific innovation input and output selection decisions to firms, which are "the best informed investor[s]" of the resources.[59] But it is debatable whether firms will make better decisions, given the potential for bureaucracies to develop multi-firm expertise across projects, markets, and technologies.[60] The approach of relying on such private funds, rights, and markets as a general strategy likely reflects deeply held belief systems regarding private markets and government regulation much more than carefully considered and particularized economic and political decisions.[61]

Imperative] (citing Richard B. Stewart, *Pyramids of Sacrifice?: Problems of Federalism in Mandating State Implementation of National Environmental Policy*, 86 YALE L.J. 1196, 1201 (1977); John P. Dwyer, *The Practice of Federalism Under the Clean Air Act*, 54 MD. L. REV. 1183, 1192–93 (1995)) (noting revenue and other constraints that may lead federal administrative agencies, particularly nascent ones, to defer to state environmental regulation even when federal regulation would be more efficient and effective).

58 *See, e.g.*, Neil B. Niman, *Picking Winners and Losers in the Global Technology Race*, CONTEMP. ECON. POL'Y, July 1995, at 77; *see also* STEPHEN MOORE & DEAN STANSEL, CATO INST., POLICY ANALYSIS 225, ENDING CORPORATE WELFARE AS WE KNOW IT (1995) ("The federal government has a poor record of picking industrial winners and losers, so the economic benefits that these programs are purported to create inevitably fail to materialize. Furthermore, corporate welfare programs create an uneven playing field; foster an incestuous relationship between business and government; are anti-consumer, anti-capitalist, and unconstitutional; and create a huge drain on the federal budget.").

59 Frischmann, *supra* note 14, at 352–53.

60 *Cf. id.* at 360 n.42, 364–66 (noting that maximizing returns on investment may not always reflect firm values and discussing the analogy to "Bayesian learning" in regard to ex ante variable estimates of potential research and product inputs of the outputs of initial R&D investment decisions). *But cf.* Arrow, *supra* note 6, at 609, 618–19 (discussing inefficiencies of decision making resulting from exclusive rights in information). Further, government decisions affect the stability of taxes compared to grant mechanisms, which in turn influences firm investment decisions. *Cf.* Victor Nee & Sonja Opper, *Bureaucracy and Financial Markets*, 62 KYKLOS 293, 298 (2009). *See generally* Paul W. Cherington et al., *Organization and Research and Development Decision Making Within a Government Department*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY, *supra* note 6 at 395.

61 *See* Frischmann, *supra* note 14, at 389–90 (noting that grants are easily justified for consumption market failures, but less easily justified—compared to intellectual property or taxes—for other market failures based on information signaling and decision-making differences; recognizing that even for such other market failures, "the government is sufficiently competent at identifying innovation types . . . amenable to market provision but for innovative process market failures, issuance of a grant may be a more targeted mechanism than alternatives and . . . . the ability for the government to monitor controllable risks . . . may be an

These belief systems may reflect even deeper concerns about protecting liberty and avoiding paternalism in regard to recognizing and forming personal preferences.[62] As a Canadian academic noted in 2006, "[S]ince the election of 1993, the motto seems to have been: Inside Government spending—*bad*, outside Government spending—*good*."[63]

B. *Limits to Natural-Experiments Analyses*

Analyses of the United States's adoption of the Bayh–Dole Act[64] and the subsequent worldwide proliferation of similar enactments[65] have looked at the

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advantage"). *Compare, e.g.*, *id.* at 373 (arguing that government market intervention is justified only when markets fail to perform efficiently and should be limited to addressing specific market failures), *with* BREZNITZ, *supra* note 16, at 6 (describing examples of rapid, national innovation developments that were contingent on extensive government involvement in many aspects of national innovation markets).

[62] *See* Sarnoff, *Continuing Imperative*, *supra* note 57, at 248–50 (discussing paternalism and effectuating jurisdictional preferences); Carol M. Rose, *Takings, Federalism, Norms*, 105 YALE L.J. 1121, 1145–46 (1996) (reviewing WILLIAM A. FISCHEL, REGULATORY TAKINGS: LAW, ECONOMICS, AND POLITICS (1995)) (discussing conflicts of jurisdiction size with Tiebout's thesis about citizen-sorting among jurisdictions to effectuate their preferences). *See generally* ALBERT O. HIRSCHMAN, EXIT, VOICE, AND LOYALTY: RESPONSES TO DECLINE IN FIRMS, ORGANIZATIONS, AND STATES (1970); Wallace E. Oates & Robert M. Schwab, *Economic Competition Among Jurisdictions: Efficiency Enhancing or Distortion Inducing?*, 35 J. PUB. ECON. 333 (1988); Charles M. Tiebout, *A Pure Theory of Local Expenditures*, 64 J. POL. ECON. 416 (1956).

[63] Brzustowski, *supra* note 15, at 42; *see also* Nymark, *supra* note 34, at 42 ("In Canada we have traditionally relied on the government sector for doing a large part of the science and technology effort. That is not sustainable. We have to find ways to shift the relative burden of innovation expenditures to the private sector—not an easy thing to do."); Stam & Nooteboom, *supra* note 49, at 421 ("The popularity of a policy instrument is not necessarily an indication of consensus about its effectiveness, or clarity about its content."); *cf.* Keric D. Clanahan, Drone-Sourcing? *United States Air Force Unmanned Aircraft Systems, Inherently Governmental Functions, and the Role of Contractors*, 22 FED. CIR. B.J. 135, 146–47 (2012) (discussing extensive government reliance on private contractors, noting a preference for outsourcing that originated with the Eisenhower Administration, and identifying the "inherently government function" doctrine); *id.* at 139 (questioning whether many tasks relating to use of unmanned aircraft are being performed by contractors "*that should be reserved exclusively for government personnel*"); Joshua Goldstein, Book Note, *Searching for Innovation in Foreign Assistance*, FLETCHER F. WORLD AFF., Winter/Spring 2009, at 131, 131–32 (reviewing REINVENTING FOREIGN AID (William Easterly ed., 2008)) (discussing William Easterly's critical comparison of Jeffrey Sachs and other foreign-aid planners to "Marxists, for whom 'all countries are destined to attain the goal of development, meaning industrialization and a high mass standard of living, not to mention peace and democracy'"). *But see, e.g.*, P. Aghion et al., Industrial Policy and Competition 2 (June 18, 2011) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1811643 (encouraging discussion not of whether industrial sectoral policies should exist but of how they should be designed and governed).

[64] Act of Dec. 12, 1980, Pub. L. No. 96-517, §§ 201–211, 94 Stat. 3019, 3019–28 (codified as amended at 35 U.S.C. §§ 201–211 (2006)) [hereinafter Bayh–Dole Act]; *see* Stevenson–Wydler Technology Innovation Act of 1980, Pub. L. No. 96-480, 94 Stat. 2311 (codified as amended at 15 U.S.C. §§ 3701–3714 (2006)) [hereinafter Stevenson–Wydler Act] (addressing technology transfer from government laboratories).

[65] *See* Thomas J. Siepmann, *The Global Exportation of the U.S. Bayh-Dole Act*, 30 U. DAYTON L. REV. 209 (2004); *cf.* David S. Abrams, *Did TRIPS Spur Innovation? An Analysis of Patent Duration and Incentives*

effects of these enactments on innovation, commercialization, and dissemination of technologies.[66] These analyses are perhaps the best-studied natural examples used to analyze the effects of government choices on innovation. They suggest that the Bayh–Dole Act and its foreign equivalents have led to increased university patenting and licensing, increased attraction of industry R&D funding for university research, and increased spinoffs.[67]

This does not prove, however, that the Bayh–Dole Act actually facilitated greater technology transfer or greater commercialization of innovations than otherwise would have occurred.[68] There are many reasons why granting

to Innovate, 157 U. PA. L. REV. 1613, 1641–42 (2009) (analyzing data to evaluate the relationship between the TRIPS Agreement's heterogeneous extension of patent terms, given different processing times by field of technology, and the number of patent counts issued and citations to them, as a proxy for assessing innovation rates); Bradly J. Condon & Tapen Sinha, Climate Change and Intellectual Property Rights for New Plant Varieties 17 (Oct. 15, 2011) (unpublished manuscript), *available at* http://ssrn.com/abstract=1944593; B. Zorina Khan & Kenneth L. Sokoloff, Of Patents and Prizes: Great Inventors in Britain and the United States, 1750–1930, at 3–5 (Aug. 2006) (unpublished manuscript), *available at* http://www.rogerfarmer.com/NewWeb/testing/AxelConference/Papers/sokoloff.pdf (analyzing natural experiments in patent systems and their effects on inducing inventive activity by "great inventors"). *See generally* Jasjeet S. Sekhon & Rocío Titiunik, *When Natural Experiments Are Neither Natural Nor Experiments*, 106 AM. POL. SCI. REV. 35 (2012).

66 *See, e.g.*, DAVID C. MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH-DOLE ACT IN THE UNITED STATES (2004); Sara Boettiger & Alan B. Bennett, *Bayh-Dole: If We Knew Then What We Know Now*, 24 NATURE BIOTECHNOLOGY 320 (2006); Loet Leydesdorff & Martin Meyer, *The Decline of University Patenting and the End of the Bayh-Dole Effect*, 83 SCIENTOMETRICS 355 (2010); Anthony D. So et al., *Is Bayh-Dole Good for Developing Countries? Lessons from the US Experience*, 6 PLOS BIOLOGY 2078, 2079 (2008); Charles R. McManis & Sucheol Noh, *The Impact of the Bayh-Dole Act on Genetic Research and Development: Evaluating the Arguments and Empirical Evidence* (Wash. Univ. in St. Louis Sch. of Law Legal Studies Research Paper Series, Paper No. 11-05-04, 2011).

67 *See, e.g.*, WENDY H. SCHACHT, CONG. RESEARCH SERV., RL32076, THE BAYH-DOLE ACT: SELECTED ISSUES IN PATENT POLICY AND THE COMMERCIALIZATION OF TECHNOLOGY 8–9 (2012); Margo A. Bagley, *Academic Discourse and Proprietary Rights: Putting Patents in Their Proper Place*, 47 B.C. L. REV. 217, 217–18, 233–34 (2006); David C. Mowery et al., *The Effects of the Bayh-Dole Act on U.S. University Research and Technology Transfer*, *in* INDUSTRIALIZING KNOWLEDGE: UNIVERSITY-INDUSTRY LINKAGES IN JAPAN AND THE UNITED STATES 269, 269–70 (Lewis M. Branscomb, Fumio Kodama & Richard Florida eds., 1999); Bhaven N. Sampat, *Patenting and US Academic Research in the 20th Century: The World Before and After Bayh-Dole*, 35 RES. POL'Y 772, 773 (2006); So et al., *supra* note 66, at 2079; McManis & Noh, *supra* note 66, at 12–19.

68 *See, e.g.*, Dov Greenbaum, *Academia to Industry Technology Transfer: An Alternative to the Bayh-Dole System for Both Developed and Developing Nations*, 19 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 311, 378–409 (2009); *cf.* BUSH, *supra* note 16, at 31–32 (suggesting that government agencies not require patenting or assignment of inventions to the government but retain flexibility to compel patent assignments); Jay P. Kesan, *Transferring Innovation*, 77 FORDHAM L. REV. 2169, 2207 (2009) (noting "overwhelming" evidence that university technology transfer activities that have developed in light of the Bayh-Dole Act are "predominantly patent-centric and revenue driven with a single-minded focus on licensing income and reimbursement for legal expenses," resulting in less technology transfer "to many different sectors" than could otherwise occur).

intellectual property rights to government grant recipients may have been inefficient and costly to the public when promoting downstream innovation. Professor Frischmann has observed that—assuming a patentable invention results from grant funding—there is unlikely to be an expansive number of downstream innovations facing impediments to development that require government intervention. The intellectual property rights limit competition in the innovation market without reducing production risks, thus enhancing positive spillovers, hastening or subsidizing the innovation, or adding information about these concerns. While the grant of rights may facilitate licensing, it also imposes costs of reduced pre-patent dissemination, underutilization of the invention, and potential blocking-patent (overlapping rights) problems. Moreover, "the risk of foreign free-riding" is the primary impetus justifying continuing government intervention downstream of grant funding.[69]

Further, it is widely believed that the Bayh–Dole Act attracted industry funding at the cost of changing academic norms that affect intrinsic and extrinsic motivations for basic research.[70] The increased level of commercialization induced by the Bayh–Dole Act is thus sometimes used to argue for intellectual property rights—particularly patents—noting that granting private ownership of intellectual property is preferable to retained government development of the research prospects (at least because of the private funding inputs that it generates). In contrast, the change in norms is sometimes used to argue against such rights and to focus on concerns about

[69] Frischmann, *supra* note 14, at 408 n.268; *see id.* at 407–13 (noting also the limits of domestic firm efforts at foreign enforcement and arguing that intellectual property is not needed in addition to grant funding if derivative research is patentable and is less efficient than the alternative of cooperative research—which enhances private capacity and builds lead-time advantage for derivative innovations—if the derivative research is not patentable).

[70] *See, e.g.*, Eisenberg, *supra* note 27; Rebecca S. Eisenberg, *Proprietary Rights and the Norms of Science in Biotechnology Research*, 97 YALE L.J. 177 (1987); Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, LAW & CONTEMP. PROBS., Winter/Spring 2003, at 289; Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77 (1999); *cf.* Bagley, *supra* note 67, at 219 n.10 (noting other social costs, including jobs and industrial research-fund losses from off-shoring university–industry collaborative research); Werner Bönte, *What Do Scientists Think About Commercialization Activities?*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 337, 337–53 (discussing German scientists' attitudes, identified by a study of the Max Planck Institute); Rebecca S. Eisenberg & Arti K. Rai, *Harnessing and Sharing the Benefits of State-Sponsored Research: Intellectual Property Rights and Data Sharing in California's Stem Cell Initiative*, 21 BERKELEY TECH. L.J. 1187, 1200 (2006) (discussing concerns over restrictions on data and materials transfers). *But see, e.g.*, F. Scott Kieff, *Facilitating Scientific Research: Intellectual Property Rights and the Norms of Science—A Response to Rai and Eisenberg*, 95 NW. U. L. REV. 691 (2001).

anti-commons and other effects that may result from such ownership.[71] But comparatively little analysis has actually been provided regarding whether the reasons for such increased innovation and commercialization may have more to do with the comparative internal cultures, expertise, and various motivations of the actors in private firms, universities, and government agencies, and less to do with the legal regime allocating rights and regulating the markets. Institutional culture is notoriously difficult to analyze,[72] expertise is hard to measure,[73] and motivation is hard to observe—particularly as it may be unconscious.[74]

Moreover, decisions regarding government innovation funding-mechanism choice may be "idiosyncratic" in that they may not fit within a general economic framework for comparing means of technology inducement.[75] For example, good analyses of international technology transfer mechanisms are developing that demonstrate these mechanisms' complex relationships to, *inter alia*, project size, number of projects, trade, foreign direct investment, intellectual property rights, economic and regulatory environments, human capital, level of education, R&D funding, natural resources, and patterns of

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71 *See, e.g.*, Rebecca S. Eisenberg, *Noncompliance, Nonenforcement, Nonproblem? Rethinking the Anticommons in Biomedical Research*, 45 HOUS. L. REV. 1059, 1084–85 (2008); Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, SCI., May 1998, at 698, 698–99; Kieff, *supra* note 70, at 692, 704–05; Arti Kaur Rai, *Evolving Scientific Norms and Intellectual Property Rights: A Reply to Kieff*, 95 NW. U. L. REV. 707, 710 (2001); *see also* Jeremy M. Grushcow, *Measuring Secrecy: A Cost of the Patent System Revealed*, 33 J. LEGAL STUD. 59, 82–83 (2004) (finding that academic patenting may have delayed research publication, increasing risks of wasteful duplication of research); *cf.* Paul A. David, *Mitigating "Anticommons" Harms to Research in Science and Technology: New Moves in "Legal Jujitsu" Against Unintended Adverse Consequences of the Exploitation of Intellectual Property Rights on Results of Publicly and Privately Funded Research*, 2 WIPO J. 59, 62–63 (2010) (summarizing studies of royalty stacking and other anticommons effects in various industries and scientific research). *See generally* MICHAEL HELLER, THE GRIDLOCK ECONOMY: HOW TOO MUCH OWNERSHIP WRECKS MARKETS, STOPS INNOVATION, AND COSTS LIVES (2008).

72 *See, e.g.*, Edgar H. Schein, *Organizational Culture*, 45 AM. PSYCHOLOGIST 109, 111–12 (1990) (noting problems of definition, of levels of manifestation—artifacts, values, and underlying assumptions—and of deciphering content); Linda Smircich, *Concepts of Culture and Organizational Analysis*, 28 ADMIN. SCI. Q. 339, 339 (1983) ("The culture concept has been borrowed from anthropology, where there is no consensus on its meaning. It should be no surprise that there is also variety in its application to organization studies."). *See generally* MARCEL DANESI & PAUL PERRON, ANALYZING CULTURES: AN INTRODUCTION & HANDBOOK (1999); W. Gibb Dyer Jr., *Culture in Organizations: A Case Study and Analysis* (MIT Sloan Sch. of Mgmt., Working Paper No. 1279-82, 1982).

73 *See, e.g.*, DEVELOPMENT OF PROFESSIONAL EXPERTISE: TOWARD MEASUREMENT OF EXPERT PERFORMANCE AND DESIGN OF OPTIMAL LEARNING ENVIRONMENTS (K. Anders Ericsson ed., 2009).

74 *See, e.g.*, DAVID C. MCCLELLAND, HUMAN MOTIVATION 15–30, 43–48 (1987).

75 Timothy J. Brennan et al., *Prizes, Patents, and Technology Procurement: A Proposed Analytical Framework* 6 (Res. for the Future, Discussion Paper No. 11–21, 2011).

production.[76] But the factors at issue may ultimately be country- and culture-specific.

In summary, we do not know very much yet about important issues that should inform our decisions. We do not know: what government innovation choices have actually been made, their results, and their effectiveness across a number of dimensions; why we have made those choices; how those choices might compare to alternatives; what factors influence the comparative effectiveness of those choices; and the extent to which those factors are driven by particular cultural considerations that may be subject to manipulation. We also do not know much about how to mediate political disputes or hurdles to adopting particular choices, which might in turn affect cultural norms and further inflect comparative effectiveness.

C. *The Need for Better Analyses and Three General Proposals to Help Perform Them*

Given the limits to the analyses described above, we desperately need better analyses of the determinants of the differences in outcomes.[77] This likely may be possible only by carefully analyzing particular institutions and trying to

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[76] *See, e.g.*, DOMINIQUE FORAY, INT'L CTR. FOR TRADE & SUSTAINABLE DEV., ISSUE PAPER NO. 23, TECHNOLOGY TRANSFER IN THE TRIPS AGE: THE NEED FOR NEW TYPES OF PARTNERSHIPS BETWEEN THE LEAST DEVELOPED AND MOST ADVANCED ECONOMIES 4–7 (2009) (providing a typology of technology transfer and noting limits to transfer by foreign direct investment and infrastructure creation); Gisèle Schmid, *Technology Transfer in the Clean Development Mechanism: The Role of Host Country Characteristics* 2–4, 21–22 (Univ. of Geneva Working Paper Series, Working Paper No. 12021, 2012); Dany Bahar, Ricardo Hausmann & César A. Hidalgo, *International Knowledge Diffusion and the Comparative Advantage of Nations* 4–5 (Harvard Kennedy Sch. Faculty Research Working Paper Series, Working Paper No. 12-020, 2012), *available at* http://ssrn.com/abstract=2087607 (noting that knowledge diffusion and technology transfer may require direct human interactions and identifying a new measure of such diffusion, i.e., the emergence of new export technologies relative to exports from geographically proximate countries); Lee Branstetter, Raymond Fisman & C. Fritz Foley, *Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U.S. Firm-Level Data* 16–28 (Nat'l Bureau of Econ. Research, Working Paper No. 11516, 2005) (analyzing relationships between intellectual property rights, multinational corporation foreign-affiliate R&D, technology transfers, and R&D spending). *See generally* KEITH E. MASKUS, INT'L CTR. FOR TRADE & SUSTAINABLE DEV., ISSUE PAPER NO. 7, ENCOURAGING INTERNATIONAL TECHNOLOGY TRANSFER (2004); Keith E. Maskus, *The Role of Intellectual Property Rights in Encouraging Foreign Direct Investment and Technology Transfer*, 9 DUKE J. COMP. & INT'L L. 109 (1998).

[77] I am limiting analysis to innovation outcomes. Measuring overall outcomes of R&D and innovation policies on society is even more complex. *See generally* STEVE OLSON & STEPHEN MERRILL, NAT'L ACAD. OF SCI., MEASURING THE IMPACTS OF FEDERAL INVESTMENTS IN RESEARCH: A WORKSHOP SUMMARY 7–17 (2011) (noting limitations of performance measures for answering policy questions, contingency of such measures on complementary policies, incompatibility of and tradeoffs among performance measures, and failure of measurable quantities to capture important outcomes—including the benefits of failures in redirecting R&D and the inability to capture internal system dynamics in performance measures).

conduct experiments with comparable institutions where different approaches are tried simultaneously (recognizing that adequate controls for such experiments may not exist). Rare natural experiments may sometimes demonstrate causal effects, but they cannot support analysis of whether alternatives not chosen would have led to better outcomes. As one commenter has noted regarding the Bayh–Dole debates, analysis is "inextricably encumbered by the problem of documenting a counterfactual assertion of the form: if we had not do[ne] that, the world would now be different."[78] The analogy here to federalism theory and the need for laboratories of democracy is apt.[79] Moreover, given that the rights and markets at issue may be national or international in scope,[80] it will require both adjustments to domestic laws—national and subnational laws—as well as amendments to international trade and intellectual property treaties to permit the necessary international or domestic segmentation of markets for the needed experimentation to occur.[81]

A better understanding needs to be developed soon. The current state of analysis is rudimentary, massive amounts of money will be spent on climate change and infrastructure innovation, and the outcomes of funding choices are very important. The three proposals suggested here would help improve evaluations of such choices and consequently help government decision making regarding them in the first instance. These proposals are: (1) better tracking of government-innovation expenditure decisions and their outcomes; (2) self-conscious and documented legislative and agency decision making

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[78] Paul A. David, *The Economic Logic of "Open Science" and the Balance Between Private Property Rights and the Public Domain in Scientific Data and Information: A Primer* 16 (Stanford Inst. for Econ. Policy Research, Discussion Paper No. 02-30, 2003).

[79] *See* New State Ice Co. v. Liebmann, 285 U.S. 262, 311 (1932) (Brandeis, J., dissenting).

[80] *Compare, e.g.*, Edward L. Rubin & Malcolm Feeley, *Federalism: Some Notes on a National Neurosis*, 41 UCLA L. REV. 903, 910–14 (1994) (noting a relatively uniform public and national decision-making process within the United States), *with* Robert F. Nagel, *The* Term Limits *Dissent: What Nerve*, 38 ARIZ. L. REV. 843, 845–47, 855 (1996) (challenging that argument based on the lack of preemptive legislation and Supreme Court decisions to overturn legislation).

[81] I am indebted to Peter Yu for this point, particularly in regard to the need to make adjustments to national treatment and nondiscrimination obligations under the Government Procurement Agreement. *See* Agreement on Government Procurement, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 4(b), 1915 U.N.T.S. 103 [hereinafter GPA]; *cf.* S. James Boumil III, Comment, *China's Indigenous Innovation Policies Under the TRIPS and GPA Agreements and Alternatives for Promoting Economic Growth*, 12 CHI. J. INT'L L. 755, 773–77 (2012) (discussing TRIPS and GPA concerns with Chinese indigenous innovation procurement policies). Note that some countries, including the United States, exclude R&D from their commitments under the GPA. *See Appendices and Annexes to the GPA*, WORLD TRADE ORG., http://www.wto.org/english/tratop_e/gproc_e/appendices_e.htm (last visited May 12, 2013).

regarding expenditure form choices; and (3) controlled experiments that go beyond existing natural experiments.[82]

Better tracking of the choices of mechanisms for government innovation expenditures and their outcomes will permit better understanding of how the money was spent and what innovation outputs resulted. At least since 2008, as a result of the adoption in 2006 of the Transparency Act,[83] U.S. government agencies have been required to track their awards of at least $25,000. The reporting targets include procurement contracts, grants, loans, and other expenditures, and thus include most innovation funding inputs—even if not broken down as such. Further, this data has been reported electronically, which permits aggregation and data analysis.[84] Government agencies also track their budget authority for R&D,[85] but they rarely track the innovation outputs from such inputs in a manner that would permit comparative analysis.

The most extensive data on R&D and innovation funding by government is compiled by the National Science Foundation (NSF) through its Federal Funds Survey.[86] This survey data provides funding input information reported by government agencies by type of performer (i.e., the organization doing the work) and plant (i.e., facilities), but does not include clandestine R&D, is not verified outside the reporting agency, contains estimates that are encouraged where actual data is not available, and (most significantly) does not contain relevant output measures.[87] These surveys lack numerous details, are provided after the fact, may not separate research from development, and may not be

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82 *Cf.* Michael J. Madison et al., *Constructing Commons in the Cultural Environment*, 95 CORNELL L. REV. 657, 676–77 (2010) (discussing a three-pronged approach to implement an Institutional Analysis and Development framework, which includes a taxomony of practices, the identification of variables, and preserving flexibility of reponses).

83 Federal Funding Accountability and Transparency Act of 2006, Pub. L. No. 109-282, 120 Stat. 1186 (codified as amended at 31 U.S.C. § 6101 (2006)).

84 The compiled data is made available to the public at USASPENDING.GOV, http://www.usaspending.gov/ (last visited May 12, 2013).

85 *See, e.g.*, OMB 2013 Budget Report, *supra* note 56, at 370–71.

86 *See Survey of Federal Funds for Research and Development*, NAT'L SCI. FOUND., http://www.nsf.gov/statistics/srvyfedfunds/ (last visited May 12, 2013) [hereinafter *NSF Survey*]; *see also Federal Funds for R&D*, NAT'L SCI. FOUND., http://www.nsf.gov/statistics/fedfunds/ (last visited May 12, 2013) (tracking budget obligations).

87 *See NSF Survey*, *supra* note 86; *see also* NAT'L RESEARCH COUNCIL, INDUSTRIAL RESEARCH AND INNOVATION INDICATORS: REPORT OF A WORKSHOP 3 (Ronald S. Cooper & Stephen A. Merrill eds., 1997) (noting the difficulty of measuring innovation outputs).

able to be accessed except at aggregate levels due to confidentiality concerns, which precludes policy analysis in real time.[88]

In contrast, some recent efforts are being developed by federal agencies to track and measure the innovation outputs of federal funding inputs, although participation in reporting is currently voluntary.[89] Further, some voluntarily reported innovation output data—on product creation, organizational creation (startups), intellectual property filings and grants, and licensing formation and revenue—is compiled annually by the Association of University Technology Managers (AUTM).[90] This data is collected from U.S. and Canadian institutions—principally universities, colleges, and hospitals, but also a few national laboratories and third-party technology investment firms—and includes government research funding inputs.[91] However, such data is not mandatory or subject to confirmation and does not include much important information regarding outputs (e.g., patent licensing efforts and license terms).[92] Thus, data on licensing and other transfers of technology may not be available and must be estimated, both in these countries and worldwide.[93] As others have noted, moreover, the lack of such data may significantly affect the marketability of the technologies.[94]

Some power to compel reporting of innovation outputs (including licensing activity and terms) already exists for federally funded research subject to the

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88 *See, e.g.*, NAT'L RESEARCH COUNCIL, RESEARCH AND DEVELOPMENT DATA NEEDS: PROCEEDINGS OF A WORKSHOP 3, 7, 12, 15 (Bronwyn H. Hall & Stephen A. Merrill eds., 2005).

89 *See What is Star Metrics?*, STAR METRICS, https://www.starmetrics.nih.gov/ (last visited May 12, 2013) (noting various innovation output measures that include job creation, scientific knowledge measures such as publications and citations, social outcome measures such as health outcomes and environmental impacts, workforce outcome measures such as student mobility and employment, and economic growth measures such as patents and start-ups). The STAR METRICS effort—Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science—is led by the National Institutes of Health, the National Science Foundation, and the White House Office of Science and Technology Policy. *Id.*

90 *See, e.g.*, *AUTM Licensing Activity Survey: FY2011*, ASS'N U. TECH. MANAGERS, http://www.autm.net/FY_2011_Licensing_Activity_Survey/8730.htm (last visited May 12, 2013).

91 *See, e.g.*, *id.*; *see also* Richard A. Jensen, *Startup Firms from Research in U.S. Universities*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 273, 273–76 (analyzing AUTM data from 1993–2004 and noting other studies using AUTM data).

92 *See, e.g.*, *AUTM U.S. Survey*, *supra* note 90.

93 *See, e.g.*, Harhoff, *supra* note 41, at 60 (discussing various estimates of world markets for technology, including royalty and licensing revenues, sales of patent rights, and effects of transfer pricing).

94 *See, e.g.*, Mark A. Lemley & Nathan Myhrvold, *How to Make a Patent Market*, 36 HOFSTRA L. REV. 257, 258 (2007) (noting that "publication of patent assignment and license terms" would make a huge difference to developing markets for patents).

Bayh–Dole Act.[95] In addition to the statutorily required reporting obligations that assure disclosures of inventions and related patenting activities,[96] implicit authority likely exists to require disclosures of licensing efforts and terms to determine whether to exercise march-in rights or use the statutory license authority.[97] Additional power to compel disclosures of federally funded innovation outputs or federally granted intellectual property rights could readily be created by new legislation without triggering any concern for regulatory takings (and certainly not if done prospectively). As noted in *Ruckelshaus v. Monsanto*,[98] federal benefits may be conditioned on the disclosure of trade secrets, and no compensable taking occurs when a private party agrees to accept the benefits with such conditions.[99] Of course, such legislation could protect trade secrecy while permitting useful data gathering and analysis.

By creating requirements for affirmative and intentional government choices and reporting regarding these mechanisms (and assuming honest disclosures), the reasons why the money went to the specific inputs can be known. This may help both to avoid automatic default to potentially costly and relatively ineffective "business as usual" approaches and allow for commencement of the process of analyzing the fit—or lack thereof—between decisions and outcomes. The premise of an extensive environmental literature regarding impact statements is that requiring ex ante consideration of alternatives leads to better decision making and policy outcomes.[100]

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95 *See* 35 U.S.C. § 202(c)(1), (5) (2006).

96 *Id.*

97 35 U.S.C. §§ 202(c)(4), 203 (2006); *cf.* MATTHEW RIMMER, INTELLECTUAL PROPERTY AND CLIMATE CHANGE: INVENTING CLEAN TECHNOLOGIES 283 (2011) (citing Lisa Larrimore Ouellette, Comment, *Addressing the Green Patent Global Deadlock Through Bayh-Dole Reform*, 119 YALE L.J. 1727 (2010)) (noting the ability to change patenting and licensing defaults and the terms of access for federally funded technologies).

98 Ruckelshaus v. Monsanto Co., 467 U.S. 986 (1984).

99 *See id.* at 1007–08. So long as the trade secret rights are not destroyed, the information should retain substantial value and thus should not result in a regulatory taking even if the requirement for disclosure of information to the government is imposed retroactively. *See, e.g.*, Lingle v. Chevron U.S.A. Inc., 544 U.S. 528, 539 (2005) ("[T]he complete elimination of a property's value is the determinative factor."); Penn Cent. Transp. Co. v. New York City, 438 U.S. 104, 131 (1978) (noting that Supreme Court cases "uniformly reject the proposition that diminution in property value, standing alone, can establish a 'taking'").

100 *See* National Environmental Policy Act of 1969, Pub. L. No. 91-190, 83 Stat. 852 (1970) (codified as amended at 42 U.S.C. § 4321 *et seq.* (2006)); Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 349 (1989); *cf.* Mark Squillace & Alexander Hood, *NEPA, Climate Change, and Public Lands Decision Making*, 42 ENVTL. L. 469, 481–85, 510–25 (2012) (discussing the need for quantitation and pricing of outputs to permit cumulative impacts assessment in regard to federal land's greenhouse gas emissions, and proposing

Some analysts have noted the need for better decision making and management within government energy innovation institutions by clarifying their mission, attracting better leadership, "cultivating an entrepreneurial and competitive culture[,] setting up a structure and management system that balances independence and accountability[,] and ensuring stable, predictable funding."[101] They have also noted that predictable, long-term funding will permit greater experimentation with alternative research pathways,[102] and they have identified the lack of fit between institutions that make R&D decisions and incentives for commercial deployment of technologies.[103] Perhaps most importantly, they have acknowledged that for the types of government funding directed at the private sector "there is no apparent rationale or strategy behind the choices made regarding what type of relationships . . . should be used in different cases . . . [and] DOE documents show no evidence of any high-level analysis or planning for optimizing interactions with the private sector."[104] This is simply shocking, given both the amount of money at issue and the needs that such funding is supposed to address. It will only get worse if extrapolated beyond the United States and the energy context to global efforts to address climate change.

Finally, creating various non-natural experiments may provide understanding as to what works better, when, and why. Such "controlled environment" experiments can help reveal which approaches perform better in particular, comparative circumstances.[105] Significantly, such better understanding will require multiple kinds of experiments employing different funding mechanisms in different national and institutional cultures to develop a meaningful body of information to analyze. To do so may sometimes require segmentation of markets within international regions or particular nations, which in turn may require amending treaty laws to permit restriction of

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rules to hold agencies more accountable). *See generally* SERGE TAYLOR, MAKING BUREAUCRACIES THINK: THE ENVIRONMENTAL IMPACT STATEMENT STRATEGY OF ADMINISTRATIVE REFORM (1984).

101 ANADON ET AL., *supra* note 34, at 2; *see* Mark Radka, *Some Perspectives About the Climate Technology Centre/Climate Technology Network*, UNITED NATIONS FRAMEWORK CONVENTION CLIMATE CHANGE, http://unfccc.int/files/meetings/ad_hoc_working_groups/lca/application/pdf/some_perspectives_about_the_ctc_ctn.pdf (last visited May 12, 2013) (discussing ten similar factors that lead to successful technology centers).

102 *See, e.g.*, ANADON ET AL., *supra* note 34, at 2.

103 *See, e.g.*, *id.* at 1–2.

104 *Id.* at 3.

105 Paul L. Joskow & Nancy L. Rose, *The Effects of Economic Regulation*, *in* 2 HANDBOOK OF INDUSTRIAL ORGANIZATION, *supra* note 36, at 1449, 1461; *see id.* at 1461–62 (discussing different types of controlled experiments).

government funding to regional or domestic private entities.[106] In particular, these experiments might measure both the timing and quality of the innovation outputs induced by various types of funding mechanisms chosen for the different markets.

Creating these types of national or subnational experiments, moreover, will not necessarily conflict with efforts to promote substantive harmonization of "best practices" for the content of national laws within the World Trade Organization (WTO) TRIPS regime,[107] the World Intellectual Property Organization (WIPO) treaty complex,[108] or other intergovernmental fora. An inadequate theoretical understanding exists regarding optimal intellectual property and other innovation-related laws. Much of the current international effort at harmonization either reproduces the default to untested beliefs in greater reliance on either private markets or government regulation, or reflects the exercise of raw political power and trade efforts to promote comparative national advantages.[109] Accordingly, the proposed experimentation may actually promote harmonization by providing reasons to harmonize at particular levels of national law protection.[110]

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[106] Intellectual property rights are based on national laws, whereas relevant product markets may be international in scope. Although some experiments may therefore permit private entities to compete for both national rights and international markets for intermediate and ultimate innovation outputs, such winner-take-all experiments may hide useful information regarding comparative effectiveness. Accordingly, by segmenting markets, different approaches can be tried simultaneously. Of course, such segmented markets may sometimes not reach sufficient scale to induce the desired innovation outputs. Careful thought will therefore be needed regarding how to design useful, non-natural experiments.

[107] *See* Agreement on Trade-Related Aspects of Intellectual Property Rights, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299 [hereinafter TRIPS Agreement].

[108] *See, e.g.*, Paris Convention for the Protection of Industrial Property, Mar. 20, 1883, as revised at Stockholm, July 14, 1967, 21 U.S.T. 1583, 828 U.N.T.S. 305.

[109] *See, e.g.*, Laurence R. Helfer, *Regime Shifting: The TRIPs Agreement and New Dynamics of International Intellectual Property Lawmaking*, 29 YALE J. INT'L L. 1, 42–45 (2004). *See generally* SUSAN K. SELL, PRIVATE POWER, PUBLIC LAW: THE GLOBALIZATION OF INTELLECTUAL PROPERTY RIGHTS (2003).

[110] There is an extensive but highly contested economic, corporate, financial, environmental, public choice, international relations, and constitutional literature on federalism and race-to-the-bottom and race-to-the-top effects of competitive experimentation within or across jurisdictions. This literature bears citation but not elaboration here. *See, e.g.*, Kirsten H. Engel, *State Environmental Standard-Setting: Is There a "Race" and Is It "to the Bottom"?*, 48 HASTINGS L.J. 271 (1997); Daniel C. Esty, *Revitalizing Environmental Federalism*, 95 MICH. L. REV. 570, 629–33 (1996); Jonathan R. Macey, *Federal Deference to Local Regulators and the Economic Theory of Regulation: Toward a Public-Choice Explanation of Federalism*, 76 VA. L. REV. 265, 274–90 (1990); Wallace E. Oates & Robert M. Schwab, *Economic Competition Among Jurisdictions: Efficiency Enhancing or Distortion Inducing?*, 35 J. PUB. ECON. 333 (1988); Richard L. Revesz, *Rehabilitating Interstate Competition: Rethinking the "Race-to-the-Bottom" Rationale for Federal Environmental Regulation*, 67 N.Y.U. L. REV. 1210, 1213–21, 1239–53 (1992); Sarnoff, *Continuing Imperative*, *supra* note 57, at 278–85; Richard B. Stewart, *Environmental Regulation and International*

Even if domestic laws are adopted and international treaties are modified to permit these proposals for tracking, decision-making documentation, and experimentation, it may still be difficult to disentangle the relationships among government funding choices, comparative outcomes, institutional and national cultural considerations, and simple fortuity or serendipity.[111] In the end, the choices may have to be "muddle[d] through" based on inadequate theoretical and empirical guidance, a limited set of values, and historic experiences.[112]

The next Part of this Article provides a classification of government choices of innovation funding mechanisms. The classification is admittedly idiosyncratic, but it has the benefit of clearly highlighting the possible major differences of approach and the substantial similarities among approaches across a number of dimensions. Legislators, administrators, and law treaty negotiators and implementers may want to pay particular attention to the broad range of options the next Part describes, in order to avoid conceptual default to a narrower set of options that may be less effective. Many options may require the creation of new institutions or bureaucracies, or the adaptation of existing institutions and bureaucracies for effective implementation. Critically, understanding the choices may generate the recognition that path dependence is not inevitable.[113]

Before turning to the classification, it bears noting that efforts to better understand how to effectively promote technology development and transfer to

Competitiveness, 102 YALE L.J. 2039, 2059 (1993); Peter P. Swire, *The Race to Laxity and the Race to Undesirability: Explaining Failures in Competition Among Jurisdictions in Environmental Law*, 14 YALE L. & POL'Y REV. (SYMPOSIUM ISSUE) 67, 75, 80–87 (1996); Tiebout, *supra* note 62; *see also* Daniel B. Rodriguez, *Turning Federalism Inside Out: Intrastate Aspects of Interstate Regulatory Competition*, 14 YALE L. & POL'Y REV. (SYMPOSIUM ISSUE) 149, 151–52 (1996) (noting in-state differences that affect racing); Stewart, *supra* note 57, at 1211 & n.65 (describing the race to the bottom as a manifestation of the "Tragedy of the Commons").

111 *Cf.* Madison et al., *supra* note 82, at 680 (identifying the goal of commons-based analysis as determining success or failure as a function of context).

112 Charles E. Lindblom, *The Science of "Muddling Through,"* 19 PUB. ADMIN. REV. 79 (1959); *see also* Charles E. Lindblom, *Still Muddling, Not Yet Through*, 39 PUB. ADMIN. REV. 517 (1979).

113 *Cf.* Tomain, *supra* note 53, at 396 (arguing that "[b]ecause clean energy and climate change present categorically different regulatory challenges, the regulatory responses must also be categorically different as well"); *see also id.* at 399–400 (discussing how firms' "locked-in" needs to recoup investments, organizational culture, and path-dependent commitments to past forms of investment and business decisions tend toward incremental advances rather than new and creative innovation).

address climate change may not fully address the serious fiscal constraints that exist and the distributional justice and other moral and ethical concerns[114] that will continue to affect such activities.[115] As has previously been noted, financial constraints dramatically affected technology development, substitution, and transfer obligations to developing countries under the Montreal Protocol.[116]

> Efforts at acquiring substitute technology [have] not been successful as the technologies are covered by IPRs [intellectual property rights], and are inaccessible either on account of the high price quoted by the technology suppliers and/or due to the conditions laid down by the suppliers. This would require domestically owned firms to give up their majority equity holding through joint ventures or to agree to export restrictions in order to gain access to the alternative technology.
>
> Financial assistance towards the acquisition of such technology has also not been effective. In fact, an interim progress report by the Executive Committee on technology transfer stated that the terms of freely negotiated transfer of technologies, including costs such as patents, designs and royalties, may not always be accommodated by the funding policies of the Multilateral Fund. Thus, while prices of alternative technologies are unaffordable on account of IPRs, access to these is limited due to inadequate funds domestically and lack of financial assistance from the Multilateral Fund, creating a major

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114 *See, e.g.*, INT'L COUNCIL ON HUMAN RIGHTS POLICY, BEYOND TECHNOLOGY TRANSFER: PROTECTING HUMAN RIGHTS IN A CLIMATE-CONSTRAINED WORLD 19–32 (2011), *available at* http://www.ichrp.org/files/reports/65/138_ichrp_climate_tech_transfer_report.pdf; Thomas Alured Faunce & Hitoshi Nasu, *Normative Foundations of Technology Transfer and Transnational Benefit Principles in the UNESCO Universal Declaration on Bioethics and Human Rights*, 34 J. MED. & PHIL. 296 (2009).

115 *See, e.g.*, Amy Kapczynski, *The Cost of Price: Why and How to Get Beyond Intellectual Property Internalism*, 59 UCLA L. REV. 970, 978 (2012) (arguing that intellectual property rights are "in significant tension with distributive values" because they use "price to ration access to information goods" and "the existing distribution of resources may be unjust"); Stiglitz, *supra* note 38, at 1697 ("[F]inancing research through monopoly profits may be neither the most efficient nor the most equitable way of doing so."); *id.* at 1715 ("[Intellectual property rights] will (effectively) recognize differences in elasticities of demand (because the monopolist can extract more profits when demand is less elastic), but not any other circumstances, and therefore inherently represents an inequitable way of financing research. The bottom line is that raising revenues for financing research through the granting of monopoly power cannot be justified by any generally accepted principles of public finance.").

116 *See* Montreal Protocol on Substances That Deplete the Ozone Layer arts. 10, 10A, Sept 16, 1987, 1522 U.N.T.S. 3.

> hurdle in transiting to ODS [ozone depleting substance] friendly production, especially among producer nations.[117]

These concerns will be correspondingly greater for climate-change mitigation and adaptation than for stratospheric ozone protection, as the number of technologies implicated for development and transfer—whether already in the public domain,[118] owned by many companies that are willing to sell at reasonable prices under reasonable conditions,[119] or owned by companies that are unwilling to transfer them except at high costs or on unreasonable conditions[120]—and the costs associated with them will be substantially larger. These distributional and ethical concerns will be further exacerbated by existing (and likely future skewed and clustered)[121] national patterns of clean technology development, patenting, and ownership.[122]

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[117] UNITED NATIONS CONFERENCE ON TRADE & DEV., ACHIEVING OBJECTIVES OF MULTILATERAL ENVIRONMENTAL AGREEMENTS: A PACKAGE OF TRADE MEASURES AND POSITIVE MEASURES 45–46 (Veena Jha & Ulrich Hoffmann eds., 2000); *see also* MARTIN KHOR, IPRS, TECHNOLOGY TRANSFER AND CLIMATE CHANGE 4–6 (2009), *available at* www.un.org/esa/policy/devplan/egm_climatechange/khor.pdf; Sarnoff, *supra* note 54, at 326–27. *See generally* STEPHEN O. ANDERSEN ET AL., TECHNOLOGY TRANSFER FOR THE OZONE LAYER: LESSONS FOR CLIMATE CHANGE (2007).

[118] *See, e.g.*, JOHN H. BARTON, CHATHAM HOUSE, ENERGY, ENVIRONMENT AND DEVELOPMENT PROGRAMME PAPER 08/02, MITIGATING CLIMATE CHANGE THROUGH TECHNOLOGY TRANSFER: ADDRESSING THE NEEDS OF DEVELOPING COUNTRIES (2008) (discussing the transfer of existing transportation technologies).

[119] *See, e.g.*, JOHN H. BARTON, INT'L CTR. FOR TRADE & SUSTAINABLE DEV., ISSUE PAPER NO. 2, INTELLECTUAL PROPERTY AND ACCESS TO CLEAN ENERGY TECHNOLOGIES IN DEVELOPING COUNTRIES: AN ANALYSIS OF SOLAR PHOTOVOLTAIC, BIOFUEL AND WIND TECHNOLOGIES 11–14 (2007) (discussing renewable energy technologies).

[120] *See, e.g.*, *supra* notes 116–17 and accompanying text (discussing ozone depletion technologies). Breakthrough climate change mitigation or adaptation technologies, such as carbon capture and some renewable energy technologies, would likely be subject to intellectual property rights and have few meaningful substitutes. *Cf.* LEE ET AL., *supra* note 5, at 21–43 (comparing patent landscapes of various renewable energy and carbon capture technologies); Tomain, *supra* note 53, at 390–91 (discussing the current costs of carbon capture given existing technologies); Mohammed Al-Juaied & Adam Whitmore, *Realistic Costs of Carbon Capture* (Belfer Ctr. for Sci. & Int'l Affairs, Discussion Paper 2009-08, 2009), *available at* http://belfercenter.ksg.harvard.edu/files/2009_AlJuaied_Whitmore_Realistic_Costs_of_Carbon_Capture_web.pdf. Developing breakthrough technologies also may be a more efficient international regulatory strategy than treaty regimes focused on emissions reduction. *See, e.g.*, Scott Barrett, *Climate Treaties and "Breakthrough" Technologies*, 96 AM. ECON. REV. (PAPERS & PROC.) 22 (2006).

[121] *See* MICHAEL E. PORTER, CLUSTERS OF INNOVATION: REGIONAL FOUNDATIONS OF U.S. COMPETITIVENESS (2001); JONATHAN SALLET ET AL., SCI. PROGRESS, THE GEOGRAPHY OF INNOVATION: THE FEDERAL GOVERNMENT AND THE GROWTH OF REGIONAL INNOVATION CLUSTERS 1 (2009), *available at* http://www.scienceprogress.org/wp-content/uploads/2009/09/eda_paper.pdf; Mercedes Delgado et al., Clusters, Convergence, and Economic Performance 1 (Aug. 2010) (unpublished manuscript), *available at* http://www.isc.hbs.edu/pdf/DPS_ClustersPerformance_08-20-10.pdf; *see also* Pontus Braunerhjelm, *Entrepreneurship, Innovation and Economic Growth: Interdependencies, Irregularities and Regularities*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 161, 185–93; Maryann P. Feldman & Gil Avnimelech, *Knowledge Spillovers and the Geography of Innovation—Revisited: A 20*

II. A TAXONOMY OF GOVERNMENT INNOVATION FUNDING MECHANISMS

Using a broad brush for classification, government choices to fund innovation can be grouped into five categories: (a) subsidization; (b) procurement; (c) direct development; (d) constructed commons; and (e) product, process, and market regulation.[123] In 2000, one American professor identified five categories of choices that are somewhat narrower but overlap in large part those just described: reliance on the "naked market"; markets and intellectual property rights; markets and R&D tax incentives; subsidies; and procurement.[124] In 2001, another American professor identified five slightly different categories of government innovation-funding action: direct development of technology; subsidization of private entities (particularly of university research); post hoc prizes or other rewards; government laws that assist concealment of private information; and conferring intellectual property rights.[125] In 2008, a Nobel Prize winning economist supplied a three-part

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Years' Perspective on the Field on Geography of Innovation, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 150; Alessandra Fogli & Laura Veldkamp, *Germs, Social Networks and Growth* 1–2 (Nat'l Bureau of Econ. Research, Working Paper No. 18470, 2010), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1679857 (discussing effects and persistence of historic social structures on productivity). *See generally* CHARLES W. WESSNER, NAT'L RESEARCH COUNCIL, GROWING INNOVATION CLUSTERS FOR AMERICAN PROSPERITY: SUMMARY OF A SYMPOSIUM (2011); Daniel Gervais, *Of Clusters and Assumptions: Innovation as Part of a Full TRIPS Implementation*, 77 FORDHAM L. REV. 2353, 2363–69 (2009).

122 *See* Sarnoff, *supra* note 54, at 318–19 (citing, *inter alia*, ANTOINE DECHEZLEPRÊTRE ET AL., INVENTION AND TRANSFER OF CLIMATE CHANGE MITIGATION TECHNOLOGIES ON A GLOBAL SCALE: A STUDY DRAWING ON PATENT DATA 4 (2008); INT'L CTR. FOR TRADE & SUSTAINABLE DEV., PATENTS AND CLEAN ENERGY: BRIDGING THE GAP BETWEEN EVIDENCE AND POLICY 9, 30–36 (2010)). However, counterpressures may be exerted from developed countries that find their technology development restricted by foreign patents. *See, e.g.*, Daniel R. Cahoy, *Inverse Enclosure: Abdicating the Green Technology Landscape*, 49 AM. BUS. L.J. 805 (2012).

123 *Cf.* Madison et al., *supra* note 82, at 667 (discussing "direct or indirect provisioning by the public sector using a combination of grants to researchers; tax credits or subsidies to researchers and enterprises that employ them; prizes; and production and distribution of knowledge and innovation by the government . . . by organizing research enterprises or by purchasing and distributing private research"). Another recent classification and comparative analysis discussed five "public innovation policies," which are: intellectual property rights; R&D subsidies; tax incentives; prizes and contests; and public procurement and production. *See* Tuomas Takalo, *Rationales and Instruments for Public Innovation Policies* 10–19 (Bank of Finland Research Discussion Papers, Paper No. 1, 2013), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2217502 (discussing each category and tradeoffs of the various approaches).

124 *See* Frischmann, *supra* note 14, at 354; *cf. id.* at 387 (lumping government direct development with subsidization). In regard to procurement, the government both creates a new market for innovation and acts in a double role within that market, as a purchaser on behalf of the pubic and as an investor. *See id.* at 374 n.102.

125 *See* William Fisher, Intellectual Property and Innovation: Theoretical, Empirical, and Historical Perspectives 2–3 (May 2, 2001) (unpublished manuscript), *available at* cyber.law.harvard.edu/people/tfisher/Innovation.pdf.

categorization—patents, prizes, and government-funded research—and focused on six attributes of these three choices: selection of research targets; financing methods; dissemination incentives; nature of the risks; innovation incentives; and transaction costs.[126] More recently, another American professor focused on a two-part basic categorization of "indirect subsidies through tax expenditure or market regulation through other tax policies, or direct spending on innovation either through direct employment or through a system of grants, rewards or prizes for creators and inventors."[127]

The categories I have chosen emphasize what I believe are the fundamentally different approaches to funding innovation and cover a broader range of subsidies and market regulation measures than are found in most other categorization schemes. The categorization may also help demonstrate the similarities and differences among the various approaches. As discussed further below, specific measures within these categories could fall into multiple categories, and thus the choices of "location"—for describing various measures within the various categories—are both idiosyncratic and not mutually exclusive. Definitional problems affect categorization, and the multiplicity of mechanisms that can be and are used makes any categorization scheme necessarily somewhat arbitrary and likely incomplete.[128] Further, it bears emphasizing that adopting multiple simultaneous approaches risks wasting limited government resources on ineffective efforts to promote innovation and on over-rewarding investors and private firms at the public's expense.[129] But it certainly helps to recognize the diversity of choices so as to improve analyses of their effects and make more informed collective decisions.

A. Subsidies

Subsidization is a very broad class that has different comparative effects on innovation.[130] The most basic form of subsidy to R&D and innovation is (1) direct and targeted subsidization of R&D and innovation efforts, such as government agency funding of university, corporate, or small business R&D,

126 *See* Stiglitz, *supra*, note 38, at 1722.

127 Michael W. Carroll, *One Size Does Not Fit All: A Framework for Tailoring Intellectual Property Rights*, 70 OHIO ST. L.J. 1361, 1368 (2009).

128 *See* Jerome S. Gabig, Jr., *Federal Research Grants: Who Owns the Intellectual Property?*, 9 HARV. J.L. & PUB. POL'Y 639, 640 (1986).

129 *See, e.g.*, Frischmann, *supra* note 14, at 385.

130 *See* OECD, NATIONAL SYSTEMS FOR FINANCING INNOVATION 11–12 (1995).

and government support for education more broadly.[131] Other subsidies include: (2) prizes, rewards, and other ex post funding; (3) consumption or production subsidies; (4) tax subsidies; (5) administrative subsidies; and (6) foreign aid.

1. *Direct Subsidies*

Direct subsidy funds may be provided through direct agreements, cooperative research agreements, and other funding vehicles.[132] They are typically provided ex ante without regard to whether they generate any specific kind or amount of innovation.[133] But direct subsidy funds potentially can be provided (usually in predetermined amounts) ex post to R&D and innovation efforts and may be conditioned upon generating particular outputs or quantities of outputs. If provided ex post and conditionally, such direct subsidies look much like prizes—the next type of subsidy mechanism. Similarly, direct subsidies to R&D or innovation may look a lot like procurement of R&D or innovation that is not linked to procurement of subsequent products.[134] As with procurement, such subsidies may fail to result in the anticipated R&D or innovation outputs, or they may be made conditional upon achieving ultimate outputs or on achieving intermediate outputs (as with progress payments).

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[131] *See, e.g.*, Frischmann, *supra* note 14, at 387 (noting subsidies to nonprofit institutions and, less frequently, to private firms, and discussing development of reasons for such funding through political processes, expert bureaucracies, and solicitations from researchers).

[132] *See id.* at 388 & nn.178, 183 (noting that direct subsidies include cash assistance, loans, loan guarantees, and insurance, and that cooperative agreements—rather than grants—are to be used for greater government involvement in the innovation R&D).

[133] *See* Federal Technology Transfer Act of 1986, Pub. L. No. 99-502, § 2, 100 Stat. 1785, 1785–87 (codified as amended at 15 U.S.C. § 3710a (2006)) (permitting Cooperative R&D Agreements (CRADAs) to allow government laboratories to negotiate licenses for use of government-owned inventions and to create a consortium for technology transfer); *cf.* Frischmann, *supra* note 14, at 367 (discussing a dynamic model of innovation that requires multiple passes of investments and noting the ability to reach an "innovative leap" in "numerous steps that can be divided into smaller increments for purposes of investigation, [permitting] the costs of research [to] become unbundled"); *id.* at 387 (noting that government bears the risk of unsuccessful efforts and foreign misappropriation from subsidies, providing a basis for developing CRADAs to share these risks).

[134] *Cf.* 41 U.S.C. §§ 405, 421(c)(1) (2006) (granting authority for the Federal Acquisition Regulations (FAR)); Frischmann, *supra* note 14, at 388 (noting that grants and procurement are distinguished principally by the functional relationship of the parties, the innovation outputs targeted—on the spectrum from basic to applied research—and whether the FAR are applicable).

2. *Prizes, Rewards, and Other Ex Post Funding*

The next set of mechanisms includes prizes, rewards, and other ex post R&D or innovation funding. These mechanisms (that I will collectively call *prizes*) are typically conditioned on generating specific innovation outputs or quantities of them. Prizes may provide hortatory recognition,[135] or financial incentives for R&D by promising ex ante, predetermined amounts, or ex ante uncertain but ex post innovation-generation-specified amounts.[136] Some forms of government hortatory recognition (e.g., certifications), particularly when based on achieving particular output or quality levels for goods or services in markets, are treated under the market regulation category below.

3. *Consumption and Production Subsidies*

The next set of subsidy mechanisms is consumption or production subsidies, which include direct subsidies, feed-in tariffs,[137] loan guarantees,

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[135] *See, e.g.*, *Patents for Humanity*, U.S. PAT. & TRADEMARK OFF., http://www.uspto.gov/patents/init_events/patents_for_humanity.jsp (last modified Dec. 6, 2012) (creating an award competition providing public recognition and accelerated patent examination—a form of administrative subsidy—for using patented technology to advance "humanitarian challenges" in the fields of medical technology, food and nutrition, clean technology, and information technology).

[136] *See, e.g.*, Michael Abramowicz, *Perfecting Patent Prizes*, 56 VAND. L. REV. 115, 119–70 (2003) (discussing features of patent-prize systems, providing reasons why imperfect decision making should not be a bar to their adoption, and reviewing earlier proposals and their limitations); *see also id.* at 171–93 (discussing two additional roles of patents that prizes do not address—commercialization of inventions and screening of patent validity—and two additional problems with patents that prizes may address—common pool patent races and inventing around activity); Jonathan H. Adler, *Eyes on a Climate Prize: Rewarding Energy Innovation to Achieve Climate Stabilization*, 35 HARV. ENVTL. L. REV. 1 (2011); Mark F. Grady & Jay I. Alexander, *Patent Law and Rent Dissipation*, 78 VA. L. REV. 305 (1992); James Love & Tim Hubbard, *Prizes for Innovation of New Medicines and Vaccines*, 18 ANNALS HEALTH L. 155 (2009); Michael Polanvyi, *Patent Reform*, 11 REV. ECON. STUD. 61 (1944); *cf.* Gregory N. Mandel, *When to Open Infrastructure Access*, 35 ECOLOGY L.Q. 205, 206–08 (2008) [hereinafter Mandel, *When to Open Infrastructure*] (discussing patent rewards—a form of prize where the government buys out an inventor's patent rights and makes them available to the public—that can act like open-access policies that do not permit price discrimination among uses and users, without diminishing ex ante innovation incentives); Gregory N. Mandel, *Promoting Environmental Innovation with Intellectual Property Innovation: A New Basis for Patent Rewards*, 24 TEMP. J. SCI. TECH. & ENVTL. L. 51, 64–67 (2005) (discussing benefits of rewards—including the reduction of deadweight losses, waste in inventing around patents, and licensing costs and thicket risks— noting existing methods of assessing social value of patents, and reciting four main criticisms of rewards: (1) failure to incentivize commercialization; (2) failure to provide incentives for fixed costs; (3) failure of opt-in systems to weed out bad patents; and (4) costs of administration).

[137] *See, e.g.*, Ann E. Carlson, *Designing Effective Climate Policy: Cap-and-Trade and Complementary Policies*, 49 HARV. J. ON LEGIS. 207, 233 (2012) (discussing use of feed-in tariffs or production subsidies to address economies-of-scale market failures); David M. Driesen, *Climate Disruption: An Economic Dynamic Approach*, 42 ENVTL. L. REP. 10,639, 10,645 (2012) (noting that feed-in tariffs sometimes require purchases at above-market prices); Jim Rossi & Thomas Hutton, *Judge Cudahy and the Deference Tension in United States*

and various kinds of credits. Consumption and production subsidies provide incentives to engage in R&D and innovation but normally are supplied conditionally and ex post to its outputs. The promise of these subsidies provides ex ante incentives to innovate, as well as to potentially fund further R&D within the same production firms (or allows consumers to redirect funds to R&D). However, because it is not tied directly to the R&D or innovation output (like direct subsidies or prizes), the potential of consumption or production subsidies to induce R&D and innovation is even more uncertain.

4. *Tax Subsidies*

Yet another set of subsidies is narrow or broad tax subsidies, which are distinguished from the direct transfer of funds to R&D, production, or consumption. Tax subsidies, like direct subsidies, may apply to basic and applied R&D expenditures, production, or consumption. Given that tax subsidies have value only in regard to taxable income, they are effective principally regarding commercial R&D and innovations.[138] However, not-for-profit R&D engaged in by tax-exempt entities reflects an implicit but untargeted tax subsidy to such innovation.

Tax subsidies can be supplied as tax credits, expense deductions, cost allowances from taxable income, depreciation and amortization allowances, differential tax rates, refunds, or carryovers.[139] They may apply to all expenditures or only to incremental ones above specified thresholds. They may also be used to attract foreign R&D and innovation investments by reducing relative costs of R&D in particular jurisdictions.[140] Thus, tax subsidies may be

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Energy Law, 29 YALE J. ON REG. 371, 382 (2012) (discussing use of feed-in tariffs or required purchases to promote project development). *See generally* KARLYNN CORY ET AL., FEED-IN TARIFF POLICY: DESIGN, IMPLEMENTATION, AND RPS POLICY INTERACTIONS (2009).

138 *See, e.g.*, Harhoff, *supra* note 41, at 57 (discussing different types of firms' comparative benefits from tax expensing compared to carry-forwards of R&D and intangibles).

139 For a discussion on tax credits and deductions, see LAURA TYSON & GREG LINDEN, CTR. FOR AM. PROGRESS, THE CORPORATE R&D TAX CREDIT AND U.S. INNOVATION AND COMPETITIVENESS: GAUGING THE ECONOMIC AND FISCAL EFFECTIVENESS OF THE CREDIT 21–22 (2012).

140 *See id.* at 22–24; *see also* 15 U.S.C. § 638 (2006) (Small Business Innovation Research Program); 26 U.S.C. §§ 41, 174 (2006) (providing for the Research & Experimentation Tax Credit and the Research and Experimental Expenditures Deduction, respectively); Small Business Technology Transfer Program Reauthorization Act of 2001, Pub. L. No. 107-50, 115 Stat. 263 (codified as amended at 15 U.S.C. §§ 638, 657 (2006)); OECD, R&D TAX INCENTIVES: RATIONALE, DESIGN, EVALUATION 4–8 (2010), *available at* http://www.oecd.org/sti/industryandglobalisation/46352862.pdf; TYSON & LINDEN, *supra* note 139, at 2 (noting that the R&D tax credit is one of the largest federal tax expenditures, and that it has repeatedly lapsed and been restored retroactively); JACEK WARDA, OECD, R&D TAX TREATMENT IN OCED COUNTRIES: COMPARISONS AND EVALUATIONS (2007), *available at* http://www.oecd.org/science/innovationinscience

tied more or less closely to the R&D activities or innovation outputs sought to be promoted, and therefore may vary regarding their stimulus to innovation. Further, they add uncertainty because potential recipients must assess ex ante the value of the perceived tax benefits for motivating R&D decisions.[141] Contrary to some earlier evidence suggesting that direct subsidies may substitute for corporate manufacturing-sector innovation funding whereas tax subsidies may induce greater expenditures,[142] some recent evidence suggests that tax subsidies may be less effective than direct government subsidies for certain small- or medium-sized entities; tax subsidies may act as complements rather than as substitutes for inducing private R&D and innovation.[143]

5. *Administrative Subsidies*

There are also various forms of "administrative" subsidies, which can reduce the costs or increase the benefits obtained by private entities engaged in R&D or innovation in their interactions with the government. These cost reductions or benefit enhancements also act as an incentive to induce ex ante innovation, but may be more uncertain in regard to the conditions of their supply or the amount of benefit they provide. Exemplary administrative

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technologyandindustry/40024456.pdf; Praveen Goyal, The Future of the Canada–United States Relationship—Innovation and Technology, Remarks at the Proceedings of the Canada–United States Law Institute Conference on An Example of Cooperation and Common Cause: Enhancing Canada–United States Security and Prosperity Through the Great Lakes and North American Trade (Apr. 2–4, 2009), *in* 34 CAN.-U.S. L.J. 107, 115–16 (2010) (comparing foreign investment attractiveness of U.S. tax credits that are contingent on appropriations with Canadian tax credits against across-the-board taxes that are not contingent); *cf.* Preston Manning & Jack Mintz, *Implications of the Recommendations of the Expert Panel on Federal Support to Research and Development* 4 (Univ. of Calgary Sch. of Pub. Policy SPP Research Papers, Research Paper No. 12-7, 2012), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2028124 (noting that Canada is second after Spain among large industrialized countries in federal and provincial tax support to innovation, but nevertheless has a "relatively low rate of business research and development activity"). *See generally* BD. ON SCI., TECH., & ECON. POLICY, NAT'L RESEARCH COUNCIL, BORDERLINE CASE: INTERNATIONAL TAX POLICY, CORPORATE RESEARCH AND DEVELOPMENT, AND INVESTMENT (James M. Poterba ed., 1997); Consuelo Lauda Kertz & James K. Hasson, Jr., *University Research and Development Activities: The Federal Income Tax Consequences of Research Contracts, Research Subsidiaries and Joint Ventures*, 13 J.C. & U.L. 109 (1986); Bronwyn H. Hall, Tax Incentives for Innovation in the United States: A Report to the European Union (Jan. 15, 2001) (unpublished manuscript), *available at* http://elsa.berkeley.edu/~bhhall/papers/BHH01%20EU%20Report%20USA%20rtax.pdf.

141 *Cf.* Frischmann, *supra* note 14, at 394–95 (noting that tax incentives are effective to the extent they are targeted at a cognizable class of innovations, and that "where the government has sufficient information or where cooperative arrangements can be structured . . . direct government funding may be [more] appropriate").

142 *See, e.g.*, Theofanis P. Mamuneas & M. Ishaq Nadiri, *Public R&D Policies and Cost Behavior of the US Manufacturing Industries* 2–3 (Nat'l Bureau of Econ. Research, Working Paper No. 5059, 1995).

143 *See, e.g.*, Isabel Busom et al., *Tax Incentives or Subsidies for R&D?* 4–5 (Maastricht Econ. & Soc. Research Inst. on Innovation & Tech., Working Paper No. 2012-056, 2012).

subsidies include reduced costs of applying for intellectual property rights and faster processing of applications for such rights.[144] The reduced costs may thus be contingent on innovation outputs and either may not be perceived as a significant ex ante inducement or may not be cycled back into additional R&D efforts. The benefits of earlier protection may depend on uncertain or ex ante unperceived market conditions that will occur in the future. Such subsidies, moreover, may be provided in the form of extraordinary rewards to particular innovation outputs, and the amount of the administrative subsidy could readily exceed any realistic measure of its innovation-inducing potential. For example, serious consideration was given to providing "wild-card" extensions to unrelated patent terms for producing certain medical innovations.[145] To the extent they provide rewards in excess of R&D and innovation costs, such subsidies look more like prizes.

6. *Foreign Aid*

Finally, foreign aid may be thought of as a subsidy to R&D and innovation. Foreign aid can include financing, expertise, and other assistance given directly or through intergovernmental organizations, provided either to the recipient jurisdiction's government or its private sector. Foreign aid can target R&D directly or indirectly through subsidized consumption or production,[146] and may be given conditionally or unconditionally to achieve particular

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[144] *See, e.g.*, 35 U.S.C. § 41(h) (2006) (providing reduced patent prosecution fees for small business concerns); Estelle Derclaye, *Not Only Innovation but Also Collaboration, Funding, Goodwill and Commitment: Which Role for Patent Laws in Post-Copenhagen Climate Change Action*, 9 J. MARSHALL REV. INTELL. PROP. L. 657, 659, 670–71 (2010) (proposing for green patents accelerated examination, reduction, cancellation, or waiver of fees, removal of green inventions from deferred examination, earlier publication and/or priority at the opposition and infringement stages, and stronger protection, and also describing the Green Tech pilot program); *Green Technology Pilot Program—CLOSED*, U.S. PAT. & TRADEMARK OFF., http://www.uspto.gov/patents/init_events/green_tech.jsp (last modified May 7, 2012). *See generally* ANTOINE DECHEZLEPRÊTRE, INT'L CTR. FOR TRADE & SUSTAINABLE DEV., ISSUE PAPER NO. 37, FAST-TRACKING GREEN PATENT APPLICATIONS: AN EMPIRICAL ANALYSIS (2013), *available at* http://ictsd.org/i/publications/154732/.

[145] *See, e.g.*, Jorn Sonderholm, *Wild-Card Patent Extensions as a Means to Incentivize Research and Development of Antibiotics*, 37 J.L. MED. & ETHICS 240, 241 (2009) (discussing such proposals); B. Spellberg et al., *Societal Costs Versus Savings from Wild-Card Patent Extension Legislation to Spur Critically Needed Antibiotic Development*, 35 INFECTION 167 (2007) (modeling the costs and benefits and suggesting cost-neutrality within ten years after marketing approval of the induced innovation); *cf.* Amy Kapczynski, Commentary, *Innovation Policy for a New Era*, 37 J.L. MED. & ETHICS 264, 265–66 (2009) (criticizing such proposals for delinking the reward from the value of the innovation, eliminating flexibility in determining the reward, and hiding the true costs of the reward from the public).

[146] *See* WORLD BANK, THE CLIMATE TECHNOLOGY PROGRAM: ACCELERATING CLIMATE INNOVATION IN DEVELOPING COUNTRIES 3–4 (n.d.), *available at* http://www.infodev.org/en/Publication.1152.html.

innovation outputs or amounts.[147] Of course, foreign aid to research may ultimately result in higher costs of purchasing research outputs by the providing governments or their citizens, cause shifts in international trade flows, and adversely affect comparative national economic advantages. For these reasons, it is rarely discussed in regard to national innovation policies, although analyses sometimes focus on the misappropriation of domestic government-funded research by foreign firms or governments, legitimately or through espionage.[148]

7. General Considerations

Direct and other subsidies to R&D may be a "useful substitute for stringent property rights designed to enhance R&D incentives and to reduce the extent of spillovers," even if the need for a close relationship between upstream research and downstream development limits the value of such subsidies and suggests their use principally in areas where they will result in substantial positive spillovers.[149] The fact that such subsidies can substitute for intellectual property rights also suggests that intellectual property rights are a form of ex post innovation subsidy (i.e., a government grant of wealth in the form of exclusive property rights)[150] conditioned on achieving certain innovation outputs. The promise of the conditional subsidy generates ex ante incentives for such innovation. Granting a property rights subsidy to *intermediate* innovation outputs (patentable inventions rather than commercial products) may direct ex ante private investment toward more basic research by avoiding concerns about keeping research secret while internally recycling it to pursue further innovation.[151] For present purposes, however, I have placed intellectual property rights in the market regulation category, as I believe they are better classified as a form of market intervention (through grants of exclusivity) and because of the importance of their relationship to market competition regulation after the grant of exclusive rights (subject to doctrines within

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147 *See, e.g.*, Goldstein, *supra* note 63, at 133 (distinguishing foreign aid "pull programs," for which the public pays only if successful products are developed, from "push programs" that fund research).

148 *See, e.g.*, Frischmann, *supra* note 14, at 355. *See generally* Economic Espionage Act of 1996, Pub. L. No. 104-294, §101, 110 Stat. 3488, 3488–89 (codified as amended at 18 U.S.C. §§ 1831, 1832 (2006)) (addressing trade secrets).

149 Janusz A. Ordover, *Economic Foundations and Considerations in Protecting Industrial and Intellectual Property*, 53 ANTITRUST L.J. 503, 509 (1984).

150 *See, e.g.*, Tom W. Bell, *Authors' Welfare: Copyright as a Statutory Mechanism for Redistributing Rights*, 69 BROOK. L. REV. 229, 235–36 (2003).

151 *See* Frischmann, *supra* note 14, at 379 (noting returns to investment through licensing and the ability to draft patent claims to cover readily identified spillovers).

intellectual property law—such as preemption, misuse, and exhaustion—and outside such law—such as antitrust, price, product or process, consumer-protection, and other regulatory laws).

The choices that government can make among the various kinds of subsidies should depend on the degree to which the innovation outputs can be reliably predicted; the commercial nature of the research; and the comparative effectiveness of government administrators and firm actors in making predictions, directing the R&D, and generating innovation outputs.[152] As noted, targeted R&D tax subsidies (and the ex ante incentives they generate) are useful principally for profit-making ventures, and they will leave control of innovation development to such firms, which is debatably better than having the government direct which innovations to target.[153] But such simple insights do not get us very far because other forms of subsidies are available that could potentially induce more effective and efficient R&D and innovation development in the private sector. Such alternative subsidies include funds provided to universities and nonprofit research centers, or development through subsidizing private foundations. There simply are too many potentially effective alternative subsidy mechanisms to choose from.[154] Further, as noted above, the preference for private control of development may not be adequately justified, in general or relative to particular government bureaucracies or public–private partnerships that exist or could be developed.[155] The comparative R&D effectiveness of the relevant actors is unlikely to be known without detailed institutional analyses or experiments. In short, far too little is known to intelligently make very important decisions with far too much money.

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152 *See id.* at 352–53; Henrik Vejen Kristensen et al., *Adopting Eco-Innovation in Danish Polymer Industry Working with Nanotechnology: Drivers, Barriers and Future Strategies*, 6 NANOTECHNOLOGY L. & BUS. 416, 416, 433 (2009); *see also* Frischmann, *supra* note 14, at 392 (discussing choices depending 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").

153 *See* Frischmann, *supra* note 14, at 352–53.

154 *See, e.g.*, *id.* at 392–95 (comparing easier cases at the ends of the public–private-goods innovation spectrum for applied research with the greater complexity in between, and noting the increased difficulty of analyzing issues for more basic research).

155 *See* Tomain, *supra* note 53, at 404–16 (discussing the five Belfer principles—clearly defined mission, visionary and technically excellent leadership, entrepreneurial and competitive culture, structure and management system balancing independence and accountability, and stable and predictable funding—and two additional principles—"sell discipline," or a focus on marketability, and planning and evaluation—and encouraging adoption of government energy-innovation agencies applying these principles); Radka, *supra* note 101.

As has long been recognized, moreover, subsidies may distort research and other markets and over-reward innovation efforts.[156] For example, direct subsidies may be provided to university professors who fail to produce quality research. Comparison to the developing understanding of intellectual property rights is helpful here. The creation of such rights to better assure the appropriability of R&D investments—or to avoid the loss of positive externalities by inducing disclosures rather than reliance on secrecy[157]—may result in raised prices, potentially wasteful duplication of research to obtain the property right, and the potential for excessive and strategically exploited market power.[158] This is true even if decentralized, competitive research and attendant waste from duplication of efforts arguably performs better at technological development than centralized, controlled research that avoids such duplication.[159] Direct R&D subsidies do not eliminate the potential for wasteful duplication of research efforts. But they also do not typically contribute to such duplication, absent intentional decisions to provide redundancy of research efforts to maximize the likelihood of achieving success from different research paths, or—as discussed *infra* in Part II.B—to avoid reliance on single sources of R&D expertise.[160]

Unlike intellectual property grants, direct, prize, administrative, and foreign aid subsidies typically do not come with any necessary relationship to market regulation. However, such subsidies sometimes may be coupled with tax, production, or consumption subsidies, or with guaranteed procurements that

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156 *See, e.g.*, Matthew L. Wald, *Solar Firm Aided by U.S. Shuts Doors*, N.Y. TIMES, Sept. 1, 2011, at B1; Hans Biebl, *Energy Subsidies, Market Distortion, and a Free Market Alternative*, MICH. J. L. REFORM ONLINE (Oct. 25, 2012), http://www.mjlr.org/2012/10/energy-subsidies-market-distortion-and-a-free-market-alternative/.

157 *See, e.g.*, Frischmann, *supra* note 14, at 372 n.91; Katherine J. Strandburg, *What Does the Public Get? Experimental Use and the Patent Bargain*, 2004 WIS. L. REV. 81, 107–08 (discussing patent and trade-secrecy tradeoffs in regard to “self-disclosing” and “non-self-disclosing” inventions).

158 *See* Ordover, *supra* note 149, at 507; *cf.* MACHLUP, *supra* note 23, at 7 (discussing simultaneous invention and noting the lack of social utility to the duplicative inventive outputs, characterizing the services of duplicative inventors as “free goods”).

159 *See, e.g.*, Frischmann, *supra* note 14, at 372–73 (noting that duplication may be wasteful only for applied research having known, narrow applications); Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839, 842–43 (1990) (discussing Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265 (1977), providing reasons why competition may be more successful, and tracing historical examples); *cf.* John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 442–44 (2004) (discussing innovation races and rent dissipation by three mechanisms—accelerated research expenditures, duplicative efforts, and reduced time for commercialization under monopoly conditions—under which competition is channeled to earlier placement of innovation in the public domain to maximize social welfare).

160 *See infra* notes 173–93 and accompanying text.

can dramatically alter market dynamics.[161] Conversely, intellectual property rights may be granted through auctions rather than through temporal races, which can reduce the implicit subsidies and wealth transfers that the exclusive rights supply. Depending on the auction's contract-like conditions, such grants can reduce the deadweight losses of patent races, monopoly pricing, and failures to develop or license within the prospect and market.[162] Arguably, direct and prize subsidies already are or could be awarded through auctions of various types, which would reduce the social costs of awarding them. For example, applications for direct subsidies are already assessed to determine which grantee is most likely to generate the desired innovation outcomes, thereby providing bidding competition based on perceived competence rather than the amount of the subsidy to be awarded.[163] Both direct subsidies and prizes could be awarded to competitors that offer to achieve the desired innovation output for the lowest reward, with the distinction being whether the amount is actually conditioned on achieving success. What should be obvious from this discussion is that choosing the right actor to direct money (or other embellishments) and the right amount of the subsidy to achieve any particular innovation output in the most efficient way may require both information that is not currently available and institutional competencies that do not currently exist. In many cases the innovation output desired is itself uncertain.

Subsidies provide financing and various other embellishments that can reduce political, currency, regulatory, execution, technology, and unfamiliarity risks that exist regarding technology dissemination efforts, and thereby induce

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161 *Cf.* Brennan et al., *supra* note 75, at 6–18 (comparing prizes, patents, contracts, grants, and standard procurement; noting similar problems of analysis and distributional effects regarding tax policy choices; and describing idiosyncratic benefits of relying on prizes).

162 *See, e.g.*, WILLIAM D. NORDHAUS, INVENTION, GROWTH, AND WELFARE: A THEORETICAL TREATMENT OF TECHNOLOGICAL CHANGE (1969); Michael Abramowicz, *The Uneasy Case for Patent Races over Auctions*, 60 STAN. L. REV. 803, 804–25 (2007) (citing, *inter alia*, Ian Ayres & Paul Klemperer, *Limiting Patentees' Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-Injunctive Remedies*, 97 MICH. L. REV. 985 (1999)); Yoram Barzel, *Optimal Timing of Innovations*, 50 REV. ECON. & STAT. 348 (1968); R. H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1 (1959); Harold Demsetz, *Why Regulate Utilities?*, 11 J.L. & ECON. 55, 63 (1968); *see also* Michael Abramowicz, *The Danger of Underdeveloped Patent Prospects*, 92 CORNELL L. REV. 1065 (2007) (suggesting a system of patent-extension auctions under which a patentee would be allowed to request such an auction, but could only win it by substantially outbidding third parties); *cf.* Michael Abramowicz & John F. Duffy, *The Inducement Standard of Patentability*, 120 YALE L.J. 1590, 1593–98 (2011) (noting that a standard where the patent will not issue if the invention would have been created anyway avoids deadweight losses, but arguing for a more limited inducement standard based on delayed deadweight losses).

163 *See, e.g.*, *Peer Review Process*, NAT'L INST. HEALTH, http://grants.nih.gov/grants/peer_review_process.htm#scoring (last updated Mar. 4, 2013) (discussing review criteria for grants and cooperative agreements, which include scientific merit, significance, and investigator suitability).

investment in R&D, innovation, and technology development.[164] Further, when subsidies are specifically tied to developing particular technologies or fields,[165] they may raise substantial trade concerns over market distortion, preferential treatment, and national efforts to promote comparative advantage.[166] As discussed *infra* in Part II.E,[167] however, R&D markets and subsidies are thought to be different from production markets and subsidies. R&D innovation subsidies—whether direct, prize based, or tax based—have been treated differently from production and consumption subsidies in light of the broad recognition of their public-goods character. For example, R&D subsidies (structured in a particular manner) were for a time considered nonactionable under the WTO's subsidies and countervailing duties code.[168] Whether and when such differential treatment is justified or tolerated may ultimately be a political question regarding how much R&D to promote. But the issue will likely remain controversial, and trade concerns will likely create pressures to direct the choices of innovation funds away from production and consumption subsidies or from R&D subsidies for particular technologies or fields.

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164 *See, e.g.*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE WORKING GRP. III, METHODOLOGICAL AND TECHNOLOGICAL ISSUES IN TECHNOLOGY TRANSFER 5–6 (2000), *available at* http://www.ipcc.ch/pdf/special-reports/spm/srtt-en.pdf; SUNIL MANI, GOVERNMENT, INNOVATION AND TECHNOLOGY POLICY: AN INTERNATIONAL COMPARATIVE ANALYSIS 29–35 (2002) (explaining the relationship between financial measures such as tax incentives and venture capital with the promotion of innovation in developed countries, finding that tax incentives are "the most important and widely used instrument" of fiscal incentives for promoting innovation and R&D); WORLD BANK, *supra* note 4, at 292–94, 303, 311; *see also* Frischmann, *supra* note 14, at 363 (discussing production and appropriation risks).

165 *See* American Recovery and Reinvestment Act of 2009, Pub. L. No. 111–5, §§ 1101, 1141, 123 Stat. 115, 319, 326–28 (extending tax credits for renewable energy production, furnishing substantial public funds for transportation and energy infrastructure, and providing a range of direct and production and consumption subsidies for various energy-efficiency and renewable-energy technologies); *cf.* American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. §§ 111–16, 123–25, 171, 724, 782 (2009). This proposal was known as the Waxman–Markey bill, and would have established an emissions trading scheme and provided substantial subsidies for clean energy technologies, carbon capture and sequestration, electric and other advanced technology vehicles, and basic R&D.

166 *See, e.g.*, INT'L TRADE ADMIN., U.S. DEP'T OF COMMERCE, FACT SHEET: COMMERCE PRELIMINARILY FINDS DUMPING OF CRYSTALLINE SILICON PHOTOVOLTAIC CELLS, WHETHER OR NOT ASSEMBLED INTO MODULES FROM THE PEOPLE'S REPUBLIC OF CHINA (2012), *available at* http://ia.ita.doc.gov/download/factsheets/factsheet-prc-solar-cells-adcvd-prelim-20120320.pdf (noting preliminary determination of dumping of various Chinese solar cells); Matthew Dalton & Jan Hromadko, *EU to Investigate Chinese Solar-Panel Makers*, WALL ST. J., Sept. 7, 2012, at B3 (noting investigations in the European Union on Chinese solar panels based on allegations of illegal subsidies from below-market export pricing, which was financed by state-owned, bank-provided low-cost loans, and discussing China's efforts to promote its solar photovoltaic sector).

167 *See infra* notes 280–84 and accompanying text.

168 Agreement on Subsidies and Countervailing Measures, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1A, 1867 U.N.T.S. 14 [hereinafter SCM Agreement].

Finally, returning to comparative innovation-inducing effectiveness, direct subsidies for particular innovation outputs will likely be more effective than indirect ones (such as generalized R&D tax subsidies) where there are market failures or other externalities that make commercialization of a technology unlikely.[169] Examples that illustrate this include the development of new medicines to address neglected diseases for which expected returns are insufficient to fund clinical trials or pollution controls when the health and environmental harms can continue to be externalized.[170] Recent studies suggest that subsidies may be less effective than market regulation (particularly regarding the internalization of externalities) in promoting innovation, that both combined are more effective than either separately, and that subsidies may, in some circumstances, be more effective and efficient in inducing innovation than taxing externalities.[171]

Again, this does not get us very far. Having canvassed subsidies relatively thoroughly, I address below the other forms of innovation funding choice (except market regulation) somewhat more cursorily, referring back to considerations that have now been elaborated.

B. Procurement

As noted above, procurement resembles R&D and innovation subsidies, but it typically provides incentives by conditioning funding on achieving innovation outputs that are commercial or noncommercial products.[172] Through 1993 in the United States, R&D procurement contracts composed the largest amount of federal public-sector support for R&D, followed by subsidies, which took the form of tax incentives more than direct grants.[173] This may seem surprising but is partially explained by the dramatic growth of military expenditures as a proportion of the overall budget and by the general decline of R&D expenditures since its peak during the Cold War space race in

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169 *See, e.g.*, Frischmann, *supra* note 14, at 382–83, 394–98.

170 *See, e.g.*, Amy Kapczynski et al., *Addressing Global Health Inequities: An Open Licensing Approach for University Innovations*, 20 BERKELEY TECH. L.J. 1031, 1053 (2005); Popp et al., *supra* note 37, at 2–3, 48–49; *cf.* Sean Flynn et al., *An Economic Justification for Open Access to Essential Medicine Patents in Developing Countries*, 37 J.L. MED. & ETHICS 184, 188–92 (2009) (discussing failures to price discriminate in providing medicines to countries with highly stratified incomes).

171 *See, e.g.*, Popp et al., *supra* note 37, at 4–5; *see also id.* at 5 (citing Rob Hart, *The Timing of Taxes on CO_2 Emissions when Technological Change Is Endogenous*, 55 J. ENVTL. ECON. & MGMT. 194 (2008)) (noting that targeted R&D subsidies may induce more rapid technological development at lower costs than increased early taxation above externality-internalizing levels).

172 *See supra* note 133 and accompanying text.

173 *See* MANI, *supra* note 164, at 10, 31 fig.1.11, 32 tbl.1.8.

the 1960s.[174] A significant portion of current defense R&D costs can be attributed to the development and procurement of very high-technology weapons systems,[175] although other governmental expenditures (within and outside the defense sector) of purchased outputs also may have led to induced R&D and innovation.

There are many possible forms of procurement that allocate risk differently between the parties to the procurement contract. These include fixed price with sealed bidding or negotiated prices, with the producer bearing most of the cost and profit risks; negotiated cost reimbursement, with the government bearing most of the risks; and all sorts of intermediate types.[176] Of course, the government bears the risk that the contractor will not produce as desired, and the contractor bears the risk that the government will not appropriate sufficient funds to fulfill the contract—which is subject to the Anti-Deficiency Act.[177] Similarly, procurement of innovation can be distinguished among the following: direct procurement for the government as the only consumer of goods and services (e.g., bomber aircraft) or as a catalyst for the market (e.g., software); procurement at commercial or precommercial stages; general procurement of innovation outputs; strategic procurement of outputs intended to stimulate the market; cooperative procurement with both public and private sectors as buyers and users; or exclusively catalytic procurement where private entities ultimately are the sole exclusive users of the innovative outputs.[178]

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174 *See, e.g.*, Robert Pollin & Heidi Garrett-Peltier, *Benefits of a Slimmer Pentagon*, NATION, May 28, 2012, at 15 (describing how military spending in 2011 reflected 4.7% of gross domestic product, while in 2000 it reflected 3%); *Policy Basics: Where Do Our Federal Tax Dollars Go?*, CENTER ON BUDGET & POL'Y PRIORITIES, http://www.cbpp.org/cms/index.cfm?fa=view&id=1258 (last updated Aug. 13, 2012) (discussing the 2011 budget, which allocated 20% to defense and international security, 3% to transportation and infrastructure, 2% to education, and 2% to science and medical research); *R&D Spending by the Federal Government*, DEPARTMENT NUMBERS (Jan. 2, 2012), http://www.deptofnumbers.com/blog/2012/01/rd-spending-by-federal-gov. *See generally* ELISA EISEMAN ET AL., RAND SCI. & TECH. POLICY INST., FEDERAL INVESTMENT IN R&D (2002), *available at* http://www.rand.org/pubs/monograph_reports/2005/MR1639.0.pdf (reviewing the federal government's R&D portfolio and recommending areas where programs should be expanded, curtailed, or maintained); Mark Boroush et al., *Research and Development: National Trends and International Comparisons*, *in* SCIENCE AND ENGINEERING INDICATORS 2012, at 4-1 (2012), *available at* http://www.nsf.gov/statistics/seind12/pdf/seind12.pdf (focusing on R&D and presenting data on public and private performance in the United States, as well as examining related international investments or transactions involving R&D financing or performance).

175 *See, e.g.*, OFFICE OF THE UNDER SEC'Y OF DEF. (COMPTROLLER)/CFO, U.S. DEP'T OF DEF., FISCAL YEAR 2012 BUDGET REQUEST: PROGRAM ACQUISITION COSTS BY WEAPON SYSTEM, at table of contents (2011), *available at* http://comptroller.defense.gov/defbudget/fy2012/FY2012_Weapons.pdf.

176 *See, e.g.*, 48 C.F.R. pt. 16 (2012).

177 31 U.S.C. § 1341 (2006).

178 *See, e.g.*, Jakob Edler & Luke Georghiou, *Public Procurement and Innovation—Resurrecting the Demand Side*, 36 RES. POL'Y 949, 953–54 (2007).

Although there is no theoretically necessary relationship between government procurement and the creation of intellectual property rights, the Bayh–Dole Act applies to government procurement contracts "for the performance of experimental, developmental, or research work funded in whole or in part by the Federal Government."[179] Additionally, a complex set of federal agency regulations and policies exists regarding the creation, ownership, or use of intellectual property rights or rights in data developed through a broader range of government contracts, including those not primarily intended to promote R&D or innovation.[180] However, contractors working "by or for" the government are free to "use or manufacture" the patents or copyrights of third parties without a license if they are within the scope of the procurement contract, and the government is subject to liability to the rights holder for "reasonable and entire compensation" through a statutory takings claim.[181]

The effects of procurement on innovation depend partly on whether the contracts take the form of "push" or "pull" mechanisms with regard to existing or future markets. Push mechanisms (ex ante market procurement) provide a demonstration of technology and a stimulus to market development so that industry may subsequently be more willing to risk market entry.[182] Push mechanisms also raise questions as to the size of the government sector and its adequacy to demonstrate commercial viability in a broader market without government subsidies to production or consumption. Regulation of market prices for innovation outputs (or rate-based returns to regulated industries, as in the electric utility sector) further complicates the evaluation of the inducement effectiveness and adequacy of innovation returns to procurement funding.[183]

Pull mechanisms (ex post market procurement) provide ex ante innovation incentives based on ex post assurances (to innovation creation) of the adequacy

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179 35 U.S.C. § 201(b) (2006).

180 *See, e.g.*, 48 C.F.R. pts. 27, 227 (2012).

181 *See, e.g.*, 28 U.S.C. § 1498(a) (2006); *see also* Zoltek Corp. v. United States, 672 F.3d 1309, 1326–27 (Fed. Cir. 2012) (holding that government liability under § 1498 is not limited to patent infringement liability under 35 U.S.C. § 271(a), but that it also applies to § 271(g)).

182 *See, e.g.*, RUTTAN, *supra* note 26, at 108–09 (discussing government procurement of software).

183 *See, e.g.*, Joskow & Rose, *supra* note 105, at 1464–77 (discussing studies of the effects on prices in various regulated and deregulated industries); C. O. Ruggles, *Problems of Public-Utility Rate Regulation and Fair Return*, 32 J. POL. ECON. 543, 543–58 (1924) (discussing lack of clear definitions, changes in conditions, duplication concerns, character of service, and efficiency of management); *cf.* Duffy, *supra* note 159, at 444–45 (citing Demsetz, *supra* note 162) (comparing patent-prospect management and auction pricing to that of natural monopolies).

of scale for commercialization, which again reduces market entry risks. These ex post assurances of procurement (advanced purchase commitment contracts) are, effectively, ex post consumption subsidies where the government acts as a consumer on behalf of the public. However, the price terms of these ex post innovation contracts may be highly uncertain and subject to statutory and "march-in" rights regarding patented innovation outputs and other contractually retained rights. Often, as with public–private partnerships, the scope of the market purchase guarantees, conditions on market behavior and pricing terms, and treatment of developed intellectual property and retained ownership rights are negotiated in advance.[184]

Bidding also affects the amount of funding that is directed at innovation through procurement mechanisms. Bidding for procurement thus resembles auctioning for prizes, with the potential awardees competing ex ante to lower the funding levels they hope to obtain and for which they are willing to work for a defined innovation output. However, the ex ante contract award (particularly with progress payments) is perhaps less conditioned on achieving the output than an ex post prize award.[185] This brings to mind the old adage, "you get what you pay for." In contrast, bidding competition regarding non-price terms resembles direct subsidy grant review, where the amount of funding is fixed but the choice of "contractor" best situated to achieve the predetermined innovation outputs are determined based on other factors.[186]

As with subsidies,[187] government procurement of R&D or innovation may sometimes crowd out private R&D funding. Procurement thus may be particularly appropriate for costly private good production where there is no market or where the recovery of costs is uncertain, and where firms will not otherwise expend funds on R&D or innovation.[188] Accordingly, procurement drives much military R&D and also some medical R&D through guaranteed purchase contracts for medicines for developing-country markets.[189]

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184 *See, e.g.*, Ron A. Bouchard, *Qualifying Intellectual Property II: A New Innovation Index for Pharmaceutical Patents & Products*, 28 SANTA CLARA COMPUTER & HIGH TECH. L.J. 287, 382 (2011–2012).

185 *See supra* notes 133–37 and accompanying text.

186 *See supra* notes 162–64 and accompanying text. Further, the outputs of bidding may often be much less specific than in contracting.

187 *See, e.g.*, Scott J. Wallsten, *The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program*, 31 RAND J. ECON. 82, 82–83 (2000).

188 *See, e.g.*, Frischmann, *supra* note 14, at 373–74 & n.100, 390, 391 n.192.

189 *See, e.g.*, *supra* note 26; *see also* U.S. PRESIDENT'S EMERGENCY PLAN FOR AIDS RELIEF, USING SCIENCE TO SAVE LIVES: LATEST PEPFAR FUNDING (2012), *available at* http://www.pepfar.gov/documents/organization/189671.pdf (documenting funding since 2004).

Procurement also may be duplicative and thus potentially wasteful of R&D funding inputs. Multiple sourcing of procured technology, however, can lead to broader and quicker diffusion of knowledge and to an increased pace of innovation.[190] Sole sourcing, moreover, is discouraged by the FAR to avoid concerns about monopoly pricing.[191]

Finally, procurement may raise serious trade concerns, particularly if procurement favors domestic industries and thereby imposes non-neutral innovation risk reductions. For example, China has recently engaged in substantial domestic procurement preferences and administrative subsidies to promote "national champion" industries that can develop export markets, which force creation of joint ventures that transfer innovative technologies "in exchange for being granted the ability to invest in China."[192] Given that R&D subsidies may be treated differently,[193] the trade concerns may be more or less severe when the procurement is directed at particular R&D outputs or at general market activities that require R&D inputs.

C. Direct Development

The government engages in all sorts of R&D and innovation funded through general or specific taxes and other sources of government revenue. This reflects that government employees are user-innovators,[194] that government agencies engage in R&D to generate different kinds of innovation outputs in the course of conducting their statutory mandates, and that

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190 *See, e.g.*, RUTTAN, *supra* note 26, at 101 (discussing the military procurement policy of "second sourcing" to avoid dependence on single suppliers and its effects on diffusion of knowledge and entry of new firms).

191 *See, e.g.*, 48 C.F.R. §§ 6.300–.305 (2012) (establishing requirements for when contracting can occur other than through full and open competition).

192 ROBERT D. ATKINSON, INFO. TECH. & INNOVATION FOUND., ENOUGH IS ENOUGH: CONFRONTING CHINESE INNOVATION MERCANTILISM 33 (2012), *available at* http://www.itif.org/publications/enough-enough-confronting-chinese-innovation-mercantilism; *see, e.g.*, Siyuan An & Brian Peck, *China's Indigenous Innovation Policy in the Context of Its WTO Obligations and Commitments*, 42 GEO. J. INT'L L. 375, 417–23, 434–42 (2011) (discussing whether, if the purchasing by Chinese government agencies requires import substitution for accredited indigenous innovation products, it qualifies as a subsidy under Article 1 and is prohibited by Article 3 of the SCM Agreement, on a de jure—mandated—or de facto—in practice—basis; also analyzing potential claims for lack of national treatment regarding maintenance and use rights of intellectual property and discrimination against patents by field of technology under Articles 3 and 27.1 of the TRIPS agreement); Boumil, *supra* note 81, at 775–77 (discussing exceptions in annexes to the GPA and to the national treatment in procurement obligation of Art. III—including for R&D activities—and noting potential violations if China were to accede to the GPA).

193 *See supra* note 168 and accompanying text.

194 *See supra* notes 39, 40 and accompanying text.

government sometimes creates specialized bureaucracies to perform R&D and generate innovation in particular sectors. The most well-known of these specialized R&D bureaucracies are the national laboratories (including weapons laboratories) operated by various government departments, but there are other government institutions primarily focused on R&D, such as the National Aeronautics and Space Administration (NASA).[195] Some national laboratories receive large amounts of funding for their particular fields, which may be greater or less than corresponding subsidies or procurement funds directed to private entities in those fields. For one example, the National Renewable Energy Laboratory (NREL) of the Department of Energy—originally, the Solar Energy Research Institute—received $110 million in innovation research funding under the 2009 American Recovery and Reinvestment Act.[196]

As noted earlier, government policy permits cooperative R&D agreements (CRADAs) with private entities.[197] This permits greater leveraging of federal funding for particular forms of innovation conducted within the government. Further, private entities may manage government research bureaucracies, such as the NREL, blurring the line between the public and private sectors.[198] Additionally, government can collaborate among its own agencies,[199] with subsidiary or foreign governments, or with intergovernmental organizations through interpersonnel agreements (IPA)[200] and other collaborative efforts and

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195 *Cf.* Federal Technology Transfer Act of 1986, Pub. L. No. 99-502, § 12(d)(2), 100 Stat. 1785, 1787 (codified as amended at 15 U.S.C. § 3710a (2006)) ("[T]he term 'laboratory' means a facility or group of facilities owned, leased, or otherwise used by a Federal agency, a substantial purpose of which is the performance of research, development, or engineering by employees of the Federal Government.").

196 *See* RIMMER, *supra* note 97, at 287.

197 *See* Federal Technology Transfer Act § 12(d)(1) ("[T]he term 'cooperative research and development agreement' means any agreement between one or more Federal laboratories and one or more non-Federal parties under which the Government, through its laboratories, provides personnel, services, facilities, equipment, or other resources with or without reimbursement (but not funds to non-Federal parties) and the non-Federal parties provide funds, personnel, services, facilities, equipment, or other resources toward the conduct of specified research or development efforts which are consistent with the missions of the laboratory; except that such term does not include a procurement contract or cooperative agreement . . . ."); *supra* note 133 and accompanying text (discussing CRADAs); *see also* RIMMER, *supra* note 97, at 276–77 (noting government institutional development alone or in joint partnerships with the private sector).

198 *See, e.g.*, *National Renewable Energy Laboratory*, BATTELLE, http://www.battelle.org/our-work/laboratory-management/national-renewable-energy-laboratory (last visited May 12, 2013). NREL is managed by the Alliance for Sustainable Energy, LLC.

199 *See, e.g.*, OMB 2013 BUDGET REPORT, *supra* note 56, at 369.

200 *See, e.g.*, Intergovernmental Personnel Act of 1970, Pub. L. No. 91-648, 84 Stat. 1909 (1971) (codified as amended at 42 U.S.C. § 4701 *et seq.* (2006)).

personnel exchanges.[201] Government also can engage in collaborative R&D, thereby pooling funds, technology, and other resources like in joint-venturing.[202]

Government direct development thus may lead to the generation of government-owned intellectual property rights. For example, NREL possesses a significant portfolio of patents on wind turbines, generators, power systems, cooling towers, biofuels, and geothermal technologies and building construction. NREL has also developed an online database—the Energy Efficiency and Renewable Energy Technology Portal—to license its rights.[203] Depending on how they are exercised, these government-owned intellectual property rights may have further effects on domestic and foreign markets and trade flows.[204] Whether and how the government chooses to license its intellectual property rights for further R&D or innovation then becomes an important issue, as the government may choose to compete with the private sector in the market (although it rarely does). Even if the government does not directly compete with the private sector and supplies only to the government sector, government development and supply can lead to price reductions in the commercial market through competitive development, as well as to private market shares that would be smaller than if the government sector were included and in which private entities could better recoup their innovation investments.

International collaborations similarly raise questions about the joint management of intellectual property that may be required or developed. For example, in regard to collaborations to develop technology and intellectual property through shared investment in research, former Secretary of Energy Steven Chu noted:

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201 *See, e.g.*, Press Release, U.S. Dep't of State, Memorandum of Understanding to Enhance Cooperation on Climate Change, Energy and Environment Between the Government of the United States of America and the Government of the People's Republic of China (July 28, 2009), *available at* http://www.state.gov/r/pa/prs/ps/2009/july/126592.htm; Press Release, U.S. Dep't of State, Memorandum of Understanding Signed Between the Government of India and the Government of the United States (Nov. 30, 2009), *available at* http://www.state.gov/p/sca/rls/press/2009/132776.htm (dealing with enhanced cooperation regarding energy security, energy efficiency, clean energy, and climate change). *See generally* BUSH, *supra* note 16, at 107–08 (discussing scientific congresses, international fellowships, and scientific attachés).

202 *See, e.g.*, *supra* notes 133, 201 and accompanying text.

203 RIMMER, *supra* note 97, at 290–91 (noting NREL patent portfolios in other technology areas).

204 *Id.* at 266 (noting comments regarding the joint ownership of intellectual property emerging from the US–China Clean Energy Center that "'the plan is for the two governments to get royalty-free access to the intellectual property that comes out of the center; private companies could buy in at low rates'" (quoting Daniel Roth, *The Radical Pragmatist*, WIRED, May 2010, at 104, 108) (citation omitted)).

> These joint efforts will allow several nations to share the costs and benefits of intellectual property they jointly fund, helping avoid disputes over intellectual property rights and speeding the world's transition to a clean energy economy.
>
> . . . Sharing of IPR . . . should be done where the sharing is mutually beneficial . . . . for example . . . by an exchange of non-proprietary information, royalty free or royalty bearing cross licensing, a patent pool . . . open source software distribution . . . . [and] may very well inure to the commercial benefit of the supplying entity by opening new markets.[205]

Like its contractors in procurement, the government cannot be enjoined from using intellectual property that it needs because it has waived sovereign immunity only for suits for reasonable compensation.[206] Given their inherent powers, government agencies may be more able than private entities to seek to compel transfers of know-how to support their R&D and innovation-producing activities.[207]

Finally, depending on their internal cultures and public mores, government agencies may be more or less able to attract needed R&D and innovation-producing expertise.[208] Government employment may currently be viewed as less attractive than jobs in the private commercial and nonprofit sectors, and government employees may currently be subject to greater public

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[205] *Id.* at 264–65 (quoting Letter from Steven Chu, Sec'y, U.S. Dep't of Energy, to F. James Sensenbrenner, Jr., Ranking Republican Member, U.S. House of Representatives Select Comm. on Energy Independence & Global Warming (May 5, 2009)).

[206] *See, e.g.*, 28 U.S.C. § 1498(a) (2006); Richmond Screw Anchor Co. v. United States, 275 U.S. 331, 341–44 (1928); *supra* note 181 and accompanying text.

[207] *See, e.g.*, FREDERICK M. ABBOTT, INT'L CTR. FOR TRADE AND SUSTAINABLE DEV., ISSUE PAPER NO. 12, INTELLECTUAL PROPERTY PROVISIONS OF BILATERAL AND REGIONAL TRADE AGREEMENTS IN LIGHT OF U.S. FEDERAL LAW 11–12 (2006), *available at* http://unctad.org/en/Docs/iteipc20064_en.pdf (discussing the inherent power of the government to compel such action by law and the U.S. Government's implied threat to compel production of ciprofloxacin in response to an anthrax scare). *See generally* Elizabeth A. Rowe, *Striking a Balance: When Should Trade-Secret Law Shield Disclosures to the Government?*, 96 IOWA L. REV. 791 (2011) (discussing how courts should approach "refusal-to-submit" cases, where companies refuse to submit information requested by the government).

[208] *See* BUSH, *supra* note 16, at 95–98 (discussing criteria for selecting civil servants to promote R&D and recommending various forms of R&D cooperation across government agencies); U.S. MERIT SYS. PROT. BD., ATTRACTING THE NEXT GENERATION: A LOOK AT FEDERAL ENTRY-LEVEL NEW HIRES (2008), *available at* http://www.mspb.gov/netsearch/viewdocs.aspx?docnumber=314895&version=315306&application=ACROBAT (exploring how the federal government attracts and hires new employees, especially in regard to R&D).

opprobrium,[209] but this is not a necessary state of affairs. Direct development by the government should not be routinely dismissed as an innovation funding choice, although creating new bureaucracies may be politically difficult in the current climate. As noted by then-Secretary of Energy Chu, "I took the challenge of being Secretary of Energy in part for the chance to ensure that the [DOE] Laboratories and our country's universities will generate ideas that will help us address our energy challenges. . . . DOE must strive to be the modern version of the old Bell Labs in energy research."[210]

This merely reinforces the need for additional study of the relative efficiency and effectiveness of direct development compared to private-sector funding options regarding the creation of large- or small-scale innovation outputs. In addition to the factors noted above, more specific analysis is needed in regard to the comparative expertise in identifying and directing development of scientific and technological research, and the comparative ability to develop, commercialize, market, and license the various kinds of innovation outputs.[211]

D. Constructed Commons

Yet another form of government innovation funding relates to the creation of various kinds of commons for managing physical or information resources to induce innovation.[212] The most obvious form of commons is government-

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209 *See, e.g.*, U.S. MERIT SYS. PROT. BD., *supra* note 208, at 31 ("[C]ollege graduates and public policy graduate students tend to view entry-level Government jobs as less challenging, rewarding and professionally beneficial than private and nonprofit sector jobs. They tend to believe that the private sector offers better compensation, more challenging work and better developmental opportunities, while the nonprofit sector offers more rewarding work."); Charles Babington, *Mitt Romney's Public, Private Jobs Claims Contradict*, HUFFINGTON POST (June 14, 2012, 2:39 AM), http://www.huffingtonpost.com/2012/06/14/mitt-romney-jobs-public-private_n_1596034.html (quoting former presidential candidate Mitt Romney as saying, "[w]e have 145,000 more government workers under this president. Let's send them home and put you back to work").

210 RIMMER, *supra* note 97, at 261 (alteration in original) (quoting *New Directions for Energy Research and Development at the U.S. Department of Energy: Hearing Before the H. Comm. on Sci. & Tech.*, 111th Cong. 17 (2009) (statement of Steven Chu, Secretary of Energy)).

211 To some extent, these considerations recapitulate the Bayh–Dole Act discussion above. *See supra* notes 64–76 and accompanying text.

212 *See, e.g.*, Michael W. Carroll, *Copyright, Fair Use, and Creative Commons Licenses*, *in* RISK AND ENTREPRENEURSHIP IN LIBRARIES: SEIZING OPPORTUNITIES FOR CHANGE 18 (Pamela Bluh & Cindy Hepfer eds., 2009); Madison, Frischmann & Strandburg, *supra* note 82, at 681–82; *see also* Terry L. Anderson & Gary D. Libecap, *Forging a New Environmental and Resource Economics Paradigm: The Contractual Bases for Exchange*, *in* PERSPECTIVES ON COMMERCIALIZING INNOVATION 117, 117–28 (F. Scott Kieff & Troy A. Paredes eds., 2012) (discussing the evolutionary nature of property rights and their creation by government, which facilitates bargaining regarding relevant resources). *See generally* ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION (1990); Garrett Hardin, *The Tragedy*

created or government-subsidized physical infrastructure, such as the highway system or the Internet.[213] But commons in information also may be constructed, subsidized, or regulated by government. For example, the World Meteorological Organization—a United Nations specialized agency—and others sponsor and make available data on polar climate conditions that are generated and submitted by governments and private sector scientists.[214] Another example, the Conservation Commons, is a cooperative effort of intergovernmental organizations, nongovernmental organizations, governments, academic institutions, and entities from the private sector; the Conservation Commons supports open access to data and sharing (with attribution) of information and knowledge for mutual benefit regarding biodiversity.[215] The U.S. government's Global Positioning Satellite (GPS) signals are freely available from the military and NASA, following an international incident after which NASA concluded that the public benefits of new, nonmilitary and nonaviation uses of the data justified continuing to provide it free of cost.[216] Government also may manage commons that are created with private data, such as the U.S. National Library of Medicine's PubMed Central, and submission to such a commons may either be encouraged or required by government agency policies.[217]

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of the Commons, 162 SCIENCE 1243 (1968); Carol Rose, *The Comedy of the Commons: Custom, Commerce, and Inherently Public Property*, 53 U. CHI. L. REV. 711 (1986).

213 *See, e.g.*, FRISCHMANN, *supra* note 23, at 5–6 (discussing various features that help to define infrastructure); Brett M. Frischmann, *An Economic Theory of Infrastructure and Commons Management*, 89 MINN. L. REV. 917, 923–24, 956 (2005) (noting "traditional" infrastructure of transportation, communication, and governance systems, as well as basic public services and facilities like schools and sewers; defining infrastructure from the demand-side by reference to non-rivalrous inputs for which social demand is driven by their use as inputs to downstream productive activity and that are used to produce widespread outputs); Mandel, *When to Open Infrastructure*, *supra* note 136, at 208–10 (discussing three stages of infrastructure for which open access may differentially reduce ex ante innovation incentives: (1) not yet conceived; (2) conceived but not yet developed; and (3) developed and need to be managed); Konstantinos K. Stylianou, *An Innovation-Centric Approach of Telecommunications Infrastructure Regulation*, 16 VA. J.L. & TECH. 221, 231–40 (2011) (discussing interactions of innovation, market forces, and regulation in telecommunications).

214 *See, e.g.*, *Welcome to the Polar Information Commons (PIC)*, POLAR INFO. COMMONS, http://www.polarcommons.org/ (last visited May 12, 2013).

215 *See, e.g.*, *Conservation Commons*, CONSERVEONLINE, http://conserveonline.org/workspaces/commons/ (last visited May 12, 2013).

216 *See, e.g.*, James Love & Tim Hubbard, *Paying for Public Goods*, *in* CODE: COLLABORATIVE OWNERSHIP AND THE DIGITAL ECONOMY 207, 208–09 (Rishab Aiyer Ghosh ed., 2005).

217 *See, e.g.*, *Revised Policy on Enhancing Public Access to Archived Publications Resulting from NIH-Funded Research*, NAT'L INST. HEALTH, http://grants.nih.gov/grants/guide/notice-files/not-od-08-033.html (last visited May 12, 2013); *see also* Omnibus Appropriations Act, 2009, Pub. L. No. 111–8, § 217, 123 Stat. 524, 782 (codified at 42 U.S.C. § 282c (2006)).

In addition to formal commons, informal commons of government-sponsored information and other outputs also exist. For example, many forms of government records qualify as public-sector information that may be made available for free or at noncommercial prices for further private, commercial and nonprofit use.[218]

Government may subsidize and regulate private-sector-commons institutions regarding prices of inputs and outputs, access, and other terms of interaction, without limiting the application of competition law and policy.[219] Similar to government direct development, government-commons approaches may supplement or compete with the private sector in regard to innovation promotion. For example, governments may affect commons-based activities by requiring or encouraging the pooling of technology or intellectual property rights;[220] providing or supporting free or low-cost access to information outputs that are R&D or innovation inputs;[221] and engaging in or encouraging interpersonnel exchanges.[222] If technology- or patent-pooling occurs, significant competition regulation issues will arise. For example, in the area of patent-pools, questions arise regarding whether patents in the pool are essential or nonessential, and concerns are raised over the preclusion of alternative technologies, which concerns supplement more routine competition concerns

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218 *See, e.g.*, Council Directive 2003/98, On the Re-Use of Public Sector Information, 2003 O.J. (L 345) 90 (EC).

219 *See, e.g.*, C. Scott Hemphill, *Network Neutrality and the False Promise of Zero-Price Regulation*, 25 YALE J. ON REG. 135, 164–75 (2008) (discussing private pricing and access contractual options and private subsidies that others seek to establish through government-mandated, zero-price approaches); Michael J. Madison, Brett M. Frischmann & Katherine J. Strandburg, *The University as Constructed Cultural Commons*, 30 WASH. U. J.L. & POL'Y 365, 375–76 (2009) (noting, *inter alia*, subsidies, safe harbors, privileges, or exemptions from antitrust liability used to facilitate or create commons). *See generally* LAWRENCE LESSIG, CODE: VERSION 2.0 (2006) (discussing how hardware and software as well as law regulates the Internet commons).

220 For a good discussion of the classic example of the government's threat to nationalize production in the aircraft sector, which led to creation of a privately managed patent pool—the Manufactured Aircraft Association—and subsequent commons-based developments, see Dustin R. Szakalski, *Progress in the Aircraft Industry and the Role of Patent Pools and Cross-Licensing Agreements*, 15 UCLA J.L. & TECH. 1 (2011); Harry T. Dykman, *Patent Licensing Within the Manufacturer's Aircraft Association (MAA)*, 46 J. PAT. OFF. SOC'Y 646 (1964); and Merges & Nelson, *supra* note 159, at 888–90.

221 *See, e.g.*, *Human Genome Project Information*, U.S. DEPARTMENT ENERGY OFF. SCI., http://www.ornl.gov/sci/techresources/Human_Genome/home.shtml (last modified July 31, 2012); INT'L HAPMAP PROJECT, http://hapmap.ncbi.nlm.nih.gov/ (last visited May 12, 2013); *Technology Mechanism*, UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/ttclear/jsp/TechnologyMechanism.jsp (last visited May 12, 2013).

222 *See, e.g.*, *Establishing Linkages with American Institutions*, BRIT. COUNCIL, http://www.britishcouncil.org/br/usa-education-marketing-guide-establishing-linkages (last visited May 12, 2013).

regarding barriers to entry, diminishing of competition, and trying to extend market power.[223]

Similarly, public-sourced or public-sponsored commons may compete with private efforts to create commons, whether through the creation of technology or intellectual property pools or databases, or through the encouragement of liberal licensing policies.[224] However, government-constructed and government-managed commons do not normally or purposefully compete with private R&D or innovation activity in research or production markets, even if they generate information outputs that are inputs to further R&D or innovation. Rather, such public commons typically seek to facilitate public or private R&D and innovation by lowering investment costs in creating infrastructure or other forms of commons resources and by pooling expertise and information that otherwise might not as readily be compiled. Such public commons thus typically supplement other forms of government sponsorship of public and private R&D and innovation, rather than substitute for them.

As public recognition has grown of the development of open-source and other commons-based collaborations for innovation (not just in the software sector),[225] more attention has been given to commons-based innovation

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223 *See, e.g.*, Richard J. Gilbert, *Ties That Bind: Policies to Promote (Good) Patent Pools*, 77 ANTITRUST L.J. 1, 1–4, 11–12 (2010); *see also id.* at 13–15 (noting also concerns for reduced innovation incentives from pooled rights to grantbacks of innovations—notwithstanding benefits from reduction of royalty-stacking—and for sheltering of weak patents from challenges due to reduced incentives to litigate, while recognizing potential benefits of reduced transaction costs for licensing complementary but not essential technologies). *See generally* U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N, ANTITRUST GUIDELINES FOR THE LICENSING OF INTELLECTUAL PROPERTY (1995), *available at* http://www.usdoj.gov/atr/public/guidelines/0558.htm (recognizing pro-competitive benefits of intellectual property pooling arrangements and identifying prohibited acts and concerns).

224 For some examples of various types of private physical, intellectual property, and information commons that a government commons might supersede, see GREEN EXCHANGE, http://www.greenexchange.com (last visited May 12, 2013) (commons real estate for eco-friendly businesses); *Eco-Patent Commons*, WBCSD, http://www.wbcsd.org/work-program/capacity-building/eco-patent-commons.aspx (last visited May 12, 2013); *Welcome to PLOS*, PUB. LIBRARY SCI., www.plos.org (last visited May 12, 2013); and *Science*, CREATIVE COMMONS, http://creativecommons.org/science (last visited May 12, 2013). *Cf.* Robert M. Kunstadt & Ilaria Maggioni, *A Proposed "U.S. Public Patent Pool,"* NOUVELLES, Mar. 2011, at 10, 10–13 (proposing adoption of a mandatory opt-in "U.S. Public Patent Pool" to separate invention ownership and exploitation).

225 *See, e.g.*, Daniel R. Cahoy & Leland Glenna, *Private Ordering and Public Energy Innovation Policy*, 36 FLA. ST. U. L. REV. 415, 435–51 (2009) (recognizing the paradigm of private ordering); Charles R. McManis, *Introduction*, 30 WASH. U. J.L. & POL'Y 1, 3–10 (2009) (classifying symposium papers according to four general categories: (1) business, law, and engineering perspectives; (2) open-source biotechnology; (3) open source and proprietary software development; and (4) collaborative innovation, the economics of innovation, and constructed commons).

strategies.[226] These analyses emphasize both the nature of the innovation outputs of the collaborations and how the R&D, innovation efforts, outputs, and inputs constitute the communities that produce those outputs. Constitutive factors include, *inter alia*, the "rules-in-use" that determine the participation structures (or "openness") of the community and its conditions on access to and uses of inputs and outputs.[227] Given the multiplicity of potential rules, structures, and conditions, numerous questions arise that are similar to those discussed above regarding the nature of licensing behaviors or other authorizations for uses of the innovation outputs.[228] Commons can adopt very differentiated approaches to the licensing of both inputs and outputs compared to non-commons-based innovation efforts of firms and individuals. Further, they can change their incentive structures over time, and various commons rules to police input and access policies may arguably violate antitrust laws.[229]

One particular form of such a commons-based approach to R&D and innovation production that is worth separately identifying is the creation of governmental and nongovernmental standard-setting organizations.[230] These organizations can both facilitate the development of innovation outputs and induce pooling of both inputs and outputs through cooperative licensing

[226] *See, e.g.*, Peter Lee, *Toward a Distributive Commons in Patent Law*, 2009 WIS. L. REV. 917, 946–92 (arguing for conditional use by public institutions of spending and other inputs such as labor and bodily materials to generate a distributive commons that enhances access to downstream patented technologies); Molly Shaffer Van Houweling, *Cultural Environmentalism and the Constructed Commons*, 70 LAW & CONTEMP. PROBS. 23, 25–26 (2007) (analogizing open-source software licenses to conservation easements, which separate rights to copy from rights to exclude further copying or private rights to possess from public rights to enjoy).

[227] *See, e.g.*, Madison, Frischmann & Strandburg, *supra* note 82, at 695–99, 704–05 (discussing openness and "rules-in-use").

[228] *See supra* notes 91–94 and accompanying text.

[229] *See, e.g.*, Stephen M. Maurer, *The Penguin and the Cartel: Rethinking Antitrust and Innovation Policy for the Age of Commercial Open Source*, 2012 UTAH L. REV. 269, 269–70, 296–309 (noting the increasingly commercial nature of open-source projects and arguing that broad viral licensing—such as the GNU Public License (GPL)—is unnecessarily restrictive and violates antitrust law).

[230] *See, e.g.*, Alan Devlin, *Standard-Setting and the Failure of Price Competition*, 65 N.Y.U. ANN. SURV. AM. L. 217, 218, 224–31 (2009) (noting benefits of standardized technology compared to competitive, conflicting substitutes; identifying ubiquitous technological, functional, and safety-related standards; and relating the need for and benefits of standardization to, *inter alia*, network effects, interoperability, and avoidance of waste in doomed standards and obsolescent technologies); Christopher B. Hockett & Rosanna G. Lipscomb, *Best FRANDs Forever? Standard-Setting Antitrust Enforcement in the United States and the European Union*, ANTITRUST, Summer 2009, at 19, 19 (noting that standard-setting enhances innovation and competition by assuring that products are compatible and interoperable); Willard K. Tom, *A Field Guide to Antitrust Issues in Standard Setting and Patent Pooling*, *in* ANTITRUST & THE DEAL 2010, at 389, 391–92 (2010) (distinguishing standard-setting from patent pooling regarding what is addressed by the commons—fragmentation of components and future development paths versus fragmentation of ownership).

behaviors. Conversely, creation of a standard may create collusion, competition, and market-power extension, as well as generate concerns regarding hold up for pooled substitute and complementary technologies and regarding lock-in effects.[231] In turn, such concerns may lead to commons-based (or government-imposed) adoption of rules to require ex ante disclosure of patents and broad, open licensing on favorable terms, such as "reasonable and non-discriminatory" (RAND) or "fair" RAND (FRAND) requirements. However, such commitments may be vague, policing such rules may be problematic, and more specific ex ante licensing negotiations between potential users and patent holders may raise other antitrust concerns.[232]

As noted for direct development and the ability to compel information transfers,[233] the government may have a greater ability to compel cooperation and participation in commons than private bodies, both through direct acquisition and through conditional spending.[234] Accordingly, government may be better able to supply needed R&D and innovation inputs to commons-based, targeted innovation activities in the public, commercial, or nonprofit sectors. However, because commons—by their nature as collective, collaborative

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231 *See, e.g.*, George S. Cary et al., *The Case for Antitrust Law to Police the Patent Holdup Problem in Standard Setting*, 77 ANTITRUST L.J. 913, 914–19 (2011); Philip B. Nelson, *Patent Pools: An Economic Assessment of Current Law and Policy*, 38 RUTGERS L.J. 539, 542–49 (2007). *See generally* U.S. DEP'T OF JUSTICE & FED. TRADE COMM'N, ANTITRUST ENFORCEMENT AND INTELLECTUAL PROPERTY RIGHTS: PROMOTING INNOVATION AND COMPETITION 33–56 (2007), *available at* http://www.ftc.gov/reports/innovation/P040101PromotingInnovationandCompetitionrpt0704.pdf.

232 *See, e.g.*, BRIAN T. YEH, CONG. RESEARCH SERV., R42705, AVAILABILITY OF INJUNCTIVE RELIEF FOR STANDARD-ESSENTIAL PATENT HOLDERS 21 (2012) (discussing a proposal from the American Antitrust Institute to disclose proposed or maximum licensing terms); Cary et al., *supra* note 231, at 930–34; Richard J. Gilbert, *Deal or No Deal? Licensing Negotiations in Standard-Setting Organizations*, 77 ANTITRUST L.J. 855, 857–59 (2011); Nelson, *supra* note 231, at 548–49; *cf.* Daryl Lim, *Misconduct in Standard Setting: The Case for Patent Misuse*, 51 IDEA 559, 560–82 (2011) (discussing various forms of opportunism in standard-setting organizations and various doctrinal efforts to control it); Lauren E. Barrows, Note, *Why the Enforcement Agencies' Recent Efforts Will Not Encourage Ex Ante Licensing Negotiations in Standard-Setting Organizations*, 89 TEX. L. REV. 967, 967–68 (2011) (noting continuing antitrust concerns over collusive action, such as price-fixing, that may impede ex ante negotiations). *See generally* Charles T. (Chris) Compton, *Tumultuous Times: The Escalating US Debate on the Role of Antitrust in Standard Setting*, COMPETITION L. INT'L, Feb. 2009, at 29, 30–34 (discussing various standards licensing enforcement disputes and responses to them).

233 *See supra* note 207 and accompanying text.

234 *See, e.g.*, 28 U.S.C. § 1498(a) (2006); Rumsfeld v. Forum for Academic & Institutional Rights, Inc., 547 U.S. 47, 59–61 (2006) (discussing the unconstitutional conditions doctrine and noting that no limits to spending conditions exist if the federal government could undertake the action by itself); United States v. Am. Library Ass'n, 539 U.S. 194, 203–04 (2003) (plurality opinion) (same); *cf.* Nat'l Fed'n of Indep. Bus. v. Sebelius, 132 S. Ct. 2566, 2601–07 (2012) (plurality opinion) (discussing coercion limits on federal spending that penalizes states). In contrast, the government may be less capable than the private sector of acquiring expertise in the form of human capital, particularly given limits on wages in government pay scales.

enterprises—may tend toward control that is comparatively more distributed than centralized,[235] governments may be unlikely to direct and less likely to fund broad, collaborative commons-based innovation activity. Further, at least to date, government has tended not to collect or compel disclosure of information held by commons participants, such as pricing and licensing policies.[236] More analysis is needed of these policies, as well as of government-commons institutions.

E. Market Regulation

Market regulation is also a very broad category. It covers: (1) direct product and process regulation; (2) information reporting and government disclosures, which may also lead to (or induce private action to avoid) direct product and process regulation;[237] (3) recognition and certification programs,[238] the premises of which are to provide incentives to direct private actions and to convey a market advantage that induces directed consumption patterns and thus greater innovation;[239] and (4) a wide variety of market-based regulations, including market-entry, price, competition, and intellectual-property-rights regulations. All of these may affect innovation incentives by governing market-based returns. In addition, government may threaten to engage in market regulation or entry to alter the effects of or induce changes in private, market-based behaviors such as through nationalization, crown use,

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[235] *See, e.g.*, Kapczynski, *supra* note 115, at 991 (distinguishing commons from property approaches to scientific and cultural production by their "disaggregated governance," compared to individual control, as well as by the rules of access and sources of support).

[236] *See, e.g.*, Rudy Santore, Michael McKee & David Bjornstad, *Patent Pools as a Solution to Efficient Licensing of Complementary Patents? Some Experimental Evidence*, 53 J.L. & ECON. 167, 169 n.5 (2010) (noting various case studies and the absence of information on pricing and licensing).

[237] *See, e.g.*, WESLEY A. MAGAT & W. KIP VISCUSI, INFORMATIONAL APPROACHES TO REGULATION 4–5 (1992).

[238] *See, e.g.*, *Climate Leadership Awards*, U.S. ENVTL. PROTECTION AGENCY, http://www.epa.gov/climateleadership/awards/index.html (last updated Feb. 28, 2013) (describing a joint, government–private recognition program for institutions and individuals in regard to leadership and to internal and supply-chain reporting and reductions); *History of ENERGY STAR*, U.S. ENVTL. PROTECTION AGENCY, http://www.energystar.gov/index.cfm?c=about.ab_history (last visited May 12, 2013) (describing a joint, governmental energy efficiency rating and voluntary labeling program for consumer household products).

[239] *See, e.g.*, U.S. ENVTL. PROT. AGENCY, EPA 430-R-03-008, ENERGY STAR®—THE POWER TO PROTECT THE ENVIRONMENT THROUGH ENERGY EFFICIENCY 2–3 (2003) (discussing consumer lack of information, split incentives, and credibility that reduces decision-making risks). *See generally* Jamie A. Grodsky, *Certified Green: The Law and Future of Environmental Labeling*, 10 YALE J. ON REG. 147 (1993); Peter S. Menell, *Structuring a Market-Oriented Federal Eco-Information Policy*, 54 MD. L. REV. 1435 (1995).

exercise of statutory rights, statutory or compulsory licensing, and other actions that affect private market returns.[240]

1. Product and Process Regulation

Much has been written about the ability to stimulate or discourage innovation through direct government product and process regulation, particularly environmental regulation, including but not limited to technology-based performance standards.[241] In particular, some analyses address the relationships among the various types of command-and-control regulation and the way such regulation encourages and discourages technology development.[242] Other analyses contrast regulation with ex post liability for damage caused by externalities and with tax or tradable permit scheme measures designed to internalize externalities and provide continuous environmental-improvement incentives.[243] The relative effectiveness of these choices may depend in part on the ability to quantify and monitor the relevant activities at issue.[244]

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240 *See, e.g.*, Jakkrit Kuanpoth, *Appropriate Patent Rules in Developing Countries—Some Deliberations Based on Thai Legislation*, 13 J. INTELL. PROP. RTS. 447, 450 (2008) (discussing uncompensated "[c]rown use" and distinguishing compulsory licensing); Joshua D. Sarnoff, *Flexible Application of Injunctive Relief in Intellectual Property Enforcement (with Reference to Lessons from the Emerging US Jurisprudence)*, *in* INTELLECTUAL PROPERTY ENFORCEMENT: INTERNATIONAL PERSPECTIVES 98, 100 (Xuan Li & Carlos M. Correa eds., 2009) (noting the potential to tailor remedies to promote domestic innovation and foreign direct investment); Luca Di Corato, *Profit Sharing Under the Threat of Nationalization* 20 (Swedish Univ. of Agric. Sci. Working Paper Series, Paper No. 2010:1, 2010), *available at* http://ageconsearch.umn.edu/bitstream/58292/2/Luca_WP_01_10.pdf (modeling effects of investment and nationalization on Nash bargaining and suggesting extension to "creeping expropriation"); *supra* notes 97–99, 181, 220 and accompanying text; *see also* YEH, *supra* note 232, at 7–18 (discussing vague FRAND commitments and pending cases in the International Trade Commission seeking exclusionary orders); Khan & Sokoloff, *supra* note 65, at 6 (noting potential for patent expropriation without compensation in Britain in nineteenth century).

241 *See, e.g.*, Nicholas A. Ashford et al., *Using Regulation to Change the Market for Innovation*, 9 HARV. ENVTL. L. REV. 419 (1985); Tomain, *supra* note 53, at 404 (discussing use of best available technology standards to create demand to "pull" technology, and contrasting it with the "push" approach of investments to solve a particular problem).

242 *See, e.g.*, Howard Latin, *Ideal Versus Real Regulatory Efficiency: Implementation of Uniform Standards and "Fine-Tuning" Regulatory Reforms*, 37 STAN. L. REV. 1267 (1985); Craig N. Oren, *Prevention of Significant Deterioration: Control-Compelling Versus Site-Shifting*, 74 IOWA L. REV. 1 (1988); David Schoenbrod, *Goals Statutes or Rules Statutes: The Case of the Clean Air Act*, 30 UCLA L. REV. 740 (1983).

243 *See, e.g.*, Bruce A. Ackerman & Richard B. Stewart, Commentary, *Reforming Environmental Law*, 37 STAN. L. REV. 1333 (1985); Richard L. Revesz, *Federalism and Interstate Environmental Externalities*, 144 U. PA. L. REV. 2341, 2376–91 (1996); Steven Shavell, *Liability for Harm Versus Regulation of Safety*, 13 J. LEGAL STUD. 357 (1984). *See generally* ROBERT V. PERCIVAL ET AL., ENVIRONMENTAL REGULATION: LAW, SCIENCE, AND POLICY 832–44 (1992).

244 *See, e.g.*, BAUMOL & OATES, *supra* note 52; Daniel H. Cole & Peter Z. Grossman, *When Is Command-and-Control Efficient? Institutions, Technology, and the Comparative Efficiency of Alternative Regulatory*

Other analyses focus on underinvestment and underproduction of innovations for environmental improvement because of their positive spillovers and on internalizing and regulating negative externalities.[245] Some studies have sought to rank the innovation-inducing and technology-adoption effectiveness of different environmental regulatory policies, but have concluded that the results are ambiguous given competing influences of raised direct costs of regulation and reduced costs of lowered output.[246] The rankings for innovation inducement may depend in part on "the innovator's ability to appropriate spillover benefits of new technologies to other firms, the costs of innovation, environmental benefit functions, and the number of firms producing emissions."[247] Similarly, the rankings for technology adoption may depend on, among other things, the impact of the innovations and government regulatory responses as costs of abatement are reduced.[248] Much additional work—particularly empirical analysis—still needs to be done to determine how to better induce innovation through such regulatory policy, how much innovation to induce, and how to determine the impact of technological change in general and of government R&D spending in particular.[249]

In general terms, product or process regulation can induce "weak" innovation, when dominant firms or new entrants can improve on existing technologies, or "strong" innovation, when new entrants (and sometimes established firms) introduce disruptive technologies and displace dominant firms.[250] Tinkering with market regulation, such as by adjusting patent doctrines (e.g., the standard for nonobviousness), can affect the financial

Regimes for Environmental Protection, 1999 WIS. L. REV. 887; Gloria E. Helfand, *Standards Versus Standards: The Effects of Different Pollution Restrictions*, 81 AM. ECON. REV. 622 (1991); *cf.* John F. Duffy, *The Marginal Cost Controversy in Intellectual Property*, 71 U. CHI. L. REV. 37, 53 (2004) ("[I]t may be a much simpler matter to tell how many cars cross a bridge or how much electricity is consumed than to determine how often an idea is used.").

245 *See, e.g.*, Popp, Newell & Jaffe, *supra* note 37, at 3–4 (noting the high uncertainty of innovation outputs that leads to underinvestment of inputs and "'dynamic increasing returns'" to technology from learning-by-doing, learning-by-using, and network externality effects).

246 *See id.* at 13. Lowered output may be undesirable and thereby make an R&D subsidy preferable to, or more effective combined with, an emissions tax. *See id.*

247 *Id.* at 12–14 (citing David Ulph, *Environmental Policy and Technological Innovation*, *in* NEW DIRECTIONS IN THE ECONOMIC THEORY OF THE ENVIRONMENT (Carlo Carraro & Domenico Siniscalco eds., 1997); Wesley A. Magat, *The Effects of Environmental Regulation on Innovation*, 43 LAW & CONTEMP. PROBS. 4 (1979); Wesley A. Magat, *Pollution Control and Technological Advance: A Dynamic Model of the Firm*, 5 J. ENVTL. ECON. & MGMT. 1 (1978)).

248 *See* Popp, Newell & Jaffe, *supra* note 37, at 24–26.

249 *Id.* at 16–18, 20–22.

250 *See, e.g.*, Nicholas A. Ashford & Ralph P. Hall, *Regulation-Induced Innovation for Sustainable Development*, ADMIN. & REG. L. NEWS, Spring 2012, at 21, 21–22.

incentives to shoot for weak or strong innovations.[251] In turn, such market regulation may alter the direction and nature of the innovation that would otherwise be induced by direct product or process regulation. Strengthening environmental regulatory controls may lead to greater innovation by new entrants. New entrants not only may benefit from "innovation offsets" of reduced production costs associated with reduced control costs, but also may displace incumbent firms and provide a national comparative advantage, particularly if stringent regulation is imposed at a comparatively later time.[252]

As some analysts have discussed, at least three factors affect the ability of such direct regulation to induce innovation. But identifying the factors and stating their influence is a far cry from analyzing their actual effects and comparative influence.

The first factor is the willingness to innovate, which is affected by at least the following four considerations: "attitudes towards changes in production in general; . . . an understanding of the problem; . . . knowledge of possible options and solutions; and . . . the ability to evaluate alternatives."[253] In turn, each of these four considerations is affected by internal firm culture, risk taking, and personnel expertise.

The second factor is the opportunity and motivation to innovate. This factor is affected on the "supply" side at least by two considerations: the nature of the regulation and the kind of technology "gap." On the "demand" side, the second factor is affected at least by the following three considerations: "opportunities for cost savings or expansion of sales; . . . public demand for more environmentally sound, eco-efficient, and safer industry, products, and services; and . . . worker demands and pressures arising from industrial relations concerns."[254]

The third factor is the capacity to innovate. This capacity may be enhanced by at least the following five considerations: "an understanding of the

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[251] *See, e.g.*, John H. Barton, *Non-Obviousness*, 43 IDEA 475, 492 (2003) (discussing reduced static and increased dynamic incentives of raising the nonobviousness bar); *cf.* Christopher-Paul Milne & Joyce Tait, *Evolution Along the Government–Governance Continuum: FDA's Orphan Products and Fast Track Programs as Exemplars of "What Works" for Innovation and Regulation*, 64 FOOD & DRUG L.J. 733, 734 (2009) (noting that the need for top-down regulatory control of risks imposes a higher bar for small entities in the life-sciences sector to enter the market, and the higher the bar the greater the ability of incumbents to maintain their dominant position).

[252] Ashford & Hall, *supra* note 250, at 21–22.

[253] *Id.* at 22–23.

[254] *Id.* at 23.

problem; . . . knowledge of possible options and solutions; . . . the ability to evaluate alternatives; . . . resident/available skills and capabilities to innovate; and . . . access to, and interaction with, outsiders."[255] Self-evidently, each consideration will be affected not only by internal firm culture and workplace policies, but also by whether the field being regulated has extensive networks for extra-firm collaboration.[256]

Where regulation itself impedes innovation, it may generate a need for regulatory reform and induce regulatory innovation.[257] Regulation also occurs within economic sectors that directly affect the funding of innovation, such as the financial sector. The financial sector recently has developed a higher-than-usual rate of litigation of its patented innovations.[258] Some recent analysis has suggested that in some cases financial regulations designed to reduce risks and increase accountability may unintentionally have interfered with innovation and entrepreneurship, venture capital, and forms of public offerings.[259]

Accordingly, market regulation as a strategy to promote product and process innovation must be viewed very broadly indeed. Further, many approaches to product and process regulation also raise trade concerns and concerns with incentives to transfer research efforts to more lenient regulatory jurisdictions. In particular, late-to-the-table countries (e.g., in regard to setting and achieving environmental goals) may become more innovative than countries achieving earlier regulatory compliance and having comparatively

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255 *Id.*

256 *Id.*

257 *See, e.g.*, Timothy A. Slating & Jay P. Kesan, *Making Regulatory Innovation Keep Pace with Technological Innovation*, 2011 WIS. L. REV. 1109, 1111–19 (discussing innovation-inducing measures—including tax subsidies and product regulation for biofuels—and burdens of regulating biofuel blending that call for revision to maximize the ability to capture social welfare from the regulation of biofuels); *cf.* Milne & Tait, *supra* note 251, at 735–36 (noting the need for regulatory innovation, focusing on three competing perspectives—innovation communities, policy makers, and stakeholders–and identifying two important developments—policy networks and formal advisory functions—within the regulatory process); Khan & Sokoloff, *supra* note 65, at 7 (discussing patent system regulatory responses in Britain following the Crystal Palace Exhibition of 1851, which brought attention to the innovative patent institutions in the United States).

258 *See, e.g.*, Harhoff, *supra* note 41, at 55 (discussing restrictions on financial inputs to innovation); Josh Lerner, *The Litigation of Financial Innovations*, 53 J.L. & ECON. 807, 827–28 (2010) (noting that the disproportionate increases in litigation over financial services patents are consistent with nuisance-suit behavior that imposes both deadweight losses of licensing payments and innovation costs of distorted incentives skewed to socially unproductive litigation).

259 *See, e.g.*, Jose Miguel Mendoza, Christoph Van der Elst & Eric P. M. Vermeulen, *Entrepreneurship and Innovation: The Hidden Costs of Corporate Governance in Europe*, 7 S.C. J. INT'L L. & BUS. 1, 3–4 (2010).

fewer regulation-induced incentives for R&D. As one former government official has noted:

> [O]ne of the things we did study in the late '90s and one of the things we noticed about environmental regulations in the United States was that the rise of the environmental regulatory regime from the '70s to '80s actually drove innovation for about 15 to 20 years because companies were scrambling to develop technologies that could meet these new environmental protection requirements. But once everybody had reached the level of compliance required by the statute, that kind of became a floor, and there was no incentive built into the system for anybody to do anything that was better than the regulations required. Companies who were capable of doing zero emission factories got no benefit, no economic incentive, out of it. So then toward the end of the '90s you started to see a whole lot of other countries that were then putting their environmental regimes in place, to start attracting a lot of R & D in the environmental technology area and to be developing innovative technologies, more innovative than what a lot of United States companies were doing. So that illustrates the impact of those kinds of regulatory issues; the other components here I think are obvious, investing in infrastructure, not just the physical plant and equipment, in roads and bridges and air traffic controller systems, which remain important, but over the years investing in the IT, in telecommunications infrastructure, in broadband capacity, all the things that make innovation possible as well as the work force.[260]

2. *Information Regulation*

Turning to the alternatives to product or process regulation, additional analyses of environmental regulatory options have addressed mandatory information disclosures and their use to generate private environmental improvement and innovation. For example, given adverse publicity and stockholder and public responses, it is widely thought that requiring disclosure of toxic chemical releases has led to efforts at and investments in R&D to achieve reduction of releases.[261] This effect may be similar to that observed for

[260] Can.–U.S. Proceedings 2006, *supra* note 15, at 54 (including comments of White House technology advisor and former Assistant Secretary of Commerce for Technology Policy Kelly Carnes).

[261] *See, e.g.*, James T. Hamilton, *Pollution as News: Media and Stock Market Reactions to the Toxics Release Inventory Data*, 28 J. ENVTL. ECON. & MGMT. 98 (1995); Shameek Konar & Mark A. Cohen, *Information as Regulation: The Effect of Community Right to Know Laws on Toxic Emissions*, 32 J. ENVTL. ECON. & MGMT. 109 (1997); *cf.* Seema Arora & Timothy N. Cason, *Why Do Firms Volunteer to Exceed Environmental Regulations? Understanding Participation in EPA's 33/50 Program*, 72 LAND ECON. 413 (1996) (discussing similar reductions through voluntary efforts and disclosures); Ginger Zhe Jin & Phillip

recognition and certification, which may provide the public with information that drives purchasing and thus feeds back to innovation incentives.[262] In this regard, the forthcoming disclosure of GHG data from domestic-law-required regulatory permits[263] and national-plan-imposed efforts to track emissions[264] will be very interesting to watch.

3. Recognition and Certification Programs

Recognition and certification programs act principally as intrinsic motivation-affecting measures or as demand-pull instruments to induce innovation. They are thus contingent on personal preferences, institutional cultures, and market perceptions of the comparative benefits of the recognized or certified outputs in the relevant markets.[265] Although an extensive literature is beginning to address teacher certifications and effectiveness,[266] relatively little theoretical and empirical analysis has studied the innovation-inducing effects of certifications on technology development and dissemination.[267] Much more needs to be done in this area.

Leslie, *The Effect of Information on Product Quality: Evidence from Restaurant Hygiene Grade Cards*, 118 Q.J. ECON. 409 (2003) (discussing consumer and consequent production responses to posting information on restaurant hygiene).

262 *See, e.g.*, Popp et al., *supra* note 37, at 9–10 (citing Richard G. Newell, Adam B. Jaffe & Robert N. Stavins, *The Induced Innovation Hypothesis and Energy-Saving Technological Change*, 114 Q.J. ECON. 941 (1999)) (discussing modeling showing that the effects of energy prices on innovation were greatest in years following adoption of product labeling requirements).

263 *See, e.g.*, 40 C.F.R. pt. 98 (2012) (containing the U.S. Environmental Protection Agency Mandatory Reporting of Greenhouse Gases Rule).

264 *See, e.g.*, Kyoto Protocol to the United Nations Framework Convention on Climate Change art. 3.3, Dec. 10, 1997, 37 I.L.M. 22; UNFCCC, *supra* note 1, at arts. 4.1(a), 12.1(a).

265 *See, e.g.*, DIRECTORATE GEN. ENV'T, EUROPEAN COMM'N, THE POTENTIAL OF MARKET PULL INSTRUMENTS FOR PROMOTING INNOVATION IN ENVIRONMENTAL CHARACTERISTICS: EXECUTIVE SUMMARY 5, 12–20 (2009), *available at* http://ec.europa.eu/environment/enveco/innovation_technology/pdf/market_pull_exec_summary.pdf (discussing a broader range of demand pull mechanisms that include certifications; describing various "company push factors" that include size, company nature/history, supply chain position, competitive edge, corporate policies, path dependence, capital availability, and technology spillovers; and listing measures to enhance visibility, adoption, and flexibility of demand pull measures); *supra* notes 42–49 and accompanying text.

266 *See, e.g.*, Thomas J. Kane, Jonah E. Rockoff & Douglas O. Staiger, *What Does Certification Tell Us About Teacher Effectiveness? Evidence from New York City* (Nat'l Bureau of Econ. Research, Working Paper No. 12155, 2006).

267 *Cf.* Milé Terziovski, Damien Power & Amrik S. Sohal, *The Longitudinal Effects of the ISO 9000 Certification Process on Business Performance*, 146 EUR. J. OPERATIONAL RES. 580, 580–81 (2003) (identifying the principal motivation to certify as consumer pressure and noting major gaps in research into operations/quality management).

4. *Market Regulation*

Turning to market regulation, both intellectual property and antitrust law are the most obvious places to look (although price controls, crown use, statutory and compulsory licensing, and other forms of regulation of private market returns may also be used).[268] As suggested above, intellectual property is best viewed as a form of market regulation in that it provides a government subsidy (a property right) and government regulation of market behaviors through regulatory clearance and litigation mechanisms, some of which may be brought by the government.[269] Analyses of direct measures to restrict static social welfare losses and balance them against dynamic innovation-incentive losses—such as price controls or compulsory licensing—have proven theoretically intractable.[270]

Much effort has therefore gone into analyzing whether broader or narrower intellectual property rights will provide the best balance of incentives and access to promote both static and dynamic innovation. As the author of one recent modeling effort stated, however, such analysis is "embryonic," and has yet to even begin its "infancy."[271] Another recent empirical analysis, which

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268 *See, e.g.*, Lionel Nesta, Francesco Vona & Francesco Nicolli, Environmental Policies, Product Market Regulation and Innovation in Renewable Energy (Dec. 21, 2012) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2192441 (discussing product market regulation effects under different forms of competition). For an excellent historical discussion of antitrust approaches to regulating innovation in the United States, see B. Zorina Khan, *Antitrust and Innovation Before the Sherman Act*, 77 ANTITRUST L.J. 757, 759–60, 784–85 (2011), which noted continuity of federal approaches under the Sherman Act with earlier, state-based regulatory strategies, and early federal reliance on a market orientation and a network of regulations and antimonopoly rulings, except in regard to the state-owned enterprise of the postal service. The other forms of market-return regulation are not discussed further here, but warrant additional consideration as they affect innovation incentives.

269 *See, e.g.*, 17 U.S.C. § 506(a) (2006); 18 U.S.C. § 2319(a) (2006).

270 *See, e.g.*, Scotchmer, *supra* note 18, at 33–35 (discussing competing incentives of strong or weak protection for first- and second-generation innovators and the lack of perfect solutions through ex ante licensing); Rudolph J.R. Peritz, *Competition* Within *Intellectual Property Regimes: The Instance of Patent Rights*, *in* INTELLECTUAL PROPERTY AND COMPETITION LAW: NEW FRONTIERS 27 (Steven Anderman & Ariel Ezrachi eds., 2011) (discussing the "analytic stalemate" between exclusionary rights and open access).

271 John M. Golden, *Innovation Dynamics, Patents, and Dynamic-Elasticity Tests for the Promotion of Progress*, 24 HARV. J.L. & TECH. 47, 50 (2010); *cf.* Michele Boldrin & David K. Levine, *The Case Against Patents* 1, 15–19 (Fed. Reserve Bank of St. Louis Research Div. Working Paper Series, Working Paper No. 2012-035A, 2012), *available at* http://research.stlouisfed.org/wp/2012/2012-035.pdf (discussing historical and comparative evidence that weak patent systems mildly increase innovation, but strong patent systems retard innovation); Andrea Blasco, Disclosure and Collaboration in Dynamic R&D Races 2–3 (Mar. 15, 2012) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1961356 (noting that the intellectual property literature has not to date considered the effects of rights on incentives for collaboration of sequential innovators with pioneering innovators, and arguing that weak patent protection may fail to promote innovation because of strategic decisions to ignore disclosed and unprotected knowledge).

collected a comprehensive dataset in a particular field (plant variety innovation), has suggested that intellectual property rights generally were not significant for innovation.[272] Again, that finding may not translate beyond the particular field, may have been historically dependent on the particular institutions and their development, and thus may not provide useful insights to extrapolate to other contexts.[273]

Notwithstanding the tremendous efforts by some of our brightest minds, things have not progressed too much past the identification of at least three basic sets of competing concerns that must be assessed and balanced in all sorts of situations. These three concerns are: (a) the adequacy of incentive effects, transactions costs, effects on cumulative innovation, and loss of consumer surplus from higher prices; (b) the adequacy of consumer signaling to producers and overinvestment in intellectual products; and (c) the duplication of innovative efforts resulting from the incentive effects, wasted efforts to design around rights to provide functional equivalents, and inefficient development of initial innovation prospects.[274] Debatably, there may be some situations where certain forms of intellectual property rights are thought to be clearly needed (such as patents for pharmaceuticals, even when they impose high social costs)[275] or to be wholly ineffectual (such as patents for pharmaceuticals for "neglected diseases").[276]

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272 *See* Paul J. Heald & Susannah Chapman, *Veggie Tales: Pernicious Myths About Patents, Innovation, and Crop Diversity in the Twentieth Century*, 2012 U. ILL. L. REV. 1051, 1053–56.

273 For plant varieties, special utility patents exist for asexually reproduced varieties, and special protection exists for sexually reproduced varieties, in the form of Plant Variety Certificates, which supplement utility patent protection in plants recognized in 1985. *See* Act of May 23, 1930, ch. 312, 46 Stat. 376; Plant Variety Protection Act, Pub. L. No. 97-577, tit. I, § 1, 84 Stat. 1542, 1542 (1970) (current version at 7 U.S.C. § 2321 (2006)); *Ex parte* Hibberd, No. 645-91, 227 U.S.P.Q. (BNA) 443, 444–45 (B.P.A.I. Sept. 18, 1985). The effects of such additional protection on innovation are theoretically uncertain. *Cf.* Heald & Chapman, *supra* note 272, at 1054–56, 1058–60.

274 *See, e.g.*, Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J.L. & ECON. 1, 2 (1969) (identifying three logical fallacies in the "nirvana approach" to public-policy economics); Kitch, *supra* note 159; Glynn S. Lunney, Jr., *Reexamining Copyright's Incentives-Access Paradigm*, 49 VAND. L. REV. 483 (1996); Merges & Nelson, *supra* note 159; Fisher, *supra* note 125, at 4–10. Note that for other public goods, it is often thought to be efficient when producers do not obtain full social returns, given the existence of positive externalities.

275 Some have argued that the pharmaceutical industry is such a situation, given the high costs of R&D and product approval, the uncertainty of successful results from particular research paths, ease of reverse engineering, and low costs of generic production. *See* Fisher, *supra* note 125, at 11. But for low-income markets, some adjustment (such as through compulsory licensing) may be necessary to address social welfare losses, albeit accompanied by higher transaction costs and diminished ex ante innovation incentives. *See id.* at 12–13. However, there is no theoretically necessary reason why alternatives to patent rights might not work as well (or better) than intellectual property rights (e.g., more substantially subsidizing pharmaceutical research

The optimal strength and scope of intellectual property rights also depend on multiple, competing considerations. These include the following eight concerns: (a) private reliance on intellectual property rights as a means of recouping investments in innovation, combined with government market regulation of the returns on such investments;[277] (b) public funding of inputs to private research and development; (c) values of private researchers (or their firms) regarding the public's interests; (d) the pioneering or cumulative nature of the research; (e) the degree of centralization of firm structures; (f) dependence on intellectual property for funding of R&D or firm ventures; (g) documentation and publication practices that make it harder to build on others' work or to avoid infringement or clear rights; and (h) various types of network externalities.[278] As remains true almost a decade after it was said, "[e]fforts to identify an optimal balance of these various effects continue, but no solution is yet in sight."[279]

Antitrust analyses reflect similar theoretical and empirical limitations. Much has been written about differences of innovation and product markets and the need to differentiate antitrust and intellectual property doctrines as a result of different market structures and dynamics for different products.[280] Innovation market concerns reflect the insight "that a merger between the only

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and clinical trials, or direct government development of pharmaceuticals). The factors that may affect these comparisons are discussed further *supra* in Part I.

[276] *See, e.g.*, So et al., *supra* note 66, at 2081. Note that effective price discrimination may not be practically possible, and even when possible, it may not be profit maximizing. *See, e.g.*, Flynn, Hollis & Palmedo, *supra* note 170, at 190.

[277] *See, e.g.*, Cohen, Levin & Mowery, *supra* note 36, at 548–49; Fisher, *supra* note 125, at 11 n.24, 19–21. *See generally* Wesley M. Cohen et al., *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* 2 (Nat'l Bureau of Econ. Research, Working Paper No. 7552, 2000).

[278] *See* Fisher, *supra* note 125, at 17–18, 24–25.

[279] *Id.* at 9.

[280] *See, e.g.*, Ordover, *supra* note 149, at 514–18 (discussing intertemporal market linkages and interactions between upstream research and downstream products, noting particular concerns when firms compete in both markets, suggesting greater solicitude for upstream research markets, and describing four contextual considerations to improve rule-of-reason analysis); J. Thomas Rosch, Comm'r, Fed. Trade Comm'n, Antitrust Regulation of Innovation Markets: Remarks at the ABA Antitrust Intellectual Property Conference 1–4 (Feb. 5, 2009), *available at* http://www.ftc.gov/speeches/rosch/090205innovationspeech.pdf (discussing the history of regulating innovation markets, practical constraints on using antitrust analysis, and the temporal relationships of innovation, product markets, and concerns over joint venturing activity). *See generally* Jonathan M. Barnett, *Property as Process: How Innovation Markets Select Innovation Regimes*, 119 YALE L.J. 384 (2009); Mark A. Lemley, *Industry-Specific Antitrust Policy for Innovation*, 2011 COLUM. BUS. L. REV. 637.

two, or two of a few, firms in R&D might increase the incentive to suppress at least one of the research paths."[281]

Again, as a recent criticism of even a limited discussion of innovation markets has stated, the "fundamental flaws in the innovation market concept are . . . [that we] don't know about the relationship between market structure and effect, that error costs are high, and that competition is multidimensional. In other words, we don't know a lot and acting on our ignorance . . . is costly."[282] Historically, such research markets or activities have been treated differently from other markets within intellectual property law to prevent their domination by exclusive rights,[283] just as they have been treated differently in competition law. More recently, some scholarship has sought to identify criteria for determining the kinds of entry-blocking or entry-burdening innovations in research markets that would warrant antitrust scrutiny or immunity for product markets, while recognizing the difficulties of assessing whether the consumer-perceived advantages are genuine and warrant the corresponding reductions in competition.[284]

Intellectual property, of course, can be a barrier to innovation, particularly where broad rights or multiple rights need to be licensed to perform research or produce products, if licensing in the research market is inefficient.[285] This

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281 MICHAEL A. CARRIER, INNOVATION FOR THE 21ST CENTURY: HARNESSING THE POWER OF INTELLECTUAL PROPERTY AND ANTITRUST LAW 297 (2009).

282 Geoffrey A. Manne, *Assuming More Than We Know About Innovation Markets: A Review of Michael Carrier's* Innovation in the 21st Century, 61 ALA. L. REV. 553, 555 (2010) (reviewing CARRIER, *supra* note 281). *But cf.* Michael A. Carrier, *Innovation for the 21st Century: A Response to Seven Critics*, 61 ALA. L. REV. 597, 601–03 (2010) (noting the limited scope of the suggested analysis, but its comparative benefits to existing analysis).

283 *See, e.g.*, Henrik Holzapfel & Joshua D. Sarnoff, *A Cross-Atlantic Dialog on Experimental Use and Research Tools*, 48 IDEA 123, 133–44 (2007–2008) (noting the origins of the experimental-use doctrine as a statutory interpretation of (non)infringement rather than as a defense to infringement, and tracing its history of and focus on noncommercial research). *See generally* Ofer Tur-Sinai, *Cumulative Innovation in Patent Law: Making Sense of Incentives*, 50 IDEA 723, 741–72 (2009–2010) (discussing innovation-inducing effects from comparing patent scope with experimental-use exceptions).

284 *See* Alan Devlin & Michael Jacobs, *Anticompetitive Innovation and the Quality of Invention*, 27 BERKELEY TECH. L.J. 1, 4–5 (2012) (suggesting antitrust immunity for innovations that merely burden competition, scrutiny for innovations that prevent market entry, and invalidity for such inventions that are not "genuine[ly]" defined as having "a feature that consumers would pay a premium to acquire, though the necessary premium is less than the five to ten percent over the existing price that often accompanies market-definition analysis" and thereby "transforms a product into a pure substitute in the eyes of consumers"); *see also id.* at 19–33.

285 *See, e.g.*, Cahoy & Glenna, *supra* note 225, at 427–30; *cf.* Condon & Sinha, *supra* note 65, at 11–13 (discussing concentration of technologies and intellectual property rights in a limited number of companies from very few countries, thus raising concerns for biodiversity, affordable access, and innovation).

reiterates the concern, although this time within intellectual property law, about whether innovation markets should be subject to differential treatment under a broad, experimental-use doctrine or a similar doctrine (e.g., fair use).[286] The need for external or internal controls of such rights may depend on the degree to which private ordering solutions are effective. Such solutions may include the following four approaches: (a) vertical integration (firm consolidation) by acquiring the rights; (b) joint-venturing or cross-licensing; (c) patent-pooling; and (d) standard-setting (with relevant commitments to provide reasonable cost access).[287] In turn, the ability to use any of these solutions may depend on the following five factors: (a) a limited number of rights at issue; (b) a limited number of parties who need to coordinate; (c) the existence of synergies or complements for the technology; (d) the duration of the market for the technology;[288] and, of course, (e) antitrust-law treatment of each of these approaches and factors. Misuse doctrine may bring these potential innovation-reducing concerns within intellectual property law without limiting the concerns to effects on competition.[289]

5. *General Considerations*

At a basic level, theory tends to distinguish the process of innovation from the market that evaluates the innovation and determines whether particular innovations are viewed as successful. Thus, one recent economic review distinguished useful innovations from useless innovations and innovation markets from product markets, while attributing "Schumpeterian creativity" to the comparatively better ability to imagine future products and production provided at lower factor-of-production prices.[290] Further, some analysts attribute successful entrepreneurial activity to the rational, profit-maximizing efforts of those with talent and who seek to create monopoly rents through

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[286] *See, e.g.*, Holzapfel & Sarnoff, *supra* note 286, at 180–84 (discussing expected returns in regard to research tool markets); Maureen A. O'Rourke, *Toward a Doctrine of Fair Use in Patent Law*, 100 COLUM. L. REV. 1177, 1205 (2000) (discussing factors to consider in adopting a fair-use approach to patent noninfringement).

[287] *See, e.g.*, Cahoy & Glenna, *supra* note 225, at 440–45.

[288] *See id.* at 446–52.

[289] *See, e.g.*, Christina Bohannan, *IP Misuse as Foreclosure*, 96 IOWA L. REV. 475, 478–79 (2011) (encouraging use of misuse doctrine to address innovation harms without equating it to antitrust analysis); Thomas F. Cotter, *IP Misuse and Innovation Harm*, 96 IOWA L. REV. BULL. 52, 55–59 (2011), http://www.uiowa.edu/~ilr/bulletin/ILRB_96_Cotter.pdf (noting concerns with line-drawing and solicitude for "false positives" or "false negatives"); Lim, *supra* note 232, at 560.

[290] Israel M. Kirzner, *Between Useful and Useless Innovation: The Entrepreneurial Role*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 12, 14.

innovation from which they can derive over-profit. In turn, the highest private returns lead to the investment (allocation) of talent and its application toward particular innovative activities.[291] And, of course, others attribute non-profit-maximizing (extrinsic or intrinsic) motivations to innovators (i.e., those with talent or other creativity who do not merely imitate).[292]

From a market-based and institutional perspective, rather than that of the individual, "increased competition or entry threat induces firms to invest more in innovation in order to escape the competitive threat."[293] Similarly, innovation should be understood as a continuous and temporally extended cycle among creators, entrepreneurs, the market, and laws, and trade liberalization not only induces investment, but also permits enhanced R&D spillovers.[294]

Further, the category of entrepreneurs as a social group or entrepreneurship as a status may also affect both choices to innovate and returns that particular innovations achieve. As a recent study noted, although the economic benefits of entrepreneurship are large and economic returns on education are higher for entrepreneurs than for employees, the preference for entrepreneurship is "not high" among more highly educated individuals.[295]

Whether private incentives for allocating either innovative resources or talent apply in the same way to publicly funded innovation activity is at least questionable. Even assuming profit maximization as the basic motivation for funding recipients, such publicly funded actors may either be risk-averse or foresee greater returns from continued public funding than from the potential for market returns on their monetary, time, and effort investments. Rent-seeking may further jeopardize profits of established productive sectors and adversely affect innovation and investment.[296]

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[291] Marcus Dejardin, *Entrepreneurship and Rent-Seeking Behavior*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 17, 18–19.

[292] *See supra* notes 43–47 and accompanying text.

[293] Philippe Aghion, *Industrial Policy, Entrepreneurship and Growth*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 45, 45.

[294] *See id.*; *see also* MICHAEL A. GOLLIN, DRIVING INNOVATION: INTELLECTUAL PROPERTY STRATEGIES FOR A DYNAMIC WORLD 94–95, 122–23 (2008).

[295] Mirjam van Praag, *Who Values the Status of the Entrepreneur?*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 24, 24.

[296] Dejardin, *supra* note 291, at 20.

As others have noted, countries have adopted very different industrial policies for development, including: import substitution policies to develop local demand (as in Latin America); export promotion policies, achieved through tariff and nontariff barriers and maintaining undervalued exchange rates (as in Korea or Japan); and targeted subsidies to industries and efforts to develop "national champion" firms (as in France and China) and different intellectual property doctrinal standards.[297] Since the 1980s, a "Washington consensus" has developed among international lending and aid institutions and economists emphasizing nontargeted policies that improve investment markets.[298] But targeted or other efforts to protect "infant industries" from lower cost foreign competition, while developing domestic acumen through "learning-by-doing," have not demonstrated notably higher productivity growth or correlation to increased skill than in the absence of such efforts.[299]

Nevertheless, in theory, targeted investment may overcome private firm disincentives to invest in new sectors of an economy given existing cross-sectoral externalities that reflect and reinforce existing patterns of specialization.[300] Even in existing developed economies that tend to innovate on the "world technology frontier," there may be a need for targeted industrial policy to minimize or overcome innovation in the "wrong direction" that maximizes private returns but does not promote long-term growth or other socially beneficial production.[301]

Similarly, financing constraints for particular kinds of firms and R&D more generally may lead to suboptimal innovation, in part due to the lack of an intermediate market for the outputs of innovation, "such as ideas, patents, licenses, blueprints, prototypes, etc."[302] Various reasons exist to think that financing for R&D will be suboptimal compared to financing for capital assets—particularly for new entrants or small firms—and the problem may be further exacerbated by differential tax treatment of R&D and intangibles

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[297] *See* GOLLIN, *supra* note 294, at 308–21; Aghion, *supra* note 293; *see also* U.S. INT'L TRADE COMM'N, PUB. 4199, CHINA: INTELLECTUAL PROPERTY INFRINGEMENT, INDIGENOUS INNOVATION POLICIES, AND FRAMEWORKS FOR MEASURING THE EFFECTS ON THE U.S. ECONOMY (2010).

[298] Aghion, *supra* note 293, at 46.

[299] *See id.* at 47–48.

[300] *See id.* at 47–49.

[301] *Id.* at 50; *see* Aghion, *supra* note 63, at 2 (noting the need for industrial policy); Arrow, *supra* note 13, at 21 (noting increasing returns-to-scale theories based on straightforward economies of scale, learning by doing, and the fact that costs but not rewards of innovation are independent of the size of markets).

[302] Harhoff, *supra* note 41, at 55.

relative to other investments.[303] Hence, government intervention of various kinds may be warranted, particularly as venture capital is not fully effective at reaching innovative private firms.[304]

In summary, far too little is known at present to make informed choices among the different forms of market regulatory measures, much less among the different forms of innovation funding choices available to government.

CONCLUSION

As the preceding discussion should make clear, the choices of government funding substitute for, complement, and interact with each other in various complex ways that are highly contingent on institutions and their cultures. No choice or combination of government innovation funding mechanism is clearly theoretically preferable. The taxonomy discussed above, moreover, demonstrates that too much choice exists for government decision makers who may have limited public support for or limited ability to make informed decisions regarding what will induce the most invention, innovation, and diffusion of technology. Given the concerns about underproduction of innovation due to externalities and positive spillovers, and given the impending climate-change needs, we likely need to more aggressively adopt and expand multiple funding choices. In particular, this includes expanding commons-creation and commons-management so as to maximize innovation infrastructure in both the public and private sectors. At a minimum, we need government to both provide more funding to innovation overall and to induce the market to supply additional funding.

Further, as we move forward, we will need to better evaluate the choices that we make to better avoid wasting massive resources and opportunities when seeking to generate desperately needed innovation outputs. In particular, we need to understand and track the outputs better, interrogate and evaluate the

303 *See id.* at 57–58 (discussing collateral and liquidity problems and information asymmetries, high adjustment costs for R&D—particularly regarding human capital losses, and financing of innovation principally from equity or retained earnings rather than debt).

304 *See id.* at 59; *see also* William R. Kerr & Ramana Nanda, *Financing Constraints and Entrepreneurship*, *in* HANDBOOK OF RESEARCH ON INNOVATION AND ENTREPRENEURSHIP, *supra* note 36, at 88.

internal cultures of both private entities and public bureaucracies, and match actual decision making with developing theoretical and empirical analyses. Hopefully this Article will contribute to efforts to create better information, better understanding, and better decision making.