INNOVATION AND INSTITUTIONS: RETHINKING THE ECONOMICS OF U.S. SCIENCE AND TECHNOLOGY POLICY

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This paper is motivated by the curious policy regime created by and developed under the Bayh-Dole Act of 1980. Under current law, a contractor working on a research project that is fully funded by a federal grant is legally entitled to "first dibs" on any resulting patent rights.[1] Although consideration and criticism of this seemingly "counterintuitive policy" have been voiced,[2] it seems that insufficient attention has been given to the economic issues involved. In a more general sense, the policy is indicative of a pervasive social and intellectual problem: science and technology policy is extremely difficult to coordinate, much less evaluate once in place. As was recently acknowledged in a report to Congress from the House Committee on Science entitled *Unlocking Our Future: Toward a New National Science Policy*,[3] the intellectual underpinnings upon which our current innovation policy is based are inaccurate and in need of significant reform. To economists studying

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1. *See* 35 U.S.C. § 202 (1994). There are of course some exceptions. *See infra* Part IV.

2. Criticism of the Bayh-Dole Act generally focuses on the preliminary justifications for government intervention and the intuitive suspicions that unwarranted rents are being extracted from the public. *See, e.g.*, Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA. L. REV. 1663 (1996) [hereinafter *Public Research and Private Development*]. Rebecca Eisenberg highlights four aspects of the Bayh-Dole Act regime that are sources of concern: that (1) the public pays twice for innovations, through taxes used to support the innovation project and through elevated prices and under-utilization as a result of the intellectual property grant; (2) the *ex ante* incentive justification for granting an intellectual property right is missing (or doubly addressed); (3) promoting private appropriation of a publicly-funded innovation undermines the public goods rationale for public funding in the first place; and (4) private appropriation of innovations that would otherwise enter the public domain may lead to a scarcity of such innovations in the public domain. *See id.* at 1666-67. These overlapping concerns seriously question the simplicity of a uniform correction to the under-utilization of government funded research that prevailed before 1980 and served as a basis for passing the Bayh-Dole Act. A more detailed economic analysis of the institutions involved sheds light on some of the more complex issues at stake.

3. *See* STAFF OF HOUSE COMM. ON SCIENCE, 105TH CONG., 1st SESS., UNLOCKING OUR FUTURE: TOWARD A NEW NATIONAL SCIENCE POLICY 8 (Comm. Print 1998), *available at* < http://www.access.gpo.gov/congress/house/science /Cp105-b/science105b.pdf> [hereinafter UNLOCKING OUR FUTURE]. *See also* AMERICAN ASS'N FOR THE ADVANCEMENT OF SCIENCE, SCIENCE AND TECH. FOR THE NATION: ISSUES AND PRIORITIES FOR THE 106TH CONGRESS (1999) (expressing the views of the science, technology, and policy community concerning UNLOCKING OUR FUTURE).

innovation this revelation is well past due. This paper develops an analytical framework that serves as a basis for understanding, coordinating, and evaluating science and technology policy ("innovation policy").[4] This framework is developed generally and then specifically applied to the Bayh-Dole Act regime.[5]

INTRODUCTION

A. Defining Innovation

In this paper, "innovation" encompasses a broad range of intangible goods rooted in intellectual development, referring to an idea, an invention, a creation, information, a method, a process, etc. A strong objection may be raised here because such a broad inclusive definition arguably sweeps in too much and blurs lines between a mere idea, an invention, and a true "Schumpeterian innovation."[6] *But that is the point.* Schumpeter distinguishes between invention and innovation on the basis of their economic dependence and finds that commercialization or reduction to practice are economic activities that elevate an invention to the status of an innovation.[7] However, this qualitative distinction between invention and innovation begs the underlying social and economic question of which types of research can or ought to be encouraged. The commercialization "jump," advocated by Schumpeter and other economists, is much more complicated than usually admitted. For similar reasons, research and development (R&D), innovation production, scientific research, etc. will be collapsed under "research." While there are qualitative differences between these productive activities, their conflation coincides with the inclusive definition of innovation and allows their interdependence to be explored more succinctly.[8] A related source of definitional difficulty is the qualitative classification of research along the basic to applied spectrum from ideas in the purest sense to commercial

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4. For expositional purposes, "innovation policy" will generally refer to federal institutions that implement U.S. science and technology policy.

5. For an overview of innovation and the institutions underlying U.S. technology policy, see STAFF OF OFFICE OF TECH. ASSESSMENT, 102D CONG. SESS., INNOVATION AND COMMERCIALIZATION OF EMERGING TECHN., OTA-BP-ITC-165 (1995) [hereinafter INNOVATION AND COMMERCIALIZATION].

6. *See* F.M. SCHERER, INNOVATION AND GROWTH: SCHUMPETERIAN PERSPECTIVES 8 (1984).

7. *See id.* (arguing that the relevancy of this distinction is to illuminate what types of intellectual activities can be, should be, and are promoted by the promise of a temporary monopoly).

8. *Cf.* Richard Nelson & Paul Romer, *Science, Economic Growth, and Public Policy*, *in* TECHNOLOGY, R&D, AND THE ECONOMY 49, 58-59 (Bruce L. R. Smith & Claude E. Barfield eds., 1996) (developing a model of innovation as a class of production inputs, called "software," that "represents knowledge or information that can be stored in a form that exists outside the brain. . . . [having] the unique feature that it can be copied, communicated, and reused."). *Id.* at 59.

application in the end. The seemingly predictable, linear progression from basic research to applied research and further to commercial application may be intuitively appealing, but it is not an accurate depiction of the innovative process.[9] The reasons for departing from the traditional definitions and theory are explored below.

B. The Need for a New Intellectual Foundation: The Problems of Traditional Theory

The U.S. promotes and produces innovation through a wide range of interdependent institutions, ranging from the grant of an intellectual property right to the direct funding of research. The justification for using multiple instruments is intuitively rather simple: no single institution would efficiently supply all classes of innovations. Why this intuitively simple explanation holds true in theory and practice is a much more difficult question. The answer depends in part on what type of "good" innovation is and in part on how amenable certain types of innovation are to certain forms of institutional provision. To put it more concretely, (1) innovation is a public good that acts as an input for producing a wide range of dependent goods, private to public, including more innovation; (2) various forms of innovation market failure arise, often depending on the type of dependent good that the innovation is expected to produce; and (3) certain institutions are better suited for correcting certain forms of innovation market failure. A comprehensive understanding of each of these aspects of innovation allows one to address the theoretical yet practical policy questions of what the appropriate "mix" of institutions is (or might look like) and whether the current system is doing well at providing the efficient amount of innovation.

Traditionally, the goal of promoting innovation was often said to be "best" advanced through the granting of intellectual property rights.[10] However, many recognize that the intellectual property rights system alone is not a sufficient engine for producing all types of innovation.[11] Numerous types of innovation are under or over-promoted by the promise of a temporary

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9. *See generally* DAVID MOWERY & NATHAN ROSENBERG, TECHNOLOGY AND THE PURSUIT OF ECONOMIC GROWTH ch. 1 (1989) (describing the neoclassical economic approach to analyzing R & D and, in turn, providing an alternative framework for the analysis of innovation).

10. *See* Mazer v. Stein, 347 U.S. 201, 219 (1954). "The economic philosophy behind the clause empowering Congress to grant patents and copyrights is the conviction that encouragement of individual effort by personal gain is the best way to advance public welfare through the talents of authors and inventors in 'Science and useful Arts.'" *Id.*

11. *See, e.g.*, George L. Priest, *What Economists Can Tell Lawyers About Intellectual Property*, 8 RES. L. & ECON. 19 (1986); Carlos Alberto Primo Braga, *The Economics of Intellectual Property Rights and the GATT: A View From the South*, 22 VAND. J. TRANSNAT'L L. 243, 254 (1989).

monopoly for various reasons, including, but not limited to, uncertainty over qualifying for the right, uncertainty over the enforceability of the right, and uncertain marketability even with a fully enforced right. Other institutional mechanisms, such as government subsidization, provide alternative means but each has various inefficiencies of its own. 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. One reason for this is the fact that the theory of innovation that guides current institutional decision making is flawed.[12]

Crucial to an *improved* understanding of innovation and innovation-providing institutions is an understanding of the innovative process—the progressive, cumulative yet stochastic manner in which innovations are developed.[13] The traditional model represents innovation as a linear progression from basic research to applied research and finally to commercial application.[14] This linear model is qualitatively appealing because like the qualitative classification of intellectual goods into ideas, inventions, and innovations, the economic and social policy questions seem to have straightforward answers.[15] The government should support basic research as a form of public goods production; the basic research pool should supply innovation inputs for applied research; private firms should step in at some point and bring the benefits of research results to the public through commercialization. At what point government funding should cease and firms should step in is never clear. Moreover, the linear model does not differentiate between innovations directed at certain ends, e.g., basic research into commercial or noncommercial areas.[16] Despite intuitive appeal, the linear

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12. *See* UNLOCKING OUR FUTURE, *supra* note 3, at 7.

13. *Cf.* Richard Gilbert & Steven Sunshine, *Incorporating Dynamic Efficiency Concerns in Merger Analysis*, 63 ANTITRUST L.J. 569, 579 (1995). "The lack of a deterministic relationship between R&D expenditure and innovation makes it more difficult to link market structure and the pace of technological innovation." *Id.*

14. The structure of the linear model and, importantly, the conceptual link between "basic to applied" and "public to private" has only recently been questioned by policy-makers. "Vannevar Bush's writings in *Science: The Endless Frontier*, which despite being more than 50 years old are still largely recognized as the basis for the Nation's existing science policy, reinforced the simplified demarcation between basic and applied research. Dr. Bush implied a linear relationship between them, with basic research directly giving rise to applied research and product development." UNLOCKING OUR FUTURE, *supra* note 3, at 8. *See also* INNOVATION AND COMMERCIALIZATION, *supra* note 5, at 32-35.

15. *See* UNLOCKING OUR FUTURE, *supra* note 3, at 9. Despite its inaccuracy, "[t]he linear model describing the relationship between basic and applied research nevertheless made for an appealingly simple policy prescription." *Id.* at 9. In short, the model begs the question without providing any real answer. Current government policy ought to be formulated and evaluated based on an appropriate model of innovation. *See id.*

16. The traditional argument for relying on the government to intervene in the private market for

model is simply inaccurate, overly simplistic, and in the end leads to confusion.[17]

The innovative process is nonlinear. The dynamic nature of innovative progress involves indeterminate feedback loops between "basic" and "applied" research and sometimes leads to unexpected spillover effects where an innovation developed in one sector leads to beneficial progress in another unrelated (or marginally related) sector.[18] Moreover, innovations are *necessary* inputs into the production of more innovation.[19] The innovation model developed in this paper incorporates the dynamic innovative process with the traditional public goods model of innovation. By doing so, the foundation is laid for comparative institutional analysis to proceed without reliance on the inaccurate and misleading linear model.

Why is the added complication needed? Simply put, better coordination of government institutions allows limited federal funds to go farther for the public and minimizes potential market distortions. On one hand, limited federal funds ought to be directed at the most beneficial activity *in need* of support. Misdirected funds are missed opportunities. On the other hand, government intervention distorts markets and the course of privately ordered conduct. When such distortions are targeted at specific market failures, they

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innovation is based on the public goods nature of innovation. Yet all innovations are public goods. The linear model ignores the fact that innovations are public goods that serve as inputs into the production of other types of goods and that the nature of these dependent goods is a crucial factor in setting innovation policy.

17. Despite being "discredited," the linear model is only slowly finding adequate theoretical substitutes. *See, e.g.*, Suzanne Scotchmer, *Cumulative Innovation in Theory and Practice* (Working Paper Feb. 1999) [hereinafter *Cumulative Innovation*]; Nelson & Romer, *supra* note 8, at 50, 59-60 (explaining the origins and limitations of the linear model and developing "software" model of innovation).

18. Spillovers are a well recognized, social benefit of innovation. *See, e.g.*, Richard Nelson, *Government Stimulus of Technological Progress: Lessons from American History*, *in* GOVERNMENT AND TECHNICAL PROGRESS 451, 459 (Richard Nelson ed., 1982) (discussing the spillover effects of government research motivated by national security interests into other applied areas); *See* UNLOCKING OUR FUTURE, *supra* note 3, at 18-19.

> The practice of science is becoming increasingly interdisciplinary, and scientific progress in one discipline is often propelled by advances in other, often apparently unrelated, fields. For example, who would have thought that nuclear physics research (the study of the inner workings and properties of the atomic nucleus) and data gathering techniques developed for experiments on elementary particles (quarks and such) would lead to a device that has advanced the boundaries of biomedical research and health care? Yet both of these lines of inquiry led ultimately to Magnetic Resonance Imaging (MRI), a tool now used in laboratories and hospitals around the world both to conduct basic biological research and also to diagnose illness. Such cross-over between fields is yet another example of the unexpected payoffs that can come from basic research.

Id. at 21.

19. This assertion is crucial to the thesis of this paper and has only recently begun to be considered in the economics literature. *See* Scotchmer, *supra* note 17, at 1.

may be corrective, ordering things in a socially desirable fashion. But when intervention is poorly targeted, costly distortions result. The Bayh-Dole Act regime, considered in Part IV, presents an example of a poorly targeted institution: Intellectual property (IP) is a blunt and costly mechanism for facilitating technology transfer from the government to industry when compared with alternatives.

Traditional theory does not provide a sufficient basis for deciding what innovative activities are in need of support or, more broadly, what form of institutional intervention is best suited for specific innovation market failures. While the fundamental prescription of the linear model, (that the government should generally fund more basic research than industry) is a useful first approximation, funding decisions must consider the expected applications of research, whether basic or applied, and industry should bear as much of the burden for commercial research, whether basic or applied, as the market permits. Otherwise, the government is unnecessarily redistributing wealth and distorting markets. For instance, the linear model directs government funds toward basic commercial research without more justification than the generalization that firms will not invest because they cannot fully appropriate the resulting benefits. There are, however, two problems with this reasoning.

First, firms will invest in basic research even when they do not expect to fully capture all of the benefits, so long as they obtain sufficient returns on their investments. Second, the appropriation problem may indicate a need for government intervention through less severe means than direct subsidization of research, e.g., IP or tax incentives. Moreover, the appropriation problem goes beyond traditional free-riding concerns and is often a function of the dynamic nature of the innovative process. Consequently, given the fact that government funds are limited (and increasingly scarce), the justifications for funding basic commercial research deserve more careful explanation than the linear model provides.

Even assuming that the government ought to subsidize basic research, the linear model does not indicate how. Should the government use tax incentives or grants? Both institutions subsidize (or offset) some portion of the research costs that a firm must sink into a project, but the degree and form of government intervention are quite different. In terms of transfers, grants direct lump sum investments while tax rewards are contingent upon positive income by the firm.[20] The choice between grants and tax incentives for

20. *Cf.* STAFF OF THE JOINT COMM. ON TAXATION, 97TH CONG., 1ST SESS. GENERAL EXPLANATION OF THE ECONOMIC RECOVERY TAX ACT OF 1981, 119, 120 (Joint Comm. Print 1981). "While [research] costs have characteristics of investment activity, the relationships between expenditures for research and subsequent earnings often are less directly identifiable, and many businesses have been reluctant to allocate scarce investment funds for uncertain rewards." Kathleen J. Lester, Note, *Availability of the Research Tax*

subsidizing basic research depends on the applications predicted *ex ante* and on which decision maker is best suited, e.g., possesses superior information, skills, etc. While the selection process for grants relies on the government's ability to assess the desirability of a project when compared with an array of others, tax incentives leave much of the same project-specific selection to private firms but cabined by the qualification criteria prescribed by the tax provision. If the research is expected to further a commercial end then tax incentives may be more effective than grants because final project selection is left to the best informed investor, the firm.

Moreover, under the linear model, the distinctions between basic and applied research, lead to confusion as to where the government ceases subsidization and allows industry to bear the production costs of research. The Bayh-Dole Act draws the line at the point where basic research leads to a patentable innovation, but this seems to be an ad hoc determination. Surely private firms would be willing to invest at an earlier stage in the course of research if they could patent the results. This is the premise upon which the intellectual property system is based. While analysis of the Bayh-Dole regime indicates that facilitating technology transfer from the government to industry may be accomplished by awarding intellectual property rights to federally funded researchers, the social costs seem unnecessarily high when alternative institutional mechanisms, such as selective tax incentives and cooperative R&D are considered. The traditional model does not indicate which institution should be used when.[21]

This paper integrates the dynamic nature of the innovative process with classic economic theory of public goods and investment decision making. The focus is generally on the *ex ante* considerations that precede public or private investment in research. Innovations are classified in terms of their expected uses. The underlying purpose of this paper is to formulate a framework for evaluating science and technology policy and for determining what form of government institution is best targeted for particular classes of innovation.

Credit for Government Funded Research: Fairchild Industries v. United States, 50 TAX LAW. 873, 874 n.11 (1997) (citation omitted).

21. This is not meant to suggest that comparative institutional analysis itself does not exist. To the contrary, an extensive amount of work has compared the efficacy of different forms of government subsidies. *See, e.g.*, JEAN GUINET, NATIONAL SYSTEMS FOR FINANCING INNOVATION, ORGANIZATION FOR ECONOMIC CO-OPERATION & DEVELOPMENT (1995) (describing four "perspectives" for technological investment). Simple intuition indicates that the best informed entity ought to be selecting what and how much to subsidize; the linear model of innovation does not work well to suggest what entity is likely to possess the best information regarding potential investments in research. However, the model developed in this paper does provide guidance for making such determinations.

C. Structure of the Paper

Parts I, II, and III develop an analytical framework for innovation policy. There are three foundational themes explored: (1) the nature of innovation itself, (2) the innovation market, and (3) institutions. Innovation and the innovation market must be clearly understood for an assessment of institutions to proceed, and the institutions themselves must be well understood for any comparison to be meaningful.

Part I, *A Model of Innovation*, lays the groundwork for analysis by explaining what type of good innovation is and how the innovative process works. It builds upon the traditional theories of innovation, clarifying the overly complex aspects of various economic models while, at the same time, arguing against some of their overly simple assumptions. The current theoretical understanding of innovation is criticized on two grounds. First, the distinction between basic and applied research is improperly associated with the public goods nature of innovation. Second, commercialization is too often seen as the end to which the innovative process develops, and consequently, as the measure for success. Part I develops a new theoretical model incorporating the dynamic nature of the innovative process and classifying innovations according to their expected applications, whether public or private, and their basic to applied nature.

Parts II and III explore institutional mechanisms. To cabin the analysis, five institutions involving private and public investments into research are roughly delineated: (1) the "naked market,"[22] (2) the market as modified by intellectual property rights,[23] (3) the market as modified by R&D tax incentives,[24] (4) direct government subsidy, e.g., research grants, and (5) government procurement of R&D results. The first three institutions rely on the market as the mechanism directing investment into research while the latter two rely on the government in lieu of the market.[25] A comparative

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22. The "naked market" refers to the market as maintained, in its normal sense, by government enforcement of private law, i.e., contract, tort, antitrust, environmental, and public law. As applied to innovation, the naked market is not defined as narrowly as in the antitrust context. *See, e.g.*, Gilbert & Sunshine, *supra* note 13, at 570.

23. Hereinafter referred to as the *IP-enhanced market*.

24. Hereinafter referred to as the *TI-enhanced market*.

25. Innovative progress in various industries is strongly influenced by private and public demands, institutional settings, and many other interdependent forces, such as environmental regulation, that are beyond the scope of this paper. *See* Nelson, *supra* note 18, at 456-57. In aviation, computers, and semiconductors, the public interest manifested through government procurement of acutely applied innovations inevitably resulted in a wealth of spillover effects. *See id.* In other areas, government regulation in pursuance of a public good like environmental quality or safety influenced innovative progress. Finally, government facilitation of cooperative development, information dissemination, and lead time advantages strongly influenced private firms' innovative activities. *See id.*

assessment of how these institutional mechanisms theoretically interact and actually perform is a needed exercise to better understand innovation and to evaluate whether the use of social resources can be improved.

Part II, *The Market for Innovation*, explains how the naked market works and why market provision of innovation alone is inadequate. Self-help mechanisms, such as lead time advantages and barriers to entry, provide sufficient protection against free-riding by competitors for certain classes of innovation but not for others. The analysis of firm decision making in the naked market is followed by a description of innovation market failures that justify government intervention.

Part III, *Institutional Intervention*, describes the institutional mechanisms through which the government intervenes to correct various forms of innovation market failure. First, it explains the available institutions for modifying the naked market, intellectual property and tax incentives. Next it explores the alternative institutions that rely on the government directly to produce and supply innovation, direct government subsidization and government procurement. Cooperative arrangements between government and industry are also briefly analyzed. Part III concludes with a comparative institutional analysis across different classes of innovations.

To ground the theoretical analysis in an existing legal regime, Part IV analyzes the *Mixed Incentive System for Publicly Funded Researchers* created by the Bayh-Dole Act, in which intellectual property rights and government support are jointly used to promote, produce, and commercialize federally funded research results. After briefly surveying the historical background and policy arguments that led to the Act's passing, the legal framework is explored to determine the contours of the regime. Next, Part IV applies the theoretical framework developed in Parts I, II, and III to the IP-enhanced grant system, finding three sources of market failure that arise during the transfer of technology from the government to domestic industry. Of the three, only foreign misappropriation of federally funded research presents a sufficient justification for mixing IP with grants when alternative corrective institutions are considered. Awarding IP rights to grantees facilitates the use of exclusive licenses to give private firms substantial lead time advantages in derivative innovation markets growing out of grant research. The presumption is that technology transfer is otherwise inhibited because derivative innovation markets are too competitive. Although mixing IP with grants may be justified on narrow grounds, tax incentives and cooperative R&D are likely to be socially preferable alternatives.

Part V offers some modest conclusions and suggestions for further study. Intellectual property, tax incentives, grants, and procurement are four of many institutions implementing science and technology policy. At first approximation, all four are government subsidies that transfer wealth from the public to innovators. Accordingly, for private investors choosing between research ventures, all four transfer mechanisms represent potential rewards with attendant risks of qualification that factor into their decision making calculus. Yet, from the perspective of an omniscient social planner (as well as the government), each operates differently and serves different functions, correcting perceived sources of market failure. Better coordination of science and technology policy requires a more nuanced approach than the linear model provides. In general, IP and tax incentives should be used to promote private investment in commercial research while grants and procurement should be used to produce innovations serving public goods ends. Analysis of the Bayh-Dole Act indicates that the government may be unwisely funding basic commercial research that would otherwise be borne by industry, perhaps raising public choice concerns.

I. A MODEL OF INNOVATION

Innovation is an elusive concept. Intuitively, it takes on a rather straightforward meaning, but in the economics, legal, and technical fields, it is beginning to be seen as a dynamic variable that drives economies, technological advancement, and social welfare.[26] This Part provides an economic model of innovation that will facilitate comparative institutional analysis.

Two broad, interrelated concepts permeate the discussion of innovation: *incentives to innovate* and the *innovative process*. A simple model incorporating the following three progressive stages captures these concepts:

Ex Ante Investment Decision:	Research (Innovation Production):	*Ex Post* Utilization:
wherein private or public investors decide how to allocate resources among prospective innovation projects.	wherein a discrete innovation is produced	wherein the results of the previous stage are used or consumed.

26. An extensive amount of research, both theoretical and empirical, addresses the value of innovation in the context of various fields of study, ranging from neoclassical economics to the history of technological development. *See, e.g.*, Bronwyn Hall, *Bibliographic Summary of Recent Research on Technological Change, Appendix to The Private and Social Returns to Research and Development, in* TECHNOLOGY, R&D, AND THE ECONOMY 140, 173 (Bruce Smith & Claude E. Barfield eds., 1996). *See also* JEAN GUINET, NATIONAL SYSTEMS FOR FINANCING INNOVATION, ORGANIZATION FOR ECONOMIC CO-OPERATION & DEVELOPMENT, 26-27 (1995) (describing four "perspectives" for technological investment).

Incentives are *ex ante* criteria, which depend on information and preferences, that influence investment decisions continuously in time. Assume that investment decisions are "all or nothing" at each point in time and include a commitment of necessary resources as inputs into the production stage.[27] These three stages can be passed through repeatedly over time such that the outcome of production and utilization affect subsequent investment decisions. Utilization may entail the use of an innovation, an intangible resource, as an input for a range of productive activities. This paper primarily focuses on the *ex ante* investment stage and the manner in which prospective stages are envisioned.

The innovative process describes the evolutionary manner in which innovations serve as inputs for subsequent research.[28] In other words, real world progress in research often involves multiple passes through the three stages above. Innovations are cycled in an iterative or continuous process in a manner which affects decision making over time. This concept is explored in detail in Subpart B.

A. Traditional Theory of Innovation

This subsection develops the theoretical background necessary to understand how innovation is produced. First, it explains the public goods nature of innovation, building on the well-known neoclassical model of Samuelson,[29] and second, develops a simple model of decision making concerning research investments. Subpart B explores the dynamic nature of the innovative process, building upon the simple model of public goods and investment decision making.

1. The Public Goods Nature of Innovation

An innovation is a pure public good that can be directly consumed or used as an input into the production of another good. Direct consumption refers to the immediate appreciation of benefits without additional transmission costs; for example, when one derives satisfaction from a new

27. This assumption is for simplification and means that decisions to invest result in an immediate "sunk" cost. Thus, production costs are fixed. This assumption is commonly referred to as "contract costs." While somewhat stylized, expanding the model to include continuous cost functions and the like is possible when the innovative process is integrated. *See generally* MORTON KAMIEN & NANCY SCHWARTZ, MARKET STRUCTURE AND INNOVATION (1982) (describing cost functions).

28. *See, e.g.*, Richard Nelson, *Understanding Technical Change as an Evolutionary Process*, *in* LECTURES IN ECONOMICS 8 (1987).

29. *See* P. A. Samuelson, *The Pure Theory of Public Expenditure*, 36 REV. OF ECON. & STAT. (1954).

idea. Utilization of an innovation as a production input involves additional (costly) steps before benefits can be appreciated; for example, when one uses a new idea to improve a product. As an example of a public good, consider a song; it may be enjoyed through direct observation of a band or may be used as an input to the production of an album. Both direct consumption and use as a production input occur in the *Ex Post* Utilization stage after the innovation itself has been produced. Without unbundling the broad definition of innovation used in this paper, it is helpful to explore the public goods characteristics of innovation.[30]

Public goods exhibit two distinguishing characteristics, nonrivalrous consumption and nonexclusion. Nonrivalrous consumption is where consumption by an individual does not deplete the amount of the good available for others to consume.[31] For example, listening to a song, reading an article, or viewing an outdoor fireworks display does not reduce the amount of the good available for others. Thus, the number of consumers does not affect the amount of the good available for simultaneous or subsequent consumption.[32] A corollary is that, unlike the benefits, the production cost[33] for a public good is not dependent upon the number of users.[34] This has

30. A thorough account of the public goods nature of innovation is justified in order to clarify common misperceptions. Some argue that innovation has attributes of both public and private goods, while others describe innovation as an intermediate good residing somewhere in the middle of the public to private spectrum. *See* Nelson and Romer, *supra* note 8, at 58-59. The placement of innovation at different points on the public to private continuum is not surprising given the confusion surrounding which public goods attribute is controlling. That is, a public good for which excludability is obtained can arguably be designated a private good. *See id.* In terms of private investment decisions and appropriation of returns, this seems reasonable and is the foundation of the intellectual property system. However, innovation remains a public good due to its nonrivalrous consumption qualities; thus private market provisions seem to be second best, at best. *See* Daphna Lawinsohn-Zamir, *Consumer Preferences, Citizen Preferences, and the Provision of Public Goods*, 108 YALE L.J. 377 (1998). "These features [nonrivalrous consumption and nonexcludability] make the supply of public goods through the market mechanism infeasible or suboptimal, thus calling for state intervention." *Id. See also* W.H. Oakland, *Theory of Public Goods*, *in* HANDBOOK OF PUBLIC ECONOMICS v.2 485, 486 (Alan J. Auerbach & Martin Feldstein eds., 1987) ("The fact that the marginal cost of additional users is zero is itself sufficient to insure market failure.").

31. *See* Samuelson, *supra* note 29, at 387-89.

32. Note that simultaneous consumption of a public good, say a performed song, may be limited by spatial constraints, and that subsequent consumption may be limited by temporal constraints, e.g., performance duration.

33. This assumes that production costs refer to the good itself, e.g., the song, and not to the transmission costs associated with consumption, e.g., radio broadcast or fixation in a CD.

34. Generally, each individual choosing to consume will obtain some independent private benefit. Furthermore, for certain public goods, individual benefits themselves may increase as a function of the number of users, commonly referred to as a *network externality*. For example, the private benefits of using an operating system depends on the number of other users. For a legal discussion of network effects, *see generally* Mark Lemley & David McGowan, *Legal Implications of Network Economic Effects*, 86 CAL. L. REV. 479 (1998). (explores the application network economic theory in various areas of the law, including anti-trust, intellectual property, and internet law). For an interesting discussion of the difficulties in assessing personal preferences, see Lewinsohn-Zamir, *supra* note 30, at 378. "A policymaker wishing to

important implications for social welfare analysis.[35] A public good ought to be produced to the extent that the summed individual benefits exceed the production cost, and once produced, the good ought to be consumed by as many people as possible.[36]

Nonexclusion refers to the difficulty of preventing nonpaying persons from consuming the good,[37] leading to a classical case of rational free-riding.[38] Nonexclusion wreaks havoc on market provision of public goods.[39] Exclusion is particularly difficult in an innovation market where communication between sellers and potential buyers may require revealing information about the innovation, possibly enabling its use and thus dissolving the need of a transaction. Furthermore, the ease with which an innovation can be inadvertently or intentionally leaked, imitated or copied enhances the exclusion problem.[40] A major hurdle to socially efficient market provision of

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base these decisions on people's preferences faces not only the problem of conflicts among the preferences of different people but arguably also the difficulty of conflicts between the revealed preferences of the same persons." *Id.*

35. Efficient production of a rivalrously consumed good entails producing the good until the last unit can be sold at its marginal cost. A nonrivalrously consumed good, on the other hand, should be produced so long as the combined value to all consumers is at least equal to the cost of production. *See* Hal R. Varian, *Differential Pricing and Efficiency* (discussing the pricing of information goods), *available at* <http://www.sims.berkley.edu/~hal/people/hal/papers.html> (published in First Monday Vol. I No.2, August 5, 1996); Hal R. Varian, *Pricing Information Goods*, *available at* <http://www.sims.berkley.edu/~hal/people/hal/papers.html> (presented at the Research Libraries Group Symposium on "Scholarship in the New Information Environment" held at Harvard Law School, May 2-3, 1995), *cited in* Julie Cohen, *Lochner in Cyberspace: The New Economic Orthodocy of "Rights Management*, 97 Mich. L. Rev. 462 (1998). This is possible only if some form of differentiated payment scheme can be implemented such that each user is charged an amount equal to the benefits they will receive from using the good. *See id.* This requires either (1) producers have perfect information of individual consumers' valuations and consumers cooperate, i.e., do not holdout, or (2) consumers have perfect information of their values and cooperate, i.e., do not misrepresent their values. An informed investor-producer intent on socially efficient production would be unable to recoup his investment unless consumers' pay their true values, and a less informed investor-producer would be unable to determine how much to invest *ex ante* without polling consumers or relying on past market performance. Both conditions are unrealistic. Ignoring negative externalities, e.g., smoke or congestion, imperfect information of individual consumer benefits and strategic behavior would preclude an efficient outcome in the real-world. *See* discussion *infra* note 41.

36. Where network externalities are likely, there is an even stronger argument in favor of broad dissemination because the benefits to each user increases.

37. For example, it is prohibitively costly to exclude nonpaying observers from an outdoor fireworks display, even if fences are built and an entry fee is charged.

38. Free-riding is a rational choice under uncertainty or where a lack of cooperation or information regarding future events persist.

39. The ability to exclude is essential to a well functioning market. Property rights are the traditional legal mechanism through which exclusion is facilitated by government enforcement.

40. The ease with which free-riding can take place in the case of innovation corresponds to the high costs of exclusion. The enforcement of intellectual property rights is one mechanism by which exclusion costs are lowered for potential investors in innovation. The government, in effect, bears the costs of erecting a barrier to free riding but only to a limited extent and with limited effectiveness. *See infra* Part

innovation is the risk, perceived *ex ante*, that consumers will free-ride *ex post* and prevent investors from recouping sufficient returns on their investment, commonly referred to as the appropriability problem.[41]

A conflict between nonrivalrous consumption and nonexclusion should be apparent. In a perfect world, efficient production of innovation is controlled by nonrivalrous consumption, and in the real-world, nonexclusion hampers market provision of innovation. Perfect world social efficiency dictates that consumption of public goods be maximized while real-world market provision requires constrained consumption in order to maximize market-based efficiency. Innovation policy must recognize that all innovations are pure public goods, and that how well optimal market provision fairs against government provision depends in part on the expected uses of particular innovations, i.e., for direct consumption or production of another good.

2. Investment Decisions

Innovation production requires the investment of resources, e.g., capital, time, effort, and innovations. Private firms invest in research if the expected rate of return is comparable with (or exceeds) other investment opportunities.[42] To frame the *Ex Ante* Investment Decision stage, consider the Investor-Innovator story described below, which was first proposed by

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III.A.

41. Appropriation problems are a result of both free-riding and pricing difficulties. *See generally* Lemley and McGowan, *supra* note 34. Generally, differentiated pricing is too costly to implement because of imperfect information and cooperation problems. Consider, for example, a concert for which exclusion is possible (it is held inside). *Ex ante*, concert producers must decide how much to invest (in sound equipment, back-up vocals, etc.) based upon expected turn-out and a planned ticket pricing scheme. Assume that consumers value the performance on a range from $1-$5. Charging $1 per ticket would result in under-investment, leading perhaps to poorer quality, because more money could have been invested in production under a differentiated pricing scheme. Both under-investment and under-utilization result if prices are set at $5 because those valuing the good at less than the price would be excluded from consideration *ex ante* and from use *ex post*. Their willingness to pay is not factored into the *ex ante* investment, and they are unwilling to pay $5.

42. This assumption is open to criticism to the extent that investors are not profit maximizers, and instead, base investment decisions on some other criteria. *See generally* MOWERY & ROSENBERG, *supra* note 9 (questioning the neoclassical economic model of appropriabilty as the sole investment criterion). In terms of public investment, Mowery and Rosenberg are correct. However, there is no reason to abandon the traditional depiction of private firms. Although some commentators argue that developing an in-house knowledge base or special expertise is not a profit-based motive, how this is so remains unclear. The assemblage of information, skills, and other nontangible assets is surely motivated by profit interests of a long term, perhaps uncertain, nature. Firms amassing these internal resources are perhaps reflecting a lower discount rate (willingness to invest in benefits more attenuated into the future) and/or building their technical capacity to capture uncertain spillovers.

Arrow[43] and reformulated by Kamien and Schwartz.[44] Although told from the firm perspective, public investment decisions are made in a similar fashion where profit motives are (ideally) replaced by social benefits.[45]

An innovator sells shares in a project, the outcome of which is uncertain.[46] The capital generated by selling the shares is used to fund the project, including equipment, salaries (including the innovator's), and all other production costs. Assume the expected costs related to commercializing the results in the *Ex Post* Utilization stage are anticipated but not invested until successful production is determined. The investment decision is made up front based on an expectation of being able to make a profit on the results of the project, which is contingent upon first succeeding in producing an innovation and then on appropriating the results.[47] The innovator is capable of purchasing shares as well. The price of the shares and the total amount of capital invested reflect investor expectations, including the innovator's. Furthermore, the allocation of shares among investors reflects their respective risk tolerances.

This characterization is a special case of the classical Principal-Agent model.[48] It illustrates the role of risk bearing in the market for innovation.

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43. *See* Kenneth Arrow, *Economic Welfare and the Allocation of Resources for Inventions*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY (R.R. Nelson ed., 1962).

44. *See* KAMIEN & SCHWARTZ, *supra* note 27, at 25.

45. A more realistic view of the government decision making must recognize the public choice concerns regarding capture by special interest groups. For a discussion of government decision making, see, e.g., D. FARBER & P. FRICKEY, LAW AND PUBLIC CHOICE: A CRITICAL INTRODUCTION (1991); Peter L. Kahn, *The Politics of Unregulation: Public Choice and Limits on Government*, 75 CORNELL L. REV. 280 (1990). *See also* Richard B. Stewart, *The Reformation of American Administrative Law*, 88 HARV. L. REV. 1669, 1684-87 (1975) (discussing regulatory capture). In this paper, the government is assumed to be trying to achieve the socially optimal result, which in turn is set by the imagined omniscient social planner. Firms, on the other hand, are assumed to be profit maximizers without regard for social optimality. Comparative institutional analysis aims to determine which institutions best approximate the imaginary social optimum.

46. For innovation projects, assume that there is an estimated likelihood of successfully producing an innovation and an estimated benefit to be realized if appropriation is successful. At this point, assume that the risks involved are known with a reasonable degree of certainty. This assumption is an unrealistic simplification given the dynamic nature of the innovative process, as explored *infra* Part I.B.

47. Assume the costs associated with securing appropriation are not sunk unless production is successful. Although some appropriation-related costs may be sunk during production for secrecy to be maintained, assume that these costs are anticipated *ex ante* and are sunk along with production costs. For example, trade secrecy protection requires efforts be taken to protect against "reasonably anticipated or prevented" misappropriation, which may occur during production. E.I. duPont deNemours & Co. v. Christopher, 431 F.2d 1012, 1016 (5th Cir. 1970), *cert. denied*, 400 U.S. 1024 (1971) (refusing to require duPont to build a roof over an unfinished plant to prevent an aerial photographer from misappropriating a trade secret).

48. Multiple layering of principal-agent relationships pervades society and can be used to extend the simple model, for example, by extending the analysis to managers and shareholders of the investing firm, *see* Steven S. Cherensky, *Shareholders, Managers, and Corporate R&D Spending: An Agency Cost Model*, 10 SANTA CLARA COMPUTER & HIGH TECH. L.J. 299, 312-13 (1994), or to government officials.

Implicit in the project "contract" are transaction costs and informational constraints that affect how well it works at attracting investment and allocating risk. Transaction costs arise in the face of prospective uncertainty and the "contractual" need to (1) identify future contingencies, (2) adequately specify contingencies and responses,[49] and (3) monitor and enforce against deviations from the "contract."[50]

Informational constraints to efficient "contracting" arise when information is asymmetrically held,[51] particularly when the innovator-agent knows more than the investor-principal about non-observable variables endogenous to the innovator-agent, such as effort, or about exogenous variables relating to the project, such as the likelihood of success or costs. The former informational constraint is commonly referred to as *moral hazard* and the latter as *adverse selection*.[52]

Importantly, investors may under-invest in projects when the innovator seems reluctant to invest.[53] This occurs for two distinct reasons. First, *moral hazard*: investors fear that the innovator will not work diligently.[54] This effort-based risk, often referred to as the controllable risk, can be alleviated through monitoring[55] or forcing the innovator to bear the risk directly by owning shares.[56] Second, *adverse selection*: investors may feel that the innovator has better information with regard to the expected return of the project and may therefore limit their exposure to risk.[57] This second concern

49. For example, the resulting costs may be legal fees and time spent with lawyers, see JEAN-JACQUES LAFFONT & JEAN TIROLE, A THEORY OF INCENTIVES IN PROCUREMENT AND REGULATION 1-4 (1993).

50. For example, the resulting costs may be litigation costs in court. *See id.* at 3 (citing OLIVER E. WILLIAMSON, MARKETS AND HIERARCHIES: ANALYSIS AND ANTITRUST IMPLICATIONS (1975)).

51. The focus here is on asymmetries where the innovator-agent has more information than the investor-principal. The converse may very well lead to interesting results but is seen to be the least likely scenario.

52. *See* LAFFONT & TIROLE, *supra* note 49, at 1-2. The presence of adverse selection allows an innovator-agent to extract rent even if its bargaining power is limited. "Substantial rents are involved at the contracting stage." *Id.* The existence of information asymmetry generates demand for information gathering on the part of the investor-principal. For *moral hazard*, information gathering takes the form of, *inter alia*, background checks, reputation assessment, and inclusion of monitoring provisions in the contract. For *adverse selection*, additional preliminary research may be conducted.

53. *See* KAMIEN & SCHWARTZ, *supra* note 27, at 25-26.

54. *See id.*

55. Monitoring is typically accomplished through reporting or direct oversight and contractual provisions that tie observable performance measures to rewards or sanctions.

56. Forcing the innovator to purchase shares aligns the innovator's incentives with the investors' because of shared downside risks and the upside potential for profit. *See* KAMIEN & SCHWARTZ, *supra* note 27, at 25-26.

57. In other words, investors take the innovator's reluctance to invest as a signal relating information about the likelihood of success rather than a signal of the innovator's risk preferences. *See id.* at 27. *See also* LAFFONT & TIROLE, *supra* note 49, at 1-3 (discussing adverse selection in the procurement context).

affects investor certainty with regard to *ex ante* assessments of the uncontrollable risk inherent in the project.[58] While some risk is unavoidable, either the inappropriate allocation of risk, e.g., overbearing by the innovator-agent, or the misperception of risk may skew investment inefficiently. A standard remedy for the risk allocation problem is to spread the risks among many investors and diversify the risks by investing in many independent projects through a collective or government financing mechanism. However, this remedy has inefficiencies of its own as will be discussed in Part III.B.

3. Preliminary Observations

The simple and well-known economic model of innovation has been shown, relying on the public goods nature of innovation and the *ex ante* investment decision. Two general types of risks can be identified that act as impediments to efficient production by a real-world market for innovation: *production risks* and *appropriation risks*.[59] Production risks include the standard risks present in any investment transaction, namely the uncontrollable risk of success and the controllable risk of effort. Appropriation risks arise from exclusionary difficulties associated with the public goods nature of innovation and from market response risks. The two types of appropriation risks should be disaggregated when evaluating institutions. For example, IP may provide sufficient exclusion of competitors but not lead to appropriation because licensing transaction costs are too high or marketability is uncertain; alternatively, exclusion through IP may be insufficient because disclosure allows others to invent around the IP right.[60]

The presence of risk leads to inefficient investment in innovation for a number of reasons. First, transaction costs may be prohibitive to the extent that future contingencies are simply unidentified (or unpredictable) and that monitoring innovators' effort is difficult. Second, risk may deter private investors from socially desirable projects if their risk preferences differ from

58. Even if the innovator works with best efforts and thus the controllable risk is zero, a residual quantum of uncertainty with regard to project success remains, commonly referred to as the uncontrollable risk. (In a Principal-Agent problem involving a farmer and a landlord, the uncontrollable risk is likened to the weather).

59. Although manifest in different stages of the innovative process, these risks are compounded. *See* Nelson, *supra* note 18, at 455 (discussing the compounding effect on technological uncertainty and market uncertainty in the innovation market); Edwin Mansfield, *Contributions of New Technology to the Economy*, *in* TECHNOLOGY, R&D, AND THE ECONOMY 114, 137 (fourth conclusion, discussing technological and market risks).

60. *See* Richard Levin et al., *Appropriating the Returns from Industrial Research and Development*, *in* 3 BROOKINGS PAPERS ON ECONOMIC ACTIVITY 783, 803, 805 (1987) [hereinafter *Appropriating Returns*].

that of the public.[61] Third, asymmetric information may lead to strategic behavior that may similarly deter private investors or lead to overbearance of risk by innovators. The problems associated with each of these impediments are accentuated by the dynamic nature of the innovative process and uncertainty as to risk estimates themselves, particularly where the number of "passes" through the three stages described above is uncertain. An additional impediment that persists even in a well functioning market when the above impediments are avoided is the necessary condition of differentiated pricing if the innovation can be nonrivalrously consumed. The impediments discussed thus far summarize the traditional justifications for government intervention.

B. Expanding the Traditional Model

This subsection expands the traditional model of innovation to account for the dynamic nature of the innovative process. There are two ways to characterize a research project in terms of the three-staged model described at the beginning of the section. Consider a commercial research project. On one hand, it can be seen as a single walk through the stages where a single lump sum investment is committed *ex ante*, successful research involves a single innovative leap, and benefits are realized *ex post* if misappropriation is prevented while the market responds favorably. Or, the project can be seen as a series of walks through a model where investments are staggered, innovations are cycled as inputs into derivative research, and commercial benefits can be realized *ex post* along numerous derivative paths when innovations act as inputs into private goods. While the latter characterization is more accurate, the former seems to guide current theory, firm decision making, and federal technology policy. This section develops the latter iterative characterization for analytic purposes.

A careful look at the status of the innovative process from each stage sheds light on how progress is made. From an *ex post* perspective, an innovation and its benefits are characterized by its use.[62] Accordingly, from an *ex ante* perspective, innovations are characterized in terms of their possible applications. For each potential innovation, there exists a probability distribution describing the likelihood that it will serve as an input to a range

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61. Actually, the appropriate efficiency reference point for comparing risk preferences is that of a risk neutral decision-maker. Nonetheless, this paper adopts the position that public investments are made through public institutions with some sense of a social risk preference, and therefore, uses that reference point for comparative purposes.

62. For the most part, this paper looks at the innovative process from the *ex ante* perspective. Thus, when discussing *ex post* utilization, the focus will usually be on the *ex ante* estimation of *ex post* utilization.

of applications. *Ex ante*, investors estimate this distribution given publicly available and privately held information [hereinafter application estimate].[63]

1. The Distinction Between Basic and Applied Research

The distinction between basic and applied research can be understood by looking to the variance of the application estimate. A larger (smaller) variance in the distribution corresponds to a basic (applied) innovation, representing a wider (narrower) range of potential applications and hence greater (less) uncertainty as to a specific application. Therefore, the distinction between basic and applied research is not dependent upon the applications themselves, i.e., whether the innovation will be used to produce a public or private good. Instead, the distinction rests on the range of potential applications and the corresponding uncertainty with regard to specific applications.[64] Both basic and applied innovations are in themselves public goods, but the case for government provision of basic versus applied innovations differs, as will be explored in the following parts.[65]

The move from basic to applied research proceeds in steps and is analogous to Bayesian learning. Importantly, successful steps affect the application estimates of subsequent innovations. Taking consecutive steps entails producing an innovation and using it as an input to produce a dependent or "second generation" innovation.[66] The linear model of the innovative process assumes a gradual narrowing of the application estimate

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63. These estimates are themselves uncertain. *Cf.* Richard Nelson, *supra* note 18, at 455.

> All of the case studies reveal that technological advance involves considerable uncertainty. When a person or organization begins a search for a new product or a process it is never clear exactly what the precise outcome will be. Design configurations and solutions take shape in the course of [research] . . . The uncertainties take on a somewhat different form in each technology.

Id. at 454. Moreover, estimates will vary across decision makers based on the information held, experience, bias, etc.

64. The range of "products" (or goods produced) exhibits variance in the public to private dimension as well as the "sectoral" dimension, which is qualitatively descriptive of the range of applications across (and within) industries at given place on the public to private continuum.

65. *See infra* Parts II, III.

66. Consider two extremes: the most basic research has an application estimate with infinite variance, i.e., a flat plane, because *ex ante* no application is more likely than any other; whereas the most applied research has an application estimate with zero variance, i.e., a point, because *ex ante* it is known with certainty how an innovation will be applied. Moving from a flat plane to a point captures the innovative process; it is not a linear progression buy dynamic. Each step is dependent on those before it; taking a single step entails producing an innovation using as a given the existing state of development. Each step affects the application functions of subsequent innovations. *See infra* note 95. As information is generated "bumps" in the plane from, where may indicate what institutional mechanism is most efficient. The subsequent parts incorporate this, admittedly rough and abstract, model into the understanding of institutional settings. *See infra* Part II.C.

as though deviation from the mean does not occur and learning from spillovers is a fiction. Yet, in reality, progress is nonlinear, meaning that distributions rise, flatten, and shift location dynamically from step to step.[67]

To illustrate, consider a basic commercial research project dealing with petrochemical lubricants for automobile engines. Before investing, CarCo. estimates that the project will last five years, will require $1,000,000 up front and $200,000 each year, and is likely to lead to a number of improvements in its race car engine design and its line of lubrication products. CarCo. invests and after the first year, research yields information that causes CarCo. to revise its estimates: the potential engine design improvements may apply more broadly within the automotive industry than previously expected, in light of a promising development with a particular lubricant mix. *The application estimate changes by broadening across the range of engine applications while narrowing across lubrication improvements.* Moreover, the expenditures increase, the time horizon extends to eight to ten years, and the potential returns increase. Of course this story is stylized to make a point, but such stories are all too common in research.

2. Conclusions

In sum, innovations are public goods that can act as inputs into production processes and thereby produce a range of public to private goods. The continuum between basic and applied innovations reflects the variance of *ex ante* estimates of potential applications that an innovation might have. This determination is independent of the type of good that may be produced. The dynamic nature of the innovative process can be understood by mapping an innovation production loop, where an innovation is used to produce a subsequent innovation. The application estimate concept can be a useful analytic tool for classifying innovations and determining what institutions are best targeted for their provision.

Limited investment resources, transaction costs, informational constraints, and divergences between private and social risk preferences and discount rates all affect *ex ante* investment decisions in a more complicated way than traditional theory suggests. The dynamic nature of the innovative process makes transaction costs high, information extremely valuable,

67. The dynamicism inherent in innovative process can be better understood when the role of innovations as inputs into the production of innovations is explored. Divide the continuum from basic to applied into N steps from X_0 to X_N, where N ranges from 0 to infinity and each point X constitutes a given state of cumulative knowledge (or innovation) within a certain range of potential applications at time t. Any section of the continuum, say from X_i to X_j, constitutes j-i dependent steps or, correspondingly, one independent leap. The degree of dependence between steps varies, presumably by field and location on the basic to applied continuum.

strategic behavior likely, risks uncertain, and time horizons attenuated into the future and often unpredictable.[68] Moreover, the coupled effects of limited resources and the dependence of future innovations on past innovations suggest that significant social costs can arise when research investments are misallocated and/or innovative progress is stifled or misdirected. The implications for social welfare analysis, understanding the innovation market, and evaluating the justifications for governmental intervention require attention.

II. THE MARKET FOR INNOVATION

Having developed a theoretic model of innovation, this part explores what types of innovation projects private firms pursue in the naked market. Subpart A discusses a set of common appropriation mechanisms that firms employ to protect against misappropriation (in the absence of intellectual property rights) and assesses the types of innovation that result. Subpart B then explains the justifications for government intervention in terms of three sources of failure in the innovation market.

A. Self-help Mechanisms to Protect Against Misappropriation: Lead Time and Barriers to Entry

The discussion above characterized innovation projects by their application estimate, in terms of its basic to applied nature and the expected end-uses, direct consumption or production of a private or public good. Generally, a private firm weighing investment options evaluates an innovation project in terms of its projected production risks, appropriation risks, and potential benefits, all of which depend on the firm's application estimate. The firm chooses where to enter the innovation market on the basic to applied scale depending on its risk tolerance, discount rate and financial and technical resources. Private firms usually focus their research efforts on innovation inputs to private goods production. Rather than approach each innovative step independently and attempt to forecast evolving application estimates, firms generally consider innovative leaps that allow for immediate use in the *ex post* utilization stage, as a production input or for direct consumption. Thus, a "successful" innovation allows a firm to attempt appropriation. However, to the extent that an innovative leap is comprised of numerous steps that can be divided into smaller increments for purposes of investigation, the costs of research become unbundled. Not surprisingly, this model of firm decision

68. Of course not all research exhibits these problems for investors. *See, e.g.*, Part II.B.

making relaxes into the traditional linear model, where dynamicism is fully contained in the research stage and the *ex post* utilization stage embodies commercial ends.[69]

In the naked market, research investment is limited largely by appropriation risks and market response risks. As the classic story goes, firms are reluctant to concentrate their investments in those areas where exclusion is prohibitively costly because of the fear that competitors will copy and use their innovations without having to pay the research costs. Competitors will then be able to sell any resulting products at a lower price than the innovating firm, stealing market share and preventing a recoupment of research costs. The crucial question addressed below is: what appropriation mechanisms do firms use to recoup their investment in the face of insufficient exclusion?[70]

Two commonly observed and understood self-help mechanisms for appropriation are the creation and use of lead time advantages and barriers to entry. Firms use lead time advantages when they take advantage of being first to develop an innovation and the resulting lag time it takes for imitators to catch up on the learning curve.[71] To be first and create lag time, secrecy must be maintained throughout R&D until the product is taken to the market. Contract, tort, and trade secret law provide the principal legal protections necessary for secrecy.[72] Beyond secrecy, firms attempt to lengthen the lag time through strategic design aimed at raising imitation costs and preventing reverse engineering. Despite innovating firms' best efforts, empirical studies have shown that information travels fast and is typically in the hands of rivals within one to two years.[73] Secrecy dissipates through many informal channels including labor movement; communication among researchers, suppliers, and customers; and general intelligence gathering.[74] However, information

69. This relaxation is expected when firm decisions are being analyzed. The crucial mistake that must be avoided is using the firm model to assess, evaluate, and fine-tune the overall system of innovation production, of which market provision is a subset.

70. These questions clearly ignore the problem of misappropriation that persists prior to the completion of research. Among other things, the mobility of the workforce and communication between rival firms may lead to risks of leaked information. While an important issue, the problem is relegated to the controllable risks associated with employee efforts for solution through contractual provisions, extensive monitoring, and proper alignment of incentives.

71. *See* J.H. Reichman, *Legal Hybrids Between the Patent and Copyright Paradigms*, 94 COLUM. L. REV. 2432 (1994) (discussing both natural and artificial lead time advantages). *See generally* Levin, *supra* note 60 (discussing analysis of survey data from high level R&D managers concerning appropriation mechanisms, finding lead time, secrecy, learning advantages, and marketing efforts to be typically more important than the patent system.). *See id.* at 795.

72. Trade secret law is herein discussed in terms of lead time and barriers to entry.

73. *See* Edwin Mansfield, *Intellectual Property Rights, Technological Change, and Economic Growth*, *in* INTELLECTUAL PROPERTY RIGHTS AND CAPITAL FORMATION IN THE NEXT DECADE 3,8 (Charles Walker & Mark Bloomfield eds., 1988).

74. *Id.* at 9-10.

spreading does not always or immediately facilitate imitation, particularly in the cases where significant technical "know-how" or development experience is involved with R&D.

Frequently, significant lead times result in an established market position that is used to establish barriers to entry. Barriers to entry are implemented by a firm to raise the costs of free riding and to preserve market position. Barrier mechanisms include technical design against copying, selective release of incremental innovations, frequent updating of products, advertising and marketing, and gaining control of needed resources and distribution channels.[75] Simply sinking costs in research can by itself be used to deter potential competitors from entering the innovation market.[76] Many empirical studies have been directed at the effectiveness of these self-help appropriation mechanisms.[77] According to a comprehensive survey of high level R&D managers, these mechanisms are considered more effective than intellectual property rights for protecting against misappropriation.[78] However, this result may indicate a number of things beyond institutional effectiveness (of IP), including an industry preference or bias favoring certain types of research, like more applied R&D, for other reasons than misappropriation risks, for example, production risks.[79]

The feasibility of self-help mechanisms depends on the nature of the innovation. Lead time advantage is primarily dependent on secrecy, timing, and the ease of copying or reverse engineering. Maintaining the market advantage gained through lead time depends on the availability of barrier mechanisms. Although these factors vary by industry, a few general observations can be made with regard to the innovation model developed earlier. First, in rapidly evolving product markets,[80] firms compete in a separate innovation market for applied innovations constituting incremental advances, i.e. sharply peaked application estimates, requiring less capital investment. In this type of market, consumer demand signals to firms opportunities to usurp market share of previous innovators. At the same time,

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75. *See* KAMIEN & SCHWARTZ, *supra* note 27, at 27; *see generally* Levin, *supra* note 60 (discussing appropriation of returns from R&D).

76. *See* Joseph Stiglitz, *Technological Change, Sunk Costs, and Competition*, 3 BROOKINGS PAPERS ON ECONOMIC ACTIVITY 883-87 (1987).

77. *See, e.g.*, Levin., *supra* note 60, at 785-86; CHRISTOPHER TAYLOR & Z. A. SILBERSTON, THE ECONOMIC IMPACT OF THE PATENT SYSTEM: A STUDY OF THE BRITISH EXPERIENCE (1973); Edwin Mansfield et al., *Imitation Costs and Patents: An Empirical Study*, 91 ECON. J. 907 (1981).

78. *See* Levin, *supra* note 60, at 816.

79. *See id.* Self-help mechanisms and IP address different classes of innovation altogether. It seems that the Levin et al. survey describes industry preferences for certain classes of research, which are influenced by, *inter alia*, available appropriation mechanisms.

80. Product markets generically refer to output markets depending on an innovation input. The timing of entry into the product market is correlated to secrecy dissipation time for a particular innovation.

previous innovators strive to use their lead time to erect barriers while competing in the same incremental innovation market. The dynamicism of such a market lends itself to self-help mechanisms because the costs of maintaining secrecy over an incremental innovative step are likely to be low. Furthermore, the costs of not being the innovating firm lessen over time because catching up on the learning curve is less difficult and involves fewer innovative steps. Although the investment costs of each innovation project are relatively low, an inherent barrier to entry is the significant cache of experience and know-how required to be competitive in the game.[81] Spillovers are less likely to occur, and when they do, are unlikely to be recognized and/or captured by the firm.[82]

Second, in less rapidly evolving product markets, the innovation market operates at different levels of "basic-applied-ness" depending on the existing market structure, firms' risk tolerances and discount rates, their accessibility to the "current state of knowledge," and their financial and technical capacities for capturing spillovers.[83] To be successful in the naked market, basic innovation projects require extended secrecy: either product markets must not reveal their innovation inputs through reverse engineering because of natural or "built-in" lead time, or innovations must be used as inputs for further research in secrecy.[84] Under the latter scenario, firms forego short-term appropriation by withholding release of products until further innovations can be developed.

However, basic projects may depend on exogenous innovation inputs.[85] Firms will, on the one hand, depend on secrecy in order to accumulate cumulative innovations to constitute a sufficient leap to gain a lead time advantage,[86] and on the other hand, depend on being apprised of external

81. To be competitive, it is not necessary to be the innovating firm at any one step; however, competitive firms must all be caught up on the learning curve. *See* SYLVIA OSTRY & RICHARD NELSON, TECHNO-NATIONALISM AND TECHNO-GLOBALISM 6-7 (Brookings 1995). "[F]irms still need to invest an enormous amount of time in designing and learning to produce a specific product or in learning to master a sophisticated production process. These investments are large enough if a company wants to keep up with a rapidly evolving technology. Far more is required to be a leader." *Id.* at 7.

82. The peaked application estimate means spillovers are less likely. Firms competing in an incremental innovation market may be less likely to possess the technical and financial capacity to identify and capture unexpected spillovers.

83. *See* GUINET, *supra* note 26, at 25 (arguing that technological investment depends on firms' capacity, sectoral specialization, and structural competitiveness).

84. *Cf.* Scotchmer, *supra* note 17, at 4 (discussing an innovator's choice between (1) disclosing an early innovation in a patent, or (2) maintaining secrecy by refusing to patent and keeping the discovery off the market).

85. *See, e.g.*, Integraph Corp. v. Intel Corp., 3 F. Supp. 2d 1255 (N.D. Ala. 1998) (Integraph sues Intel because Intel refuses to share newest chip set information upon which Integraph depends when developing its products.)

86. Of course, there is always the chance of making a leap without cumulative efforts. In fact,

developments in the field. If a basic innovation is indivisible, i.e., it cannot be broken down into its constituent steps, the inability to stagger contingent production costs increases the importance of maintaining secrecy.[87]

2. Observations

Without government intervention (except through common law tort, contract, and trade secret law), a number of social inefficiencies result. First, firms tend to bias investments towards more applied innovations that involve less innovative steps.[88] In the short term, this strategy may be fruitful, particularly when consumer demand directs investment. However, many opportunities for development may remain undiscovered over the long run, which is particularly costly from the social perspective.[89] Furthermore, non-captured spillovers may result in significant social costs, particularly when not identified or disseminated to the public.

Second, firms are likely to engage in a competitive "race to innovate" in secrecy.[90] This has two potentially deleterious results: (1) the benefits of sharing research results will be diminished, and (2) duplicative efforts by multiple firms may raise net research costs. The former result is well known

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many significant advances are made in this fashion. Commentators have struggled to incorporate this random leap into their understanding of innovation. A simple explanation, perhaps too simple, can be derived from the application estimate concept: *a leap or major advance is an extremal event where a successful innovation yields an unlikely application, modifying successive application estimates dramatically.*

87. *Cf.* GUINET, *supra* note 26, at 58. Indivisibility of innovation leads to two particular types of market failure. "The first has to do with the minimum critical size of technological investment needed, in the research phase, to limit the exploration by rivals of parallel approaches and, in the marketing phase, to make it more difficult for rivals to contest the market positions achieved." *Id.* The second is related to the difficulty in separating a major research project into a series of separately conducted projects, and hence the need to concentrate major projects within a certain firm.

88. Some recent commentators have observed this same tendency in nations. *See* OSTRY & NELSON, *supra* note 80, at 112 ("Many firms, *and nations*, in the name of competition, focus their R&D on technologies that offer clear and immediate commercial payoffs... to minimize spillover and to keep payoffs internal." (emphasis added)). *Id.* The authors note the longer-term problems of this bias. *See id.* Moreover, the bias has been seen in the grant application process as a result of limited funds and intense competition. *See* UNLOCKING OUR FUTURE, *supra* note 3, at 19-20.

89. "From a social point of view, effective pursuit of technological advance seems to call for the exploration of a wide variety of alternatives and the selective screening of these [alternatives once] their characteristics have been better revealed – *a process that seems wasteful with ... hindsight.*" Richard Nelson, *supra* note 18, at 455.

90. *See* Suzanne Scotchmer, *Incentives to Innovate*, PALGRAVE ENCYCLOPEDIA OF LAW & ECONOMICS 273, 275 (1998) (discussing the two views on patent races that has emerged from the literature, the first concerning wasteful duplication of costs and the second concerning an efficient increase aggregate research investment, which accelerates innovation). The race to innovate is very similar in the naked market and IP-enhanced market, e.g., patent races, although the cost-benefit structure is likely to be of lesser magnitude in the naked market than in the IP-enhanced market.

and is often considered to be a significant social cost that serves as a justification for the intellectual property system as a means for disseminating information.[91] The latter concern is frequently raised in the analogous context of "patent races" where firms engage in presumably identical research. Some commentators question whether duplicative but competitive research is more efficient than "coordinated" but monopolistic innovation.[92] This tradeoff has been explored at length in the IP literature and is common to innovative progress.

The need to facilitate dissemination to prevent duplication is founded on two related premises: first, that innovative progress is linear, and second, that efficiency dictates that duplicative efforts be minimized.[93] These premises presuppose that similarly aimed research efforts follow the same course of research, lead to identical results, and are thus economically wasteful. But this supposition is only valid for applied innovation projects; two independent research projects having the same extremely peaked application estimate will likely result in duplication because achieving the expected mean application is highly likely and spillovers are highly unlikely.

But, as the variance of their application estimates increase, so do the merits of competitive duplicative efforts for three reasons. First, progress in a general sector may be hastened.[94] Second, the likelihood of identifying and capturing spillovers increases. Third, the variety of innovations and applications increases.[95] However, shared results and coordinated efforts may be necessary for certain classes of innovations, e.g., basic research within a particular sector or industry, to the extent that success depends on exogenous

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91. The IP literature generally acknowledges that secrecy or reduced dissemination entails significant social costs. *See, e.g.*, Braga, *supra* note 11, at 257.

92. *See* Robert Merges & Richard Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839, 877 (1990) (arguing that in the positive sum game of dynamic innovation, "rivalry facilitates technical advance and unified control damps it"). This question is discussed further in Part III.

93. *But see* Scotchmer, *supra* note 89, at 275 (associating inefficient duplication with the assumption that "R&D costs have a large fixed component... [where] if two firms invest, the cost is needlessly duplicated.") Scotchmer distinguishes the fixed R&D cost process, which leads to duplicative results, from the variable R&D cost process, which leads to duplicative but accelerated results. *See id.* The distinction is clearly valid if the innovative process is linear and the R&D project is applied. *But see infra* note 94.

94. *See* Merges & Nelson, *supra* note 91, at 876-80; *see also* Scotchmer, *supra* note 89, at 275.

95. For example, imagine that firm A and B each begin with a shared pool of common knowledge and identical sets of resources (capital, labor, expertise, know-how, etc.). Furthermore, each begins an independent innovation project X at time t_1 with identical application estimates $P_1(X)$ but without any sharing of information after t_1. The outcome of each firms' project at t_2 yields X_A and X_B. The likelihood that the outcomes are the same depends on the variance of the application estimate. When the outcomes are secret and not equal, each firms' new application estimate is different, creating both different opportunities for innovative progress in the broad sense and different incentives for continued investment. The communication of outcomes from period 1 leads to a separate application estimate with its own shape and location.

inputs. For example, consider a basic research project that is divisible into constituent, interdependent steps but is too costly for a single firm to take on in the naked market. If a number of firms tackle different steps, an anti-commons may arise in which consensus-based sharing is necessary to make the innovative leap.[96] Holdout problems may be extremely costly to all involved and will likely deter investment in the first place if predicted and *ex ante* contractual agreement is not reached.[97]

B. Innovation Market Failure

Government intervention into the innovation market is appropriate only when the naked market fails to approximate the socially efficient level of production of certain innovation types. Thus, intervention is narrowly justified and limited to the extent that it addresses a certain form of market failure. Poorly targeted intervention leads to significant social costs in the form of direct economic waste and market distortions. This paper argues that, although a difficult challenge, improving the "mix" of government institutions depends on a more careful identification and targeting of specific forms of innovation market failure.

In addition to the common forms of market failure, i.e., imperfect information, high transaction costs, and imperfect cooperation,[98] market failures associated with the public goods nature of innovation and the dynamic nature of the innovative process require intervention.[99] Public goods market failures take two forms: consumptive and exclusionary. Consumptive market failure (CMF) occurs when well functioning markets (with perfect exclusion) fail to approximate the socially efficient level of production because of the dominance of a good's nonrivalrous consumption attribute. For example,

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96. *See* Michael Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 622, 677-78 (1998); Rebecca Eisenberg & Michael Heller, *Can Patents Deter Innovation? The Anticommons Dilemma in Biotechnology*, 280 SCIENCE 698, 699 (1998).

97. *See* Jerry Green & Suzanne Scotchmer, *On the Division of Profit in Sequential Innovation*, 26 RAND J. ECON. 20, 21 (1995) (discussing *ex ante* licensing and IP licensing in general).

98. The common forms of market failure justify intervention into the innovation market in the same manner as for other product or services markets. Improving market functionality is accomplished through a variety of legal institutions including antitrust, unfair competition, contract, tort, and property law. *See, e.g.*, U.S. DEP'T OF JUSTICE, 1994 MERGER GUIDELINES (1994); U.S. DEP'T OF JUSTICE & FTC, ANTITRUST GUIDELINES FOR THE LICENSING OF INTELLECTUAL PROPERTY (1995) [hereinafter U.S. DEP'T OF JUSTICE].

99. *See, e.g.*, sources cited in Wendy J. Gordon, *An Inquiry Into The Merits of Copyright: The Challenges of Consistency, Consent, and Encouragement Theory*, 41 STAN. L. REV. 1343, n.21 (1989). "Private markets do not reliably provide optimum supplies of "public goods," and it is often argued that this failure justifies some kind of governmental intervention either to provide the goods directly (e.g., in the case of roads or national defense) or to restructure legal rights to create the excludability on which private markets depend (e.g., copyright)." *Id.*

CMF can occur when consumption is nonrivalrous and not limited by transmission restraints, or when the "end-product" is a public good.[100] Generally, private investors will under-invest in these types of research projects, and the government must conduct the research itself through direct subsidization,[101] or enter the innovation market and control demand with respect to a particular innovation type through procurement.[102] Exclusionary market failure (EMF), on the other hand, affects the functioning of the market, i.e., the behavior and decision making of investors and consumers (paying and free riding). Both imitation by competitors *and* consumer free riding are common impediments to private investment in innovation types that do not provide sufficient natural lead time or exclusion. Intellectual property law is the primary mechanism for addressing EMF. IP rights extend (or substitute for) natural lead time through a supplemental layer of government enforcement.

Innovative process market failure (IPMF) occurs when the dynamic nature of the innovative process and its uncertain progression press investors toward more applied research than is socially desirable. IPMF has two defining characteristics:[103] (1) dynamic dependence, i.e., future innovative progress depends on the existing state, and (2) prospective uncertainty, i.e., risks, time horizons, expenditures, and spillovers are uncertain as estimated *ex ante*.[104] Limited public and private investment resources require a careful balance between applied and basic innovation projects over time to ensure

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100. Firms generally invest in innovations with application estimates concentrated closely to the private goods end of the spectrum. Production of public goods like national security are not amenable to market provision because of information and cooperation difficulties even with exclusion. *See* discussion of public goods, *supra* Part I. Intellectual property is ineffective at correcting this type of market failure because, at best, intellectual property rights improve exclusion and thus market functioning but do not facilitate differentiated pricing as needed for the market to approximate socially efficient production.

101. Subsidization includes direct funding of research at public and private institutions, and generally refers to the situation where the government acts as an investor (or principal) in the Investor-Innovator model, discussed *supra* Part I, or as the innovator who purchases shares in the project. *See generally* discussion *infra* Part III.B.

102. Procurement refers to government purchasing that in effect creates a new market unto itself and does not include purchasing of staple goods where the government participates in the market as any other private actor does. In a general sense, the government acts as a consumer on behalf of the public, but at the same time, it also acts as an investor in the Investor-Innovator model. *See supra* Part I.

103. These two characteristics operate in a similar fashion as nonrivalrous consumption and exclusion for public goods. Dynamic dependence indicates a criterion for social efficiency while prospective uncertainty highlights the impediments to efficient allocation of resources.

104. *Cf.* GUINET, *supra* note 26, at 58 ("Innovation is a sequential process characterized by a degree of uncertainty and investment mix that [both] change with time".). *Id.* An important aspect of these characteristics is the manner in which investors and innovators *perceive* the current state, potential progress, and eventual applications. Framing issues are not considered at length in this paper but deserve attention in the future. For a discussion of framing issues in investment decision making, see Larry T. Garvin, *Adequate Assurance of Performance: Of Risk, Duress, and Cognition*, 69 U. COLO. L. REV. 71, 156 (1998).

efficient progress. However, in the face of prospective uncertainty, investors skew innovation investment from the socially optimal distribution between applied and basic research, irrespective of public goods market failures.[105] For the most part, this paper addresses IPMF that affects commercial research although the problem manifests in grant solicitations and other noncommercial areas.

Irrespective of prospective uncertainty as to estimates, firms will under-invest in basic research and over-invest in applied research to the extent that (1) firms lack the financial and technical resources, therefore being too small to sink large fixed costs or to fully capture the benefits of a successful innovation,[106] (2) firms' risk tolerances are more averse than the public's,[107] or (3) firms' discount rates are higher than the public's.[108] In dynamic areas of research where uncertainty looms, the allocation inefficiency is accentuated. This type of market failure may seem to be a stylized version of imperfect information; they are closely related. For commercial research, the informational gap that the market taken to its perfected extreme would close relates future consumer demand to the current state of innovation such that firms could allocate resources accordingly. However, finite resources require that private discount rates approach the social discount rate and that firms' risk tolerances approach society's. Furthermore, prospective uncertainty itself may deter investors.[109]

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105. All types of market failure interact with each other dynamically; but holding other forms constant, the dynamic nature of innovative progress hinders efficient market provision. Even in a perfectly functioning market, firms may avoid investing in the extremely basic project because of the perceived risk of not capturing full benefits associated with an innovation or because benefits are attenuated in the future. Uncaptured spillovers within the private sector represent real risks to private investors that are not a result of exclusionary or consumptive market failure.

106. For a discussion of financing difficulties faced by small businesses, see Curtis J. Milhaupt, *The Small Firm Financing Problem: Private Information and Public Policy*, 2 J. SMALL & EMERGING BUSINESS 177 (1998).

107. Divergence between firms' risk tolerances and the public's lead to inefficient investment whether the divergence is on the side of risk-neutral or risk seeking. Moreover, from a true efficiency perspective, divergence from a risk-neutral portfolio may be a more appropriate standard for analysis. Even if firms are risk neutral, uncertainty as to risk itself will bias investments towards more applied research.

108. Firms may be less willing to invest in projects whose expected benefits are attenuated in the future, especially when the length of time is uncertain.

109. Recent studies have demonstrated that decision-makers have a general aversion towards uncertainty itself. That is, certain risks, e.g., betting on a flip of a coin (50/50), are preferred over less certain risks, betting on the color of ball picked from an urn containing an unknown distribution of black and white balls. *See* W. Kip Viscusi, *Individual Rationality, Hazard Warnings, and the Foundations of Tort*, 48 RUTGERS L. REV. 625, 640-41 (1996) (describing "ambiguity aversion" and the Ellsberg Paradox) (citing D. Ellsberg, *Risk Ambiguity, and the Savage Acioms*, 75 Q. J. ECON. 643 (1961)); Garvin, *supra* note 103, at 153 (citing Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, 47 ECONOMETRICA 263, 268 (1979)).

The social costs of IPMF are an interesting brand of opportunity costs, ranging from slowed technological development within an industry to significant macroeconomic effects on competitiveness in emerging industries. As commentators have noted, under-investment in basic research will likely undercut the supply of new ideas and, equally important, the supply of future avenues of research.[110] Moreover, innovative process market failures interact with public goods market failures and the corrective institutional mechanisms employed by the government.[111]

III. INSTITUTIONAL INTERVENTION

In theory and practice, many institutional arrangements are simultaneously required to correct the different types of market failure that arise in research.[112] Although these arrangements are disaggregated and somewhat generalized for analytic convenience, a systematic approach is needed to evaluate the potential for overlapping social cost-benefit structures.

A. Corrective Institutions that Modify the Naked Market

This subpart explores the institutional mechanisms employed to improve market provision of innovation. The institutional mechanisms discussed—intellectual property and tax incentives—have the potential to realign private investors' incentive structures, including risk tolerances and discount rates, in a socially desirable fashion.[113] In theory, each institution can be tailored to offset specific risks associated with the different forms of market failure discussed above. However, in practice, the subsidies offset net risk perceived by investors in the *ex ante* investment stage. When reading this subsection, consider what naked market risks are modified and at what stage

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110. *See, e.g.*, Nelson, *supra* note 18.

111. For example, the dynamic effects of granting IP rights can clearly be positive or negative depending on the actual and perceived scope of the rights. *See generally*, Merges & Nelson, *supra* note 91, at 876-80; Scotchmer, *supra* note 89.

112. *Cf.* Braga, *supra* note 11, at 254.

> First, one can argue that there are other institutional arrangements which could in theory generate the same results of the concession of legal rights in new knowledge. As Dasgupta and Stoneman point out, the theory of public goods suggests at least two other solutions for the problem of efficient production and allocation of knowledge: (1) the direct production of knowledge by the government which would "allow free use of it, and finance the expenditure by the imposition of lump-sum taxes"; or (2) the encouragement of "private production of knowledge by the imposition of (differential) subsidies for their production and the levying of lump-sum taxes to finance these subsidies."

Id.

113. Generally, assume that an *incentive structure* includes risk preferences and discount rates.

in the innovative process the relevant subsidy applies. Many of the inefficiency concerns present in the naked market, e.g., races to innovate, are still present.

1. Intellectual Property Rights and the IP-Enhanced Market

Intellectual property rights are expressly permitted by the Constitution "[t]o *promote* the [p]rogress of [s]cience and the useful [a]rts by *securing for limited* [t]imes to [a]uthors and [i]nventors the *exclusive* [*r*]*ight* to their respective [w]ritings and [d]iscoveries."[114] The Framers carefully prescribed the form of government intervention necessary to correct the exclusionary market failure inherent in innovation markets. The grant of a temporary, exclusive right that is enforced by the government extends the natural lead times of innovations and allows investors, including innovators, to better appropriate returns with less fear of free riding.[115] While the self-help mechanisms discussed earlier indicate that firms will overcome the exclusionary market failure and efficiently invest in certain types of innovation projects without IP protection,[116] recognition that other socially desirable projects will be avoided led to the development of additional protections against misappropriation.

The intellectual property mechanism modifies the naked market by improving excludability and thus lessening misappropriation risks, while retaining the market as the production engine for innovation.[117] As in the naked market discussed in Part II, private firms will invest in basic and applied commercial research based on their incentive structure. IP lessens firms' dependence on self-help mechanisms when the qualification criteria for an IP

114. U.S. CONST. art. I, § 8, cl. 8 (emphasis added).

115. While often referred to as a monopoly right, IP does not necessarily, or even often, convey sufficient market power in the antitrust sense to be considered a monopoly, and may be regarded more accurately as a property right. *See generally* U.S. DEP'T OF JUSTICE, *supra* note 97. Nonetheless, it does not seem to matter which characterization is used. It is simply a matter of drawing lines around the scope of the rights and the resulting effect on market power. Either explanation is sufficiently descriptive for the Department of Justice to exercise its supervisory role, in the antitrust context, by looking primarily at firm behavior and licensing practices to determine whether the scope of the rights (monopoly or property) are being expanded. *See id.*

116. Efficient private investment will result for those innovation types that lend themselves to trade secrecy, are difficult to reverse engineer, or that yield a sufficient lead time to appropriate returns. *See* discussion *supra* Part II.

117. "[I]ntellectual property [mechanisms] should be understood as social structures that *improve* the appropriability of returns from innovation. They are not the only nor necessarily the primary barriers that prevent general access to what would otherwise be pure public goods." Levin, *supra* note 60, at 816.

grant can be met. Thus, secrecy during the research stage remains an issue for firms as does technical and financial capacity to capture spillovers,[118] but *ex post* exclusion of non-paying users during the statutory period of IP protection is secured.

Two intellectual property regimes have developed under the Constitution to promote industrial works under the patent system and artistic works under the copyright system.[119] Each regime has different qualification criteria that must be met in order to obtain intellectual property right protection, and each offers different degrees of protection. For firms weighing investment options, the sufficiency of appropriable returns depends on the breadth and duration of protection.[120] For expositional purposes, the discussion is limited to patents although the analysis extends to copyrights as well.

The patent grant awards the greatest breadth of protection, excluding simultaneous independent inventors from using the innovation. Accordingly, the qualification criteria for a patentable innovation are the most stringent.[121] In order to obtain a patent, an innovation must be patentable subject matter,[122] useful,[123] nonobvious,[124] and novel.[125] In addition, a patent application must sufficiently disclose the innovation such that "any person skilled in the art" can make and use it.[126] These patentability criteria, in theory, define a class

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118. *See supra* Part II (discussing role of secrecy and technical and financial capacity in the naked market).

119. Trademarks are often regarded as a form of intellectual property because they confer an exclusive right to use a form of intangible expression, e.g., the design of a distinctive mark or trade dress. The economic incentive arguments that support granting a temporary patent right are analogous to those for granting a trademark, and most of the analysis is applicable to both. *See generally* Roger E. Meiners and Robert J. Staaf, *Patents, Copyrights, and Trademarks: Property or Monopoly?*, 13 HARV. J.L. & PUB. POL'Y. 911 (1990) (discussing the role of exclusive rights to use intangible goods in the market).

120. *See, e.g.*, Merges & Nelson, *supra* note 91, at 876-80; *see generally* WILLIAM NORDHAUS, INVENTION, GROWTH, AND ECONOMIC WELFARE (1969) (theorizing that change and problems are due to economics of technology through models of invention).

121. Patentability criteria are well known. *See, e.g.*, ROBERT MERGES ET AL., INTELLECTUAL PROPERTY IN THE NEW TECHNOLOGICAL AGE 136-229 (1997).

122. Patentable subject matter includes any "new and useful process, machine manufacture, or composition of matter, or any new and useful improvement thereof." 35 U.S.C. § 101 (1994).

123. *See id.* §§ 101, 112. The utility standard is a minimum threshold; a showing of likely utility will suffice. Some commentators have suggested a stricter utility standard may limit the dynamic costs of granting patent rights to basic innovations. *See, e.g.*, Arti K. Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. (forthcoming 1999); ACADEMIC NORMS (1998).

124. *See* 35 U.S.C. § 103. The nonobvious standard sets a lower bound on step size for incremental innovations by prohibiting trivial advances over the existing art from being awarded patent protection.

125. *See id.* § 102. Novelty requires an innovation to be an actual step or advance.

126. *See id.* § 112. The enablement requirement operates so as to maximize disclosure and prevent secrecy or withholding of information that is relevant to the innovation. It also operates in conjunction with the other criteria, for example, when enablement demonstrates utility, and when prior enablement, whether actual or constructive, in the public domain erodes novelty or non-obviousness.

of innovations for which the social benefits of improved market provision exceed the social costs of government administration and enforcement, and of limited *ex post* use due to the monopoly right.[127]

In practice, the patentability criteria indicate an endpoint—or release valve for internal pressure—during research. Consider a firm engaging in basic research. In the naked market, the firm must conceal incremental research results while recycling innovation inputs into derivative research until sufficient lead time can be established for market barriers to be created and returns to be generated. In the IP-enhanced market, the firm would similarly conceal research results but (possibly) only until a patent can be obtained.[128] Thereafter, continued recycling may continue but with less fear of misappropriation.[129] To the extent that the patent grant extends natural lead time, firms with fewer resources are able to engage in more basic research because (1) firms will not have to finance extended cycling of innovation in secrecy,[130] (2) through licensing arrangements, the coordination of derivative research efforts with external firms is facilitated, and (3) identifiable spillovers can be captured by the firm if explicitly contained in the patent claims.

The patent system, with its strong form of exclusion, involves a significant trade-off between improved supply and reduced utilization for classes of innovations.[131] By correcting the exclusionary market failure associated with innovation in the first instance, the patent system induces social costs by allowing a patentee to exercise "monopoly control" of the

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127. The social cost of under-utilization may include higher prices due to monopoly provision of the end-good, assuming alternative substitutes are lacking, and stifling of innovative progress. This cost seems illusory in that it only arises *ex post*, as a necessary incident to the innovation's creation-in the absence of the patent system, the innovation arguably would not exist. If patents are only awarded for innovations that would not be created *but for* the promise of enhanced exclusion, then *ex post* under-utilization is an illusory cost. However, where an innovation would be created in the absence of an IP right, i.e., in the naked market or through government subsidization, the *ex post* under-utilization cost is an important consideration for comparative purposes and social policy analysis. The discussion earlier on the naked market provides an illustrative example. *See* discussions *supra* Part II.

128. Firms may compare the costs and benefits of patent protection and of trade secrecy protection as means for appropriation. *See* Levin, *supra* note 60, at 816. Patent protection is not always preferable. *See id. See also* Scotchmer, *supra* note 17, at 4.

129. However, other firms may engage in experimentation with the patented innovation and produce a derivative innovation that they may, in turn, patent. This leads to blocking patents. *See infra* notes 135-38 and accompanying text.

130. The costs of extensive innovation cycling in secrecy involve monitoring employees, contractors, and even clients through contractual or other means. *See supra* Part II.A.

131. *See, e.g.*, Merges & Nelson, *supra* note 91; Braga, *supra* note 11, at 243, 254-55 (discussing the need to re-evaluate "the benefits associated with increased production of knowledge" and "the costs due to its under-utilization" in the context of an open international economy). Braga, *supra* note 11, at 255. There are other social costs to the IP system that generally mirror the costs arising under the naked market, discussed *supra* Part II.A.

innovation, restricting use and extracting monopoly rents on derivative products.[132] In a more subtle fashion, IP may aggravate consumptive and innovative process market failures, leading to substantial social costs. Recall that consumptive market failures occur when a public good is not amenable to a market provision, even under perfect exclusion, because of the good's nonrivalrous consumption attribute.[133] Take, for example, national security. Absent government subsidization or procurement, no firm would invest in national security or the tools, e.g., innovations, necessary for its provision. Relying on the IP-enhanced market to provide such production inputs would be foolhardy.[134] Not only would market signals be inaccurate (if not utterly non-existent), but under-utilization would be inevitable and particularly costly if an IP award was granted.

On the other hand, consider the situation of firms competing in a rapidly evolving innovation market.[135] If a firm obtains a patent on an incremental advance, then not only are independent inventors of the same innovation barred from its use and consumers made to pay higher prices but subsequent innovation is stalled (significantly unless licensing agreements can be negotiated although even then at a higher cost).[136] *The entry and maintenance costs for competing in the market are raised without a commensurate increase in potential benefits.* Supplanting the naked market with the IP-enhanced market leads to social inefficiencies, in terms of net costs in the static sense, and dynamic effects caused by negative incentives. Natural lead time and resulting barriers to entry would otherwise allow firms to appropriate sufficient returns to overcome exclusionary market failure.

The negative effect of IP on innovative progress derives from the reduced use of patented innovations as inputs into further innovation.[137] In the patent

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132. The extent of monopoly control is limited to the scope of the patent claims and does not always, or even often, lead to dominant market power; this is primarily due to the existence of substitutes of comparative price and quality that constrain the exercise of monopoly control in the antitrust sense. *See generally* U.S. DEP'T OF JUSTICE & FTC, *supra* note 97 (discussing what is needed in order to demonstrate that a patent, copyright, or trade secret has conferred market power to its owner).

133. Consider research concerning the cure for cancer. Granting an IP right to the cure would lead to tremendous social inefficiencies, in the form of under-utilization or monopoly pricing.

134. The idea that the government would enforce exclusion of an IP right for the sake of encouraging defense-related innovation seems ridiculous. *Cf.* Roger Funk, Comment, *National Security Controls on the Dissemination of Privately Generated Scientific Information*, 30 UCLA L. REV. 405 (1982) (discussing the government's ability to control private information based on national security).

135. *See* discussion *supra* Part II.B.

136. *See generally* Green & Scotchmer, *supra* note 96 (discussing the role of IP and licensing for sequential innovations).

137. Of course, patents bring about the dissemination of ideas that would arguably be kept secret otherwise. But it is unclear to what extent the dissemination function of patents generates or facilitates related development. Sharing of innovation project results does allow firms engaging in research to 'update' their application estimates, but the exclusionary function of patents may effectively close avenues

literature, this phenomena is commonly referred to as the "blocking patents" problem because the use of derivative innovations can effectively be blocked.[138] Derivative innovations may still be granted a patent—"improvement patents"—that effectively block the initial patentee from pursuing certain avenues for development. Moreover, the threat of blocking patents may deter investment in incremental innovations and basic innovations for which significant development is expected in the first place. This problem may be avoided if firms are able to contract around the blocking problem *ex ante*,[139] or may be lessened if transaction costs and strategic behavior can be controlled *ex post*.[140] Taken to its extreme, however, this phenomenon may lead to an "anticommons" dilemma if blocking patents are sufficiently numerable and dispersed such that innovative progress cannot continue in the absence of consensus among patent holders.[141]

On the other hand, some commentators, notably Edmund Kitch, have argued that IP rights facilitate efficient coordination of research such that duplicative waste is minimized.[142] There are a number of scenarios where this argument holds true, some of which depend on the bargaining positions of primary and secondary researchers, and some of which depend on the innovation types involved.[143] Perhaps the most straightforward example of the bargaining position scenario is where valuable information is asymmetrically held by the primary researcher that can be selectively doled out to willing licensees. The latter scenario may occur, for example, in the derivative market

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of research. Firms choose alternative appropriation mechanisms over the patent system when a patent is not expected to sufficiently block downstream research. *See generally* Levin, *supra* note 60. *See* discussion *supra* Part II.A. Still the dissemination function of the patent system is viewed by many to be the source of essential social benefits. *See, e.g.*, Brian P. O'Shaughnessy, *The False Incentive Genus: Developing a New Approach to the Sufficiency of Patent Disclosure Within the Unpredictable Arts*, 7 FORDHAM INTELL. PROP. MEDIA & ENT. L. J. 147 (1996) (analyzing disclosure requirement). For an argument that the public should have access to copyrighted works, see Robert A. Kreiss, *Accessibility and Commercialization in Copyright Theory*, 43 UCLA L. REV. 1 (1995).

138. *See generally* Robert Merges, *Intellectual Property Rights and Bargaining Breakdown: The Case of Blocking Patents*, 62 TENN. L. REV. 75 (1994) (discussing bargaining between pioneer and improvement patent holders). *See generally* Mark Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989 (1997) (comparing the "blocking patents" and "blocking copyrights" regimes and arguing that copyright law should mirror patent law in its treatment of improvements).

139. Cooperative research through joint ventures or some form of *ex ante* licensing agreement may alleviate these problems to some extent but may *also* lead to poor coordination and/or a reduction in research investment. *See* Scotchmer, *supra* note 89, at 275-76.

140. *See* Robert P. Merges, *Contracting into Liability Rules: Intellectual Property Rights and Collective Rights Organizations*, 84 CAL. L. REV. 1293 (1996).

141. *See* Heller, *supra* note 95, at 688. *See also* Eisenberg & Heller, *supra* note 95, at 698.

142. *See generally* Edmund Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265 (1977) (likening a patent to a mining claim, where society benefits from efficient exploitation of a patent and its prospects).

143. *See* Green & Scotchmer, *supra* note 96, at 31 (discussing bargaining positions of primary and secondary innovators in IP licensing context).

for applied incremental innovations for which duplication is likely, i.e., the range of improvements is narrow.[144] In this case, uncertain patentability and the resulting dependence on lead time may combine with infringement concerns to efficiently prevent a derivative innovation market from forming.[145]

Applied to innovation broadly, IP is a blunt instrument involving a rather straightforward trade-off between static and dynamic efficiency. However, when analyzed across innovation types, subtleties emerge. IP promotes efficient downstream coordination for some classes of innovation as Kitch predicts, but stifles efficient downstream coordination for others. Still, for other types of innovation, IP simply makes no sense because exclusion is unnecessary or particularly costly.

2. Tax Incentives and the TI-Enhanced Market

Like the intellectual property system, tax incentives have the potential to improve market-based efficiency by providing indirect subsidies that align private firms' incentives in a socially desirable fashion. It is important to recognize that the market remains the production engine and that firms continue to concentrate their investments in innovation inputs into private goods production (commercial research).

The TI-enhanced market is primarily aimed at affecting *ex ante* investment decisions by allowing firms to lessen their tax exposure if they increase their allocation of investment resources for research. In effect, this lowers the research costs and thus the downside risks associated with an unsuccessful project. This corrective mechanism is not directly applied to the exclusionary or consumptive forms of market failure, although it may offset or counterbalance those risks.[146] Instead, tax incentives counterbalance innovative process market failures and improve allocative efficiency along the basic applied spectrum, where perfect exclusion would still lead to an inefficient allocation of private resources. However, this may be overstated because both tax incentives and intellectual property are indirect subsidies that lessen the aggregate risk of research investments for firms. Although the risks

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144. This scenario is essentially a race to innovate in the naked market. *See supra* Part I.A. IP may efficiently stifle needless races before they start.

145. *Cf.* Kitch, *supra* note 141, at 276-77. Only in the case of a patented product is the firm able to make the expenditures necessary to bring the advantages of the product to the attention of the consumer without fear of competitive misappropriation. Kitch refers to the marketing of certain patented advantages, but his argument can be extended to suggest that expenditures into derivative innovations that would run the risk of competitive misappropriation remain within the patentee's control so long as their patentability remains uncertain. *See id.* This class of derivative research involves the highest likelihood of duplicative costs and is thus best coordinated under a patent.

146. In practice, firms considering their investment options may avoid disaggregating risks by type. Reductions in research costs will offset exclusionary or any other risks in the net cost-benefit calculus.

they target most effectively manifest in different stages of the innovative process, both mechanisms affect investors in the *ex ante* investment stage.[147]

There are many forms of tax incentives. The two discussed here are taxable income deductions and investment tax credits.[148] The former mechanism allows firms to deduct current expenses and/or capital expenditures incurred from qualified R&D when computing taxable income.[149] Tax credits allow firms to offset the taxes owed to the government by a percentage of their R&D expenses.[150] In the United States, sections 41 and 174 of the Internal Revenue Code[151] delineate how these mechanisms are applied.

Under section 41, firms that engage in "qualified research" and bear the downside risks, i.e., those which are dependent upon success, are eligible for a tax credit for a percentage of increased expenses incurred in the taxable year.[152] The credit does not apply to research that is government funded, related to post-commercial production, or otherwise disqualified.[153] The circumscribed definition of "qualified research" excludes those classes for

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147. Tax incentives lessen production costs and the downside risks during research while intellectual property increases exclusion and lessens the appropriation risks in the *ex post* utilization stage, when an innovation has been produced.

148. Tax credits and deductions are the primary forms of positive tax incentives that encourage R&D investment. Regulatory tax provisions are another powerful type of incentive mechanism but are not discussed in this paper. *See* INNOVATION AND COMMERCIALIZATION, *supra* note 5, at 90-94. Table 3-7 lists the relevant tax provisions as of 1995. *See id.* at 93.

149. *See, e.g.*, Jules Charette, *R&D Tax Incentives Make Quebec a Prime Location for Foreign Firms*, 6 J. INT'L TAX'N. 82 (Feb. 1995) (discussing favorable tax conditions for R&D that include use of tax deductions, tax credits, and tax holidays for foreign researchers).

150. *See id.* at 82. The research tax credit has generally been seen to be an effective instrument for encouraging private investment in qualified research. *See* UNLOCKING OUR FUTURE, *supra* note 3, at 41(recommending that the research and experimentation tax credit be made permanent).

151. *See* I.R.C. §§ 41, 174 (1998).

152. *See id.* In addition, firms that support certain forms of basic research may receive a credit. The net amount of the credit available is the sum of (1) 20% "of the excess (if any) of the qualified research expenses for the taxable year, over the base amount," and (2) 20% of "basic research payments." *Id.* § 41(a). Thus, credits may be claimed for one-fifth of any increased investments in "qualified research," which is defined in section 41(d), and any net investments in "basic research," which is defined in section 41(e)(2)(A) as "any amount paid in cash during such taxable year by a corporation to any qualified organization for basic research" in excess of certain minimum amounts and subject to additional regulations. *Id.* §§ 41(d); 41(e)(2)(A). However, if the researcher is made to bear the downside risks of an unsuccessful project, then she may claim the credit. *See also* Treas. Reg. § 1.41-2(e)(2) (1999); Fairchild Indus. v. United States, 71 F.3d 868, 870 (Fed. Cir. 1996).

153. "Qualified research" excludes government-funded research, post-commercial production research, adaptations or duplication of existing business components, certain surveys and studies, computer software for internal use, research conducted outside the United States, and social science, arts, and humanities research. I.R.C. § 41(d)(4). *See also* Lester, *supra* note 20, at 873 n.6 and accompanying text.

which IPMF are less likely.[154] For example, research into incremental innovations related to existing commercial products are excluded.[155]

Under section 174, firms may choose either to deduct their research or experimental expenditures in the taxable year in which they are paid or incurred, or to amortize such expenditures over a period of at least five years.[156] Since 1954, a major difficulty in applying section 174 has been determining what qualifies as "research or experimental expenditures."[157] As with the qualified research definition under section 41, the answer to this question turns on risk bearing. In order to qualify for deductions of research or experimental expenditures, a firm must bear "technological risk."[158] Exclusionary or market response risks are not sufficient or even relevant to qualifying for the deduction.[159] The less precise definition of research or experimental expenditures, which derives from case law and regulatory interpretation, does not indicate (or even suggest) application be based upon the degree of technological uncertainty, but instead, depends solely on its existence.[160]

Thus, while both forms of tax incentive modify the naked market by reducing the downside risks associated with unsuccessful R&D, they are targeted differently based on what types of innovation projects qualify.[161] The broad manner in which section 174 applies to any project involving technological uncertainty indicates an acknowledgment of innovation as a public good; generally, the deduction is meant to make innovation investment more attractive relative to other types of investments. The more tailored

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154. *See* I.R.C. § 41(d)(4) (1997).

155. *See id.*

156. *See* I.R.C. § 174 (1998).

157. *See* David S. Hudson, *The Tax Concept of Research or Experimentation*, 45 TAX LAW. 85, 119-20 (1991) (detailing case law and legislative and regulatory initiatives to define "research or experimentation" and discussing types of risks for which deduction or credit applies).

158. *See id.* at 119-22. Although the definition of qualified research or experimental expenditures does not explicitly mention risk, the case law and legislative/regulatory efforts to define the statutory term have repeatedly implied the element of technological uncertainty. *See id.* The type of risk involved must be a technological risk— that is, the taxpayer must be uncertain as to its ability to achieve, or how to achieve, the desired result through its research activities. Thus, the taxpayer's uncertainty must be about its ability to produce a desired result through its research activities. The definition of research or experimental expenditures could be clarified by explicitly including it in the definition the element of risk—an element that has been inherent in its definition since Congress enacted section 174. *See id.* at 120.

159. See *id.* at 119. "If the risk involved in the research activity is caused primarily by uncertainty about whether consumers will buy the product— that is, it is caused by consumer preferences or taste— then the research should [not qualify]." *Id.*

160. *See id.*

161. An interesting comparative analysis might look at the "qualification" criteria of different institutions, e.g., for a patent, copyright, tax deduction, and tax credit. The criteria define classes of innovations in a generic fashion and indicate a starting point for comparing social cost-benefit structures. However, this paper does not develop this idea significantly.

qualification criteria of the research tax credit indicates a recognition that certain types of research investment by private firms need additional encouragement.[162] The tax credit still targets production risks but not uniformly. By lessening the downside risks, it can be seen to shift private firms' incentives in favor of more risky, basic investments. Generally, tax incentives are considered an effective means of guiding private investment.[163]

The social costs of the TI-enhanced market are a decrease in general revenue[164] and the potential for private risk preferences to be more risk-seeking than socially desirable, leading to over-investment in risky projects. This latter concern is particularly amplified where market signals are imperfect. In addition, the tax system may have high administrative costs compared with other corrective mechanisms. Moreover, to the extent that the TI-enhanced market overlaps with other institutional settings, there is a risk that society is paying too much for the benefits it receives and that private firms are being over-rewarded.[165] Overlap is particularly likely to occur when tax incentives are uniformly available as in the case of deductions for research or experimental expenditures under section 174.[166] For example, consider a project that would readily be undertaken by firms in the naked market or IP-enhanced market. In this case, providing a tax deduction merely redistributes wealth from the public to the firm without a commensurate increase in social welfare. This amounts to a form of rent seeking.

3. Enhancing the Naked Market: Socially Efficient or in Favor of the Firm

Although the treatment of the IP and TI-enhanced markets has been brief, a general framework for assessing the institutional settings that depend on the market has been developed. Social inefficiencies that arise in the wake of production and appropriation risks present in the naked innovation market and from the dynamic nature of the innovative process may be alleviated or

162. *See* Lester, *supra* note 20, at 874 n.11.

163. *Cf.* Rudolph Penner, *Extending the R&E Tax Credit: The Importance of Permanence*, TAX NOTES TODAY, Dec. 1, 1994, at 4 ("[In a] study conducted by the Policy Economics group of KPMG Peat Marwick, it was found that private industrial R&D spending is highly responsive to the R&E credit.").

164. "Every dollar of foregone tax income is equivalent to an additional dollar of expenditures." INNOVATION AND COMMERCIALIZATION, *supra* note 5, at 91. Despite the apparent one-to-one correspondence between foregone revenue and expenditures, this view ignores the dynamic effects of the tax incentive. In the absence of the incentive to invest in a particular research project, firms may invest in another activity with some tax-reducing qualities. Moreover, research intensive industries may relocate in jurisdictions with favorable tax conditions leading to a net reduction in tax income. *See* Charette, *supra* note 148, at 85.

165. Of course, overlap is potentially costly irrespective of the institutions, but lack of public awareness will more often exist for tax subsidies than for direct funding.

166. *See* I.R.C. § 174 (1998).

aggravated depending upon the institutional mechanism employed and the class of innovation at stake. A uniform assessment of the institutional settings described is impossible given the variability of the innovation types. However, one tentative prescription is that institutions ought to be tailored to correct specific forms of market failure to the extent possible; uniform institutions are likely to be inefficient.[167] A more detailed application of the institutional framework follows in Part III.C. and Part IV.

B. Government Subsidization and Procurement

In this subpart, two alternative institutional settings are discussed where the underlying mechanism for selecting, financing, and performing research is the government rather than the market. A fully detailed account of the broad array of institutions employed by the government under the categorical titles of "subsidization" and "procurement" is well beyond the scope of this paper.[168] Instead, two somewhat generalized institutional types are explored: (1) direct subsidization through the issuance of grants[169] and (2) procurement markets. Each of these mechanisms overlap and interact with each other and with market-based settings[170] in complex ways. At the end of this section, cooperative agreements between government and industry are briefly discussed.

1. Direct Subsidization through the Grant System ("GS")

Direct subsidization through a government grant is exogenous to the market.[171] Rather than relying on the market to signal consumer demand to private firms, who will then invest in research based on their profit-maximizing inclination, the government determines how to use capital

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167. *Cf.* Levin et al., *supra* note 60, at 818. "Since the impact of legal protection of [IP] depends on the strength of other appropriability mechanisms and varies widely among industries, focused efforts to solve problems in specific markets would be more prudent than a broad attempt to upgrade protection." *Id.*

168. Commentators have acknowledged definitional difficulties in the general area of government support because of the vast array of instruments employed. *See, e.g.*, Jerome S. Gabig, *Federal Research Grants: Who Owns the Intellectual Property?*, 9 HARV. J.L. & PUB. POL'Y 639, 640 (1986).

169. For analytic convenience, direct subsidization is limited to the grant system. Other forms of direct subsidy are ignored.

170. *See infra* Part IV. (discussing the mixed institutional setting under the Bayh-Dole Act where grants and intellectual property operate in conjunction).

171. When the government issues a grant to a private firm through a grant-matching arrangement, this assumption seemingly erodes. However, the mechanism is, arguably, still partially isolated from the market although the public good to which the grant funding is directed may be improved market performance in a particular sector, or simply aimed at supporting a local industry for distributional reasons.

generated through the tax system in a socially beneficial way.[172] Historically, this has included supporting basic research for innovation inputs into both private and public goods production.[173]

Although grants cover the production costs for innovation projects in a similar fashion as incentive-based subsidization, there are two primary differences between the institutional settings. First, under the grant system, the government does not rely on either the market to signal public demand for innovation-dependent goods or on firms to process and act on such information. Instead, the government obtains demand information from the political process, its expert bodies (administrative agencies), and solicitations by researchers. Government also conducts the research itself, for example, through government laboratories. Additionally, it funds projects at non-profit research centers such as universities, and research by private firms, which is less often the case.[174]

A second poignant difference is when utilizing grants, the government, as investor-principal, often bears the entire downside risk of an unsuccessful project. The exclusionary risks associated with a successful project that manifest in the *ex post* utilization stage are likewise borne by the government, although presumably the only risk of misappropriation is by foreign actors.[175] Depending on the recipient, the innovation type, and the funding agencies' priorities, however, the government may require that funds be matched to some extent in order to spread the risks and properly align incentives.[176]

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172. In terms of demand, the market is the most efficient signaling mechanism for purely private goods while the government is, arguably, the most efficient signal processor for purely public goods. In theory, investment into inputs for these types of goods should be directed by the most efficient signal processor. Prescriptions are more difficult for less than pure private or public goods. *See infra* Part III.B. Public choice arguments rightfully question the assumption that the government allocates funds "in a socially beneficial way."

173. For a brief historical account of government funding of research, see *infra* Part IV.A.

174.

> The primary channel by which the government stimulates knowledge-driven basic research is through research grants made to individual scientists and engineers. Typically, these funds go to professors who lead a university-based research team, but in some cases, researchers in non-profit research centers, hospitals or even in industrial settings or federal laboratories receive this type of funding for basic research projects....To obtain these grants, the researchers must vie for the limited federal funding available in a competitive process that is based on peer review....In order to facilitate basic research, the federal government should continue to administer research grants that include funds for offsetting indirect costs and use a peer-reviewed selection process, to individual investigators in universities, non-profit research centers, hospitals, and some industrial laboratories for support of investigator-driven, non-commercial research.

UNLOCKING OUR FUTURE, *supra* note 3, at 18-19.

175. The issue of foreign misappropriation is discussed *infra* Part IV.C.

176. This is the case for cooperative research and development agreements (CRADAs) between the government and industry.

Grants are generally exercised through legal instruments that are less formal than procurement contracts. Accordingly, the law governing government grants is much less delineated and defined than government procurement law.[177] There are three general categories of grants that are used by the federal government: grant agreements, cooperative agreements, and direct subsidies.[178] Grant agreements and cooperative agreements are research funding mechanisms considered in this paper (together referred to as grants), although direct subsidies are also utilized. The primary legal distinctions between grant agreements, cooperative agreements, and procurement contracts are the functional relationship between the government and the recipient[179] — grantee or contractee—and the applicability of Federal Acquisition Regulations (FARs), which apply to procurement contracts and not to grants.[180] Important for the analysis in this paper, the instruments are targeted at different classes of innovations along the basic to applied spectrum.[181]

A grant must be utilized when "the principal purpose of the relationship is to transfer a thing of value to the State or local government or other recipient to carry out a *public purpose of support or stimulation* authorized by a law of the United States."[182] The decision to use a grant agreement or cooperative agreement depends solely on the degree of involvement that the federal government has in the funded project. If "*substantial* involvement is not expected," a grant agreement should be employed,[183] otherwise, a cooperative agreement is used.

Grants are often employed to support or stimulate innovation without a predetermined application or result in mind. Although the subject matter and general purpose may be designated with a high degree of specificity, project expectations and hence the application estimate exhibit a significant variance. The transaction costs of identifying future contingencies and providing an

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177. *See* Gabig, Jr., *supra* note 167, at 640 (comparing the "obscure legal discipline" of grant law with its "highly refined cousin, the law of procurement contracts"). *Id.*

178. *See* 31 U.S.C. § 6302 (1994). Direct subsidies include "direct United States Government cash assistance to an individual," subsidies, loans, loan guarantees, and insurance. *Id.* § 6302(2)(A).

179. Recipient includes States, local governments, and other authorized entities, including charitable or educational institutions. *See id.* § 6302(3)-(4).

180. *See* Gabig, Jr., *supra* note 167, at 641-42.

181. Much more can be said about grants as legal instruments. The focus here is on the general institutional mechanism as a means for allocating public resources into research. For a discussion of the enforceability of grant agreements, see Jeffrey Walker, Note, *Enforcing Grants and Cooperative Agreements as Contracts Under the Tucker Act*, 26 PUB. CONT. L. J. 683 (1997).

182. 31 U.S.C. § 6304 (emphasis added). Compare guidelines determining when to use procurement contracts, *infra* note 185 and accompanying text. In fact, the full text of sections 6304 and 6305 explicitly contrast the principal purpose of the grant agreement and cooperative agreement respectively with that of a procurement contract. *See id.* §§ 6304, 6305.

183. *See id.* § 6304(2) (emphasis added). Compare the second clauses of section 6304 and section 6305; they differ by the inclusion of "not." *See id.* §§ 6304, 6305.

elaborate roadmap are simply too high to be justified. Accordingly, the legal instrument is very flexible. It leaves much of the decision-making at the discretion of the researcher (although subject to approval),[184] and does not have "success-determining" specifications.[185] The uncontrollable risks are borne by the government and are, in a sense, considered small because spillovers are welcome. Information held by potential grantees is typically revealed in the solicitation process, which is competitive and often subject to peer review.[186] At the same time, the controllable risks (or moral hazard) are addressed through contractual requirements for, among other things, submission and presentation of reports and periodic renewal of funding.

The grant is rather easily justified as a corrective mechanism for consumptive market failure because alternative mechanisms are poorly suited. Innovation inputs into public goods production must be supported by the government if the public goods are to be supplied. The authority for agencies to issue grants is derived directly from prescriptive legislation, which is usually aimed at improving the provision of a particular public good, e.g. national defense.[187]

Grants issued to stimulate market-based corrections are less easily justified when compared with intellectual property and tax incentives, primarily because of differences in information signaling and decision-making

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184. Permitting the grantees to retain discretionary control over the course of research is an important aspect of the grant mechanism: "Direct funding of the individual researcher must continue to be a major component of the federal government's research investment, as it is the ideas generated by individual scientists that are in large measure responsible for the creative directions that basic research takes." UNLOCKING OUR FUTURE, *supra* note 3, at 19. However, grantee autonomy and the traditional norms of the scientific community may be at risk on two fronts: The first is increased competition to publish and to obtain a share of increasingly scarce funds. *See id.*

> Yet, as the research enterprise—and the number of scientists within it—has grown, competition for peer-reviewed grants has become fierce. If limited funding and thus intense competition for grants causes researchers to seek funding only for "safe"—that is, incremental—research instead of research that challenges the status quo or pushes the boundaries of conventional wisdom, the research enterprise as a whole will suffer....There are no rewards for risky science. It is too important to publish.

Id. at 19-20 (statement of Suzanne Rutherford). The second front is the introduction of profit incentives in the form of rights to patentable results. *See infra* Part IV.

185. Although some measure of success may be required, reasonable pursuit of the grant objectives is typically sufficient under the terms of the grant.

186. *See generally* Thomas O. McGarity, *Peer Review in Awarding Federal Grants in the Arts and Sciences*, 9 HIGH TECH. L.J. 1 (1994) (reviewing the peer review process at four federal agencies: National Institute of Health, National Science Foundation, Environmental Protection Agency, and National Endowment for the Arts).

187. This is quite different than the authority for agencies to enter into procurement contracts, which is considered to be an inherent power vested in the agency. *See* Council on Environmental Quality & Office of Environmental Quality-- Cooperative Agreement with National Academy of Sciences, 65 Comp.Gen. 605, Comp.Gen. B-218816, June 2, 1986.

processes. Reliance on the market to signal demand for private goods, and hence inputs necessary for their production, is generally preferable to comparable signal processing by the government. However, where the government is sufficiently competent at identifying innovation types that are amenable to market provision but for innovative process market failures, issuance of a grant may be a more targeted mechanism than alternatives and thus justifiable. Moreover, the ability for the government to monitor controllable risks and to prevent overly risky investment may be an advantage over tax incentives. However, the identification and targeting of innovative process market failures associated with divergent social and private risk preferences, inadequate financial and technical firm capacity, and indivisible projects is a formidable task. Limited public resources must be allocated carefully with some assurance that, at least in theory, direct government support is required.

2. Procurement Markets

Similar to the grant system, procurement markets are an alternative mechanism to market-based provisions of innovation. Again, the government allocates funds toward the purchase of specified goods or services having a public purpose and allows firms to compete for the procurement contract. An extensive body of administrative, statutory, and common law governs the procurement relationship between government and private firms.[188] Treatment here is focused on the creation of procurement markets as an institutional mechanism to produce innovation.

A procurement contract should be utilized when "the principal purpose of the instrument is *to acquire . . . property or services* for the *direct benefit* or *use* of the United States Government."[189] Government agencies have the inherent ability to enter into procurement relationships as a means of carrying out their general mandate. There is a temptation to treat procurement using a different principal-agent framework differently than grants based on the existing legal differences in the institutions,[190] but a more coherent distinction

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188. In addition to the Federal Acquisition Regulations, which govern most contractual relations through which the government acquires something of value from a private entity, many agencies have additional sets of rules and procedures. *See, e.g.*, Andrew Mayer, *Military Procurement: Basic Principles and Recent Developments*, 21 GEO. WASH. J. INT'L L. & ECON. 165 (1987) (reviewing legislative and administrative reforms in military procurement law). Both grant and procurement relationships are exempted from the Administrative Procedure Act.

189. 31 U.S.C. § 6303(1) (1994) (emphasis added). An agency may also decide "in a *specific instance* that the use of a procurement contract is appropriate." *Id.* § 6303(2) (emphasis added).

190. For grants, a multi-tiered principal-agent framework seems appropriate with the grantee supplying the government with goods purchased on behalf of the public; on the other hand, procurement contracts seem single-tiered, with the government purchasing on its own behalf. This dichotomy is false

seems to turn on the goods being "paid for," the transactions costs involved, and the information held *ex ante*.

The benefits derived from the flexible attributes of grants disappear as the end product of the innovation project is more ascertainable. Thus, the choice of procurement contract over grant agreement seems to turn on the ability of the government to identify and specify both future contingencies and public demand for a particular innovation or innovation-dependent good. Through detailed specifications of what it desires, the government creates a procurement market through unitary demand manifest in a solicitation. Firms may then compete through a bidding process, for example, an auction, to obtain the procurement contract, thereby ensuring some degree of cost-effectiveness and quality.

Procurement contracts are generally targeted at applied innovation projects having a relatively narrow range of expected applications concentrated at the public goods end of the private to public spectrum.[191] Procurement contracts are thus justified under the traditional public goods rationale for correcting consumptive market failures. In some cases, procurement may be justified to correct exclusionary market failures.[192]

3. Cooperative Arrangements

The primary form of cooperative arrangement is the cooperative research and development agreement (CRADA).[193] In forming CRADAs, a formal partnership is created between a federal agency or research laboratory and industry or a university. CRADAs are found to be an effective instrument because "[t]hey serve a dual purpose by helping to leverage federal research funding and allowing research conducted by federal agencies to benefit more quickly the U.S. economy through technology commercialization by the private sector."[194]

As an institutional mechanism, CRADAs bridge the gap between government-based and market-based institutions and facilitate technology

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because in either case the government remains an agent for the public. Although legal accountability is a more complicated issue, the purchasor, benefactor, and ultimate principal is the public.

191. The government is less likely to fund applied commercial research rather than relying on a market based institution. Of course, when the government purchases staple goods necessary to its everyday functions, e.g., word processors, it acts in the private market as a private consumer would.

192. Procurement may be appropriate for applied innovation inputs into private goods production when the project is costly but the expected result will provide insufficient natural lead time and patentability is uncertain.

193. The Federal Technology Transfer Act of 1986, 15 U.S.C. § 3710 (1994), amended the Stevenson-Wydler Technology Innovation Act of 1980, 15 U.S.C. §§ 3701-3714 (1994), to authorize cooperative research and development agreements (CRADAs) between the government and industry.

194. UNLOCKING OUR FUTURE, *supra* note 3, at 30. *See* 15 U.S.C. § 370(1994).

transfer and the development of "dual-use" technologies. Technology transfer is the process by which publicly funded research results in innovation inputs for private goods production.[195] The transfer is accomplished through either spillovers or directed public investment aimed at correcting IPMF (or perhaps EMF), and is transferred to industry for further development and commercialization. CRADAs allow industry researchers to gain first-hand expertise and technical know-how while participating in the joint project.

Dual-use technologies are innovations with applications at both public and private goods extremes. During early phases of research, the application estimate for such a project may span the public to private spectrum; as the course of research develops, different sets of applications arise, calling for government funding on one hand and private investment on the other. CRADAs allow limited public and private funds to be leveraged in a fashion that promotes efficient sharing of production risks and information such that both application sets can be pursued without duplicative waste.

C. Institutional Justification by Innovation Type

This subsection brings together the discussion in Parts I and II with the discussion in this Part by comparing institutions as means for producing certain types of innovations. Choosing between institutions rests on subtle differences in the manner in which they target innovation market failures, rely on information processing, and have dynamic effects on incentives and other institutions.

Returning to the innovation model described earlier, it is rather straightforward to determine the appropriate, "corrective" institution for applied innovation projects concentrated at either end of the public to private spectrum. At the private extreme, the naked market may have to be enhanced through intellectual property to correct exclusionary market failures or through tax incentives to correct exclusionary or innovative process market failures, depending on the particular innovation type. For illustration, contrast the impediments to investment in a research project aimed at a specific product that is easy to reverse-engineer, having insufficient natural lead time, with one that is extremely costly to reverse-engineer but is also extremely costly to finance because the size of the expenditure is beyond firm capacity. IP may be appropriate for the former, providing the social costs of reduced utilization and heightened prices do not outweigh the benefits of improved provision, while tax incentives may be appropriate for the latter. Procurement

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195. The Stevenson-Wydler Technology Innovation Act, *supra* note 190, made technology transfer an explicit mission and responsibility of federal researchers. *See* 15 U.S.C. § 3701 (1994).

may be appropriate for applied innovations near the private extreme if the government clearly recognizes consumer demand and a reluctance by firms to invest because of a lack of natural lead time or IP protection.[196]

At the public extreme, procurement is the appropriate mechanism for applied research because relying on a market-based provision would result in under-supply. For example, consider an auto-pilot guidance system for a bomber plane. The application range for this innovation can be extremely narrow, particularly if the specifications are explicitly known up front, and the use is to promote national security. The market will not direct private investment efficiently for this type of innovation; government selection is required.

Moving off the public and private extremes but retaining a narrow application estimate, the analysis becomes more complex depending on which public goods market failure led to the shift. If the application yields a rivalrously consumed, nonexcludable good, then intellectual property is likely the appropriate mechanism. Efficient provision is feasible through the market if exclusion can be attained. Consumption of the end-product ought to be dictated by the market. Thus, market demand signals would direct investment but for risks of free-riding. IP may alleviate free-riding concerns both in the innovation and product markets.

On the other hand, if the result is a nonrivalrously consumed, excludable good, then tax incentives may be used to encourage market investment, or the government may allocate resources directly if demand signals are ascertainable. For example, this class includes the majority of entertainment goods where increasing the number of consumers at any one point in time or space beyond some threshold imposes increasing costs, such as through congestion. The consumption of a museum display or a movie by one person does not deplete its availability or value to another *per se*. However, because the costs of exclusion are not high, marginal transmission costs can be balanced against marginal benefits to additional consumers.[197] In the case of museums, government funding may be necessary to overcome deficiencies in market signals and high market response risks. On the other hand, market demand for movies is readily ascertainable, and private investment is not deterred.[198] In theory, there is still under-supply due to the nonrivalrous consumption characteristic. Some people will be priced out from viewing a

196. This tentative observation likely falls by the wayside when the limited scope of government resources is taken into account and priorities are ordered.

197. Efficient transmission does not always mean no congestion. Packing another person into the movie theater and imposing a negative externality may be efficient if the value that extra person receives exceeds the aggregate cost imposed on the rest of the moviegoers.

198. Copyright law prevents misappropriation by competitors.

movie and there may be some under-investment.[199] However, given limited government funds and the adequacy of market provision, there is not a strong case for government subsidization. If, however, market signals were poor or the public had an interest in ensuring that some parts of society were not priced out, perhaps for distributional reasons, then government subsidization would be appropriate.

The analysis is considerably more difficult for less applied innovations. For inputs into public goods production, the case for government provision remains strong; however, the grant system replaces the procurement system. Private investment is unlikely to find its way into these types of projects, although spillovers from private investment may yield some public goods benefits.[200]

Although the market is the most efficient resource allocation mechanism at the applied extreme for commercial research because demand information is easily translated into targeted innovation investments, firms may still under-invest in basic research. The reasons for under-investment include risk preferences, high discount rates, and the capacity to support large investments, to adjust to changing application estimates, and to capture spillovers. These impediments are accentuated by the dynamic nature of the innovative process, which may breed uncertainty and prevent market signals from being efficiently translated.

Unfortunately, institutional corrections are not easily prescribed for IPMF, which justify government subsidization of basic commercial research. IP and tax incentives both act as indirect subsidies that offset net risk but neither generates information, builds capacity, or hastens progress. IP is a rather blunt instrument in its current state.[201] The government can subsidize production costs and offset net risk based on decision criteria more in tune with society's if it can identify such opportunities. Tax incentives may be preferable to the grant system as a means for correcting IPMF for commercial research because government intervention is minimized and firms continue to process market signals. To be effective, however, a tax mechanism must be targeted at a cognizable class of innovations for which IPMF is likely, else it may inappropriately distort markets. In some cases where the government has

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199. *See supra* note 41.

200. For discussion of how to transfer spillovers to private industry, see *infra* Part IV.

201. *See, e.g.*, Scotchmer, *supra* note 89, at 273 ("Patents are a very crude incentive mechanism with many pernicious side effects."). An IP institution that awarded rights of variable breadth and length depending on the innovation type could, in theory, lead to social efficiency. *See id.* at 273-74. Another alternative is a reward system where the government pays innovators *ex post* based on the value of their innovation and releases it for public use. *See* STEVEN SHAVELL & TANGUY VAN YPERSELE, REWARDS VERSUS INTELLECTUAL PROPERTY RIGHTS, (National Bureau of Econ. Research Working Paper No. 6956 1999).

sufficient information or where cooperative arrangements can be structured to leverage limited federal funds and spur private investment, direct government funding may be appropriate.

There is a considerable degree of complexity in the overlapping social cost-benefit structures for the institutions available for correcting innovation market failures. Comparative institutional analysis is clearly needed for evaluation and coordination of U.S. technology policy in the future. In this vein, Part IV addresses these issues more directly in terms of the Bayh-Dole Act regime and evaluates the use of IP within the grant system as a means for coordinating downstream research stemming from government-funded projects.

IV. MIXED INCENTIVE SYSTEM FOR PUBLICLY FUNDED RESEARCHERS

This Part applies the framework developed *infra* to the Bayh-Dole regime wherein federal grants and patent rights are used in tandem to promote, produce, and commercialize innovation. Subpart A briefly describes the historical background that led to the Bayh-Dole Act in 1980 and subsequent developments in U.S. technology policy.[202] In a somewhat myopic fashion, attention is focused on the mixture of IP with grants, avoiding many peripheral issues raised in earlier Parts. Subpart B considers the statutory provisions set forth in the Bayh-Dole Act. Subpart C frames the economic issues and considers the institutional setting created at a theoretical level. In the IP-enhanced grant system, IP is used to encourage technology transfer by enabling the grantee-patentee to reward investing firms with an exclusive (or partially exclusive) license.[203] This finding comports with recent scholarly work on the manner in which IP licensing sets the bargaining positions of investors in derivative research projects.[204] Derivative innovation projects arising out of technology transfer are made much more attractive for firms through these licenses because, in effect, they create a lead time advantage in derivative innovation markets or patent races. Further analysis of the technology transfer mechanism, in terms of the innovation model developed in Part I, leads to the identification of three sources of potential market failure that justify a corrective mechanism. Subpart C concludes with an analysis of the social benefits and costs of mixing IP with grant funding, which rests on

202. The framework set-up by the Bayh-Dole Act is the focus of this analysis. While the subsequent developments concerning technology transfer are related and deserving of considerable attention, they are beyond the scope of this paper.

203. This is a rather significant departure from the traditional "incentive to invest" role of IP.

204. *See* Green & Scotchmer, *supra* note 96.

whether it is sufficiently tailored to address the potential market failures without aggravating others.

A. HISTORICAL BACKGROUND

1. Pre-1980

A thorough historical account of the United States technology policy is readily available from many sources. Accordingly, the treatment here is limited.[205]

Before World War II, federal funding of research was largely directed at agricultural concerns.[206] In 1862, the same year that the Department of Agriculture was established the Morrill Act was passed, creating the land-grant colleges. Both were perceived as valid exercises of Congress' spending power, supporting ends within the purview of the "general welfare." During World War I, research aimed at fulfilling particular military needs was conducted by the military. Mowery and Rosenberg describe the important role that universities played in local economies prior to World War II: "The American higher education system [was] highly decentralized and remarkably diverse. Within this diversity, it has found ways to provide constructive responses to a wide variety of changing economic needs."[207] Universities supplied trained and educated individuals as well as significant innovations in the absence of significant federal funding.[208]

World War II marked a major transformation in U.S. technology policy. The United States enjoyed a considerably advantageous economic and technological position in the world. The federal government shook any narrow constitutional restraints (of earlier years) and became a major investor in and performer of research through the grant system, as well as a major purchaser of R&D results through procurement. From 1953 to 1978, between one-half and two-thirds of net research was supported by federal financing.[209] The federally-financed share of support for basic science research exceeded two-thirds from 1965 to 1984.

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205. *See, e.g.*, Eisenberg, *supra* note 2, at 1671.

206. Through 1940, agricultural innovation projects received the bulk of government support. *See* MOWERY & ROSENBERG, *supra* note 9, at 92-93 (noting that in 1940, the last year before military expenditures grew substantially, funding of agricultural R&D exceeded the total budget for the Department of Defense).

207. *Id.* at 93.

208. *See id.* at 95 (describing "the background against which the American university system and its dramatic transformation due to the infusion of federal funds during and after World War II must be seen."). *Id.*

209. *See id.* at 129, tbl 6.3.

2. Technology Policy Debate

Not surprisingly, what to do with the results of federally-funded research has been and continues to be a contentious issue.[210] The underlying economic concerns center on how best to manage innovations.[211] Prior to 1980, the federal government limited the use and diffusion of publicly-funded research by retaining intellectual property rights in most inventions and controlling the dissemination of information. A small fraction of the inventions were licensed or otherwise made available to the public,[212] and as a result, the public's return on its investment was severely constrained.[213] However, the inefficient transfer of technology was largely overlooked due to the dominant market position of the United States in commercial technologies.[214] Global economic growth throughout the 1970s and 1980s led to a significant increase in competition, particularly amongst the United States, Europe, and Japan, and to a re-examination of the U.S. technology policy.[215]

The pre-1980 debate focused on whether the government ought to (1) release innovations to the public domain for costless consumption, (2) seek patents for qualifying innovations in order to retain management responsibility, or (3) allow private innovators to obtain a patent with an explicit exception for governmental use.[216] The underlying concern fueling the debate was that subsequent commercialization of a given invention would not result if potential users (developers or innovators) were unable to harness sufficient lead time through either an exclusive license under option (2) or a patent. This concern led to the passing of the Bayh-Dole Act, which adopted the third approach and a number of related federal laws intended to facilitate "improved" management of innovations through technology transfer and cooperative research between government and industry.[217] Overall, the

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210. *See* Eisenberg, *supra* note 2, at 1671-74 (discussing the title–license debate over what to do with research results).

211. As noted earlier in the section on intellectual property rights, this debate persists. *See, e.g.*, Kitch, *supra* note 141, at 288.

212. *See* GENERAL ACCOUNTING OFFICE, PUB. NO. GAO/RCED-98-126, TRANSFERRING FEDERAL TECHNOLOGY, TRANSFER-ADMINISTRATION OF THE BAYH-DOLE ACT BY RESEARCH UNIVERSITIES (1998) ("At the time [1980], fewer than 5 percent of the 28,000 patents being held by federal agencies had been licensed, compared with 25 percent to 30 percent of the small number of federal patents for which the government had allowed companies to retain title to the invention.").

213. *See id.*

214. *See id.*

215. *See generally* GRAHAM MITCHELL, U.S. DEP'T COMM., THE GLOBAL CONTEXT FOR U.S. TECHNOLOGY POLICY 1 (1995).

216. *See* Eisenberg, *supra* note 2, at 1671-73.

217. Specifically, the Stevenson-Wydler Technology Innovation Act of 1980, Pub. L. 96-480, 94 Stat. 2311-2320 (codified as amended at 15 U.S.C. §§ 3701-3714 (1994)) made technology transfer an

technology policy has evolved to further the express overarching purpose of increasing dissemination and commercialization of federally- funded research results.

A second source of debate centered on whether a uniform policy could feasibly be adopted to cover the broad range of federally-funded projects within the various agencies. Prior to the Bayh-Dole Act, federal agencies were largely left free to prescribe their own policies regarding what to do with research results. In 1980, there were twenty-six different agency policies governing the vesting of patent rights in inventions developed with U.S. government funds.[218] Uniformity eases the burden of legislation and implementing regulations, *may* lead to reduced uncertainty regarding what to do with a particular innovation, and *may* simplify the dissemination-commercialization process. However, it may also lead to significant social costs that outweigh these potential benefits, e.g., increased under-utilization through intellectual property rights,[219] greater innovative process market failure,[220] and misdirected over-allocation of government resources into commercial research.[221] As was noted earlier, uniform institutional treatment

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explicit mission and responsibility of federal researchers. The Federal Technology Transfer Act of 1986 amended the Stevenson-Wydler Act to authorize cooperative research and development agreements (CRADAs) between the government and industry. *See* Pub. L. No. 99-502, § 7 (1986), *reprinted in* 1986 U.S.C.C.A.N. (100 Stat.) 1785, 1792-1794 (codified at 15 U.S.C. § 3710(c) (1994)). The National Competitiveness Technology Transfer Act of 1989, Part C of the National Defense Authorization Act for Fiscal Years 1990 and 1991, Pub. L. No. 101-189, §§ 3131-3133, *reprinted in* 1989 U.S.C.C.A.N. (103 Stat.) 1675, further amended the Stevenson-Wydler Act to include government-owned, contractor-operated laboratories. *See id.* at § 3133(a)(2)(A), *reprinted in* 1989 U.S.C.C.A.N. (103 Stat.) 1675. The National Technology Transfer and Advancement Act of 1995, further expanded the rights of private sector CRADA partners to obtain exclusive licenses, providing for the sharing of federal royalty income with laboratory scientists, and clarifying the rights of federal employees to own inventions that the agency chooses not to patent. *See* Pub. L. No. 104-113, §§ 4-6, *reprinted in* 1996 U.S.C.C.A.N. (110 Stat.) 775. These developments are beyond the scope of this paper.

218. *See* H.R. REP. NO. 96-1307, pt. 1, at 3 (1980), *reprinted in* 1980 U.S.C.C.A.N. 6460, 6462.

219. Granting IP rights over government-funded research leads to an additional layer of bargaining for licensing and consequently an incremental price increase in end-products purchased by consumers, who have supported the research through tax revenues in the first instance.

220. While government funding tends to alleviate the firm size and capacity-related sources of IPMF, the use of IP rights reintroduces the problem in two ways: first, firms that might otherwise engage in a certain type of basic innovation project might be deterred from doing so if government-funded researchers may be able to exclude their use of independently derived research results (of course, the perfect patent system may avoid this problem by setting the qualification criteria correctly, but government funding misdirected at patentable research still leads to this problem); second, the reliance on IP-coordinated recycling of innovation inputs.

221. The use of IP rights to coordinate subsequent research only makes sense for private goods and end-products. To the extent that the government is directing research investments in projects concentrated at the private goods extreme, there may be error costs associated with government selection when compared with market selection.

of innovation is likely to be inefficient because it ignores important differences in various innovation types.

3. Post-1980 History

Publicly funded research has decreased as a percentage of GNP from over 2.2% in 1964 to 0.9% in 1995 and also as a percentage of net research investment. Private firms have increased their share of research funding both within private sector and at non-profit research centers. Generally, internationalization of innovation markets has led to increased worry over free-riding by foreign firms and governments. Since the end of the Cold War, the share of federal funding aimed at serving military ends has decreased while the share going to commercial research has increased.[222]

B. Bayh-Dole Act: Statutory Conditions that Delineate the IP-Enhanced Grant System

The Bayh-Dole Act of 1980 was primarily aimed at facilitating technology transfer in order to get the benefits of public funding (i.e. the invention) back to the public at the lowest cost. It is premised on the belief that putting patent rights of inventions in the hands of those most likely to pursue patent protection and to commercialize the invention will best accomplish this goal. Bayh-Dole and its amendments and regulations establish a policy regime that allows "contractors"[223] to obtain patent rights of

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222. As noted earlier, the framework set up by the Bayh-Dole Act is the focus of this Part. While the subsequent developments concerning technology transfer are related and deserving of considerable attention, they are beyond the scope of this paper. For a discussion of the U.S. innovation system through the Reagan, Bush, and Clinton administrations, see David Mowery, The U.S. National Innovation System: Recent Developments in Structure and Knowledge Flows (prepared for OECD meeting on National Innovation Systems held on Oct. 3, 1996) (on file with author).

> The future U.S. innovation system is likely to be characterized by: [(1)] lower levels of overall federal R&D spending[;] [(2)] lower levels of defense-related R&D funding and procurement activity[;] [(3)] a higher level of internationalization, both in terms of U.S. R&D investment in foreign economies and in terms of higher levels of non-U.S. R&D investment within the domestic U.S. economy[;] [(4)] more stringent domestic and international protecting of intellectual property rights[;] [(5)] less stringent domestic antitrust policy[;] [(6)] higher levels of interfirm collaboration, university-industry collaboration, and collaboration between U.S. and foreign firms in R&D[; and] [(7)] greater efforts by U.S. universities to seek to protect and license the results of publicly and privately funded research.

Id.

223. Contractors are defined as "any person, small business firm, or nonprofit organization that is a party to a funding agreement." 35 U.S.C. § 201(c) (1994). Funding agreement is defined as "contract, grant, or cooperative agreement entered into between any Federal agency, other than the Tennessee Valley Authority, and any contractor for the performance of experimental, developmental, or research work funded

"subject inventions"[224] resulting from government-funded research under numerous statutory conditions.[225]

There are two groups of relevant statutory provisions in Bayh-Dole: a requirement of certain contractual provisions in funding agreements creating mandatory limits on the scope of the IP institution in the grant system and establishment of residual government rights that an agency may exercise at its discretion.[226]

1. Required Provisions in Government Funding Agreements

Under section 202 entitled *Disposition of Rights*, paragraph (c) requires all funding agreements to contain "appropriate provisions to effectuate the following:"[227] (1) that contractors must disclose all subject inventions to the funding agency within a reasonable time, else the government may obtain title;[228] (2) that contractors must elect to retain title in writing within two years or shorter if the one year statutory bar begins[229] or else the government may obtain title;[230] (3) that once elected, contractors must file patent applications before any statutory bars become effective and then file foreign patent applications within a reasonable time, or else the government may do so;[231] (4) that the government retains the residual right of a "nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the

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in whole or in part by the Federal Government." *Id.* § 201(b). President Reagan practically extended the reach of Bayh-Dole in an executive order in which he required agencies to allow IP to be obtained by all contractors "regardless of size" but "to the extent permitted by the law." Exec. Order No. 12,591, 3 C.F.R. § 220 (1987), *reprinted in* 15 U.S.C.A. § 3710, app. at 578-579 (1997). *See also* Edward C. Walterscheid, *The Need for a Uniform Government Patent Policy: The D.O.E. Example*, 3 HARV. J.L. & TECH. 103 (1990).

224. Subject inventions are those "inventions" that a contractor conceives of or reduces to practice during performance of work under a funding agreement. 35 U.S.C. § 201(e) (1994). Inventions are defined as "any invention or discovery which is or may be patentable or otherwise protectable under this title or any novel variety of plant which is or may be protectable under the Plant Variety Protection Act." *Id.*. § 201(d).

225. *See generally id.* §§ 200-212 (discussing guidelines on how federally-owned inventions should be managed).

226. *See id.* §§ 207-209. Although these provisions are an important part of the federal technology transfer scheme, they are not discussed in this paper because title to newly created inventions generally vests in the contractor if they so elect and only in the federal government under limited circumstances. *See id.* §§ 202-203.

227. *Id.* § 202(c).

228. *See id.* § 202(c)(1).

229. Publication, public use, or sales will initiate the one year time clock after which patent applications are barred from consideration. *See id.* § 102.

230. *See id.* § 202(c)(2).

231. *See id.* § 202(c)(3).

world;"[232] (5) that the agency may require periodic reporting on utilization efforts;[233] (6) that the contractor must acknowledge that the invention was made with government support in its patent specifications;[234] (7) that for nonprofit organizations, among other things, (i) assignments of patent rights must be approved by the funding agency; (ii) the contractor must share royalties with the inventor; and (iii) licensing should, when feasible, be made to small businesses;[235] and (8) that the march-in rights of the government (§ 203) and exclusive licensing preference for U.S. industry (§ 204) be made express.[236]

The mandatory contractual provisions cabin researchers' discretion and direct their efforts toward technology transfer and commercialization. The disclosure requirement, strict deadlines for filing patent applications, and periodic reporting promote prompt dissemination of research results first to the agency and then through the patent system,[237] and facilitate governmental oversight and maintenance of its residual rights. Default provisions allowing the government to obtain title if the contractual obligations are not met create a strong incentive for contractors to be on the look-out for any patentable inventions and to be conscious of statutory bars. These factors not only keep contractors on their toes but also allow the government to monitor progress under the funding agreement and to exercise its residual rights, discussed below.

For nonprofit contractors, royalty provisions introduce profit incentives and spread controllable risks among the organization and the individual researchers.[238] Incentives are created for inventors to produce patentable innovations, to consider the commercial applicability of their inventions, to patent promptly, and to cooperate in the commercialization of their inventions. At the same time, incentives are created for organizations to reduce the

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232. *Id.* § 202(c)(4).

233. *See id.* § 202(c)(5).

234. *See id.* § 202(c)(6).

235. *See id.* § 202(c)(7).

236. *See id.* § 202(c)(8).

237. Whether dissemination in this manner is efficient is context dependent. The incentive to postpone publication or public presentation at conferences to avoid statutory bars occurs, but the effects are uncertain.

238. If controllable risks were inadequately allocated under the grant (between the government and contractor) or under employment contracts (between the organization and individual researcher), or if contractor-researcher participation in technology transfer and derivative research is necessary, then the royalty sharing provision may improve risk allocation. However, it is not clear that grants or employment contracts do not provide sufficient monitoring to alleviate controllable risks. The latter possibility is narrow and uncertain, and is discussed more fully below. *See infra* Part IV.C.2. Of course, grant funding removes the downside, uncontrollable risks, (*see supra* Part III.B) except to the extent that the contractor sinks costs, e.g., when the grant requires government funds to be matched.

internal administrative costs of applying for patents and to establish and develop industry relationships to facilitate commercialization.

Section 204 expressly prohibits the ability of contractor-patentees to use an exclusive license unless the licensee "agrees that any products embodying the subject invention or produced through the use of the subject invention will be manufactured substantially in the United States."[239] However, the agency may waive this prohibition if domestic manufacture is commercially infeasible.[240] The implications of this section are discussed infra Part IV.C.2.

2. Residual Government Rights

The government retains a discretionary authority to cabin the scope of rights extended to contractors under Bayh-Dole. Foremost among these is a paid-up license to practice (or have practiced) a patented invention. This allows the government to use innovations for the public interest and thereby avoid under-utilization, for example, when spillovers into public goods production occur. When this government authority is exercised, there is no need for an explicit transaction or for administrative or judicial review because it does not infringe upon contractor rights.

In addition to the default provisions that must be expressed in the funding agreement, the agency may include provisions that prohibit a contractor from retaining title if (1) the contractor is not located in or does not have a place of business in the United States or is under the control of a foreign government, (2) the agency determines that "restriction or elimination of the right to retain title to any subject invention will better promote the policy and objectives of this chapter," or (3) the project involves national security or a government-owned, contractor-operated facility of the Department of Energy dealing primarily with naval nuclear propulsion or weapons.[241] The inclusion of these limiting provisions is subject to an administrative appeals procedure and additionally to review "on the record" in the United States Court of Federal Claims.[242]

Additionally, the government retains rights that affect how a patentee licenses or assigns patent rights. These rights aim to control or minimize the social costs arising from the IP rights themselves, e.g., under-utilization. In certain statutorily delineated cases, the government may alter contractors' rights by (1) utilizing "march-in" rights under § 203,[243] (2) waiving the § 204

239. 35 U.S.C. § 204 (1994).
240. *See id.*
241. *Id.* § 202(a).
242. *Id.* §§ 202(b)(4), 203(2).
243. *Id.* § 203 (1994).

exclusive licensing preference for U.S. industry,[244] (3) retaining a right to assign foreign patent rights in subject inventions to meet international obligations,[245] and (4) requiring subject inventions to be licensed to specific third parties.[246] The march-in rights allow the government to require an entity[247] to issue an exclusive, nonexclusive, or partially exclusive license to use a subject invention to a "responsible applicant" upon reasonable terms and in any field of use.[248] If the entity refuses, the government may issue a license if it finds such action to be necessary (1) to promote "effective steps" be taken "to achieve practical application . . . in [a] field of use,"[249] (2) "to alleviate health or safety needs,"[250] (3) to satisfy regulatory obligations "for public use,"[251] or (4) to uphold domestic industry preferences of § 204.[252] Despite the seemingly broad sets of controls that the government has available, they are exercised at the agency's discretion and are subject to varying degrees of administrative and judicial review.[253] In practice, agencies have rarely (if ever) used these rights.

C. Institutional Analysis: IP-Enhanced Grant System

This subsection abstracts somewhat from the historical background and applies the framework developed in Parts I, II, and III to the institutional setting of grants and IP mixed together. The legal provisions discussed above are returned to in Part IV.C.2.

As explained in Part III, the economic justifications for granting IP rights differ from those for directly financing innovation projects, although each institution targets innovations that the naked market inefficiently supplies. IP rights create *ex ante* incentives to invest based on a "promised" reward *ex post*.[254] By design, they alleviate the appropriation risks associated with innovation projects, in effect creating an artificial lead time advantage for private firms that would otherwise bear production and market risks. As an institution, IP relies on the market mechanism to inform and motivate firm decision making as to the allocation of resources for research.

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244. *See id.* § 204.
245. *See id.* § 202(c)(4).
246. *See id.* § 202(f)(2).
247. The entity may be a contractor or their assignee or exclusive licensee.
248. *Id.* § 203(1).
249. *Id.* § 203(1)(a).
250. *Id.* § 203(1)(b).
251. *Id.* § 203(1)(c).
252. *See id.* § 203(1)(d).
253. *See id.* §§ 202(b)(4), 202(f)(2), 203(2).
254. Conversely, another way to look at the IP right is to say that the *ex post* reward is "consideration" that is contingent upon *ex ante* investment and success.

Government financing, on the other hand, is justified when directed at innovation projects that will be avoided by private firms because of consumptive market failure or innovative process market failures,[255] rather than exclusionary market failure. Funds are provided *ex ante* and are not contingent upon prospective success.[256] From an institutional perspective, the market mechanism is foregone in lieu of government selection. Grants cover the production costs by spreading risks across the general public and taking into account the social discount rate, i.e., the willingness to postpone benefits into the future.

1. Framing the Institutional Setting

Walking through the simple three-staged model—(1) *Ex Ante* Investment, (2) Research, (3) *ex post* utilization—for a few iterations demonstrates the complications that arise when mixing government funding and IP rights. Consider a basic research project for which the range of potential applications of a successful venture are expected to lead to commercializable benefits, i.e., private goods production. Assume that government investment is required to initiate the innovative process, and that the number of iterations through the three stages above is uncertain.[257] At the outset, the government allocates funds to the selected project based on its knowledge of the potential applications and the probable sources of market failure. A grant is the institutional mechanism of choice given the basic nature of the project. Research proceeds with some general governmental supervision although the grantee retains significant discretion over how the project develops.

Throughout the lifetime of the grant, a grantee will typically uncover numerous incremental innovations that affect the course of research.[258] In the absence of potential IP rewards, these incremental results may be disseminated (1) to the public generally through publication, demonstration, conferences, etc., when perceived by the grantee, funding agency, or peer community to be meritorious,[259] and (2) to the relevant industry through more directed

255. But remember that innovative process failures affecting private investment into commercial research may be corrected through tax incentives which retains the market as the production engine.

256. However, success may be a determinant that is considered when future funding is sought.

257. This assumption lies at the heart of innovative process market failure and seems plausible in many types of research projects. It leads to uncertain risk and uncertain time horizons and consequently to high transaction costs and inefficient investment.

258. In a more complicated model of R&D decision making, each of these incremental innovations "update" the project's application estimate and may initiate a new *ex ante* investment stage. However, this "internal cycling" of innovations can be contained in the research stage for the lifetime of the grant with some outputs leading to separate projects, which may be publicly or privately funded.

259. Reputation among the peer community is a primary incentive for dissemination by these means. Moreover, employment benefits, particularly at universities, are often dependent upon reputational

technology transfer, which may involve cooperative efforts in order to spur private investment.[260] Dissemination and technology transfer allow private firms to "take over" certain avenues of research that they deem worthwhile. Firms incorporate the research results into their application estimates and then decide whether to pursue derivative research which leads to commercialization.[261]

When the grant ends, the choice between private and public funding becomes an explicit policy choice in a new *ex ante* investment stage. The government must decide whether to continue funding the project or to abandon the results to the competitive innovation market. Additional public financing should only be made if the adjusted application estimate suggests that the persistence of consumptive or innovative process market failures will inhibit efficient private investment. For example: if there remains a sufficient likelihood of spillovers outside commercial applications; if the project remains too risky, either still requiring fixed capital investment beyond the capacity of private firms, or extending too far into the future; or if these considerations themselves remain sufficiently uncertain. Otherwise, the justification for public financing is lacking.

If the grantee is entitled to any patentable results, a number of changes occur to the grant scenario. First, the incentive to disseminate through the mechanisms under (1) above are tempered, if not overcome, by the incentive to postpone release until a patent application is filed.[262] The interaction of these incentives is dynamic and may result in a shifting of norms within the scientific research community. Second, technology transfer is coordinated through patent licensing around the interests of the grantee-patentee and licensee firms. Depending on what government interests motivated the initial grant funding, this may or may not be desirable. Assuming commercialization is the desired end,[263] and thus general government interests are being

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factors as evidenced, for example, by the number of publications in respected or peer-reviewed journals.

260. Creation of more applied research markets through procurement (or regulation) may also be used.

261. A firm's decision whether to invest occurs in a private *ex ante* investment stage.

262. The incentive to postpone arises in order to protect the grantee's ability to patent from statutory bars under 35 U.S.C. § 102. The Bayh-Dole Act may seem to counter these incentives somewhat through strict deadlines encouraging early application for patents, *(see supra* Part IV.B) but it does not do so fully because researchers will essentially cycle innovations in secrecy until enough of a leap is made to qualify for a patent. This is very similar to the actions of firms in the naked market or IP-enhanced market. *See supra* Parts II, III.A.

263. This assumption is commonly made but rarely justified in the technology policy debate. It is unclear why limited public funds are best spent on basic, commercial research. Nonetheless, as commercial applications become more certain during the course of research, the justifications for continued government funding weaken. This issue is not pursued strongly in this paper although it deserves attention, as suggested in the conclusions.

furthered, there remains a question of whether licensing-based technology transfer is necessary or efficient. Third, and relatedly, a blocking patents regime arises if derivative research by firms leads to patentable results. These final two effects are addressed below.

2. Justifications for Mixing Grants and IP

The primary justification proffered for modifying the grant system with IP is that IP facilitates exclusive licensing, which is deemed necessary to attract private investment in derivative research. The statutory provisions generally facilitate IP licensing and allow the grantee-patentee to enter into a wide range of agreements with investing firms. Essentially, exclusive or partially exclusive licenses supplement natural lead time, lessening misappropriation risks and effectively cooling down competition in derivative innovation markets. For the most part, development efforts are left to the discretion of the grantee-patentee, although subject to government monitoring, review, and possible intervention through its residual rights.

IP rights are not introduced into the grant system to create *ex ante* incentives to invest resources based on an *ex post* reward that is contingent upon success— the traditional institutional mechanism. Instead, they are used to promote technology transfer in two ways. First, IP rights give the grantee-patentee a prospective profit motive. This affects grantees' incentives during research; as intended, technology transfer and eventual commercialization are brought into immediate focus. To what extent profit motives affect the course of research itself and dissemination outside the patent system has yet to be determined, although some empirical research demonstrates an increased tendency to withhold publication, public presentation, or research results.[264] Second, IP licensing provides an *ex ante* reward to attract private investors to derivative research projects. An exclusive license gives firms a lead time advantage in the derivative innovation market.[265] Therefore, this *ex ante* reward is supplemental to the traditional *ex post* reward of IP rights in successful, derivative research that qualifies for an IP right. Is this supplemental reward necessary? If so, is the institutional setting itself socially efficient, in light of alternatives and in terms of the net costs and benefits to society?

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264. *Cf.* David Blumenthal et al., *Withholding Research Results in Academic Life Sciences: Evidence from a National Survey of Faculty*, 277(15) JAMA 1224 (1997) (finding delays in publication and dissemination of research results to be related to the commercialization of research and industry-university relationships), *cited in* Rai, *supra* note 122, at 51.

265. This suggests that dampened competition is needed for an efficient innovation market, which is clearly a debatable premise.

i. Necessary?

It is not readily apparent why an additional incentive is needed to encourage firms to invest in derivative research projects stemming from federally funded research that is patentable. As a starting point, assume a grantee discovers a patentable innovation with expected commercial applications that will require additional research. The situation is similar to that facing the government when it decides to continue funding a project when a grant ends (discussed above), although the sources of market failure are different (as seen below). If a sufficient likelihood of market failure in the derivative innovation market persists, private firms will under-invest and government intervention is justified.

Given the starting point of a patentable innovation, it seems unlikely that the classes of socially desirable, derivative innovations for which impediments exist are expansive. Moreover, the congruence between IP (or an exclusive license) and potential sources of market failure is unclear. Limited competition in the innovation market, resulting from an exclusive license, may lessen market response risks and perhaps misappropriation risks, but it will not lessen production risks or the risk of noncommercial spillovers. Nor will it hasten the innovative process or directly subsidize large capital investments. Certainly, it does not add information that reduces uncertainty as to any of these variables.

If the government were concerned with recouping its grant investments, then misappropriation risks might require enforced exclusion through IP. However, the government is generally not in the business of commercializing its research results;[266] it generally seeks to transfer technology to domestic, private firms and promote competition in order to get the resulting commercial products to the consumer at the lowest cost. Therefore, at first glance, it seems unlikely that the government will under-invest due to exclusionary market failure because the government is not a market actor.

a. Foreign Free-Riding

Although the government does not commercialize research results directly, misappropriation by foreign firms (or governments) may be a significant impediment to efficient technology transfer to domestic firms and

266. Recovering public investments from research investment in order to fill the coffers for other social programs is not entirely absurd, but it would likely involve significant transaction costs.

hence to public investment, perhaps justifying the use of IP to protect domestic public investments.

There are two ways in which the Bayh-Dole Act expressly addresses domestic concerns over misappropriation of federally- funded research results: the domestic industry preference (section 204) and the domestic contractor preference (section 202(a)). The former is mandatory in all funding agreements but waivable by an agency if domestic licensing is infeasible, the latter is exercised at the discretion of the agency and subject to review.

The domestic industry preference demonstrates congressional intent to prevent foreign firms from obtaining the *ex ante* reward created through an exclusive license, a privilege reserved for domestic firms. It implies a concern regarding foreign misappropriation that is manifested in a fear of foreign competition in applied commercial innovation markets.[267] In other words, these innovation markets may be too competitive for domestic industry because of foreign competition. The increased competition in commercial markets in the 1970s by Japan and Europe likely supported this view. Under this view, the technology transfer process in the absence of IP licensing will under-supply lead time for domestic industry in the race to innovate, thus requiring an exclusive license to create it. Moreover, because foreign firms are eligible for U.S. patent protection, foreign competition presumably affects patent races in a similar fashion as the more applied innovation markets,[268] collapsing the third source of market failure, discussed below, into this one.

The domestic contractor preference is rather straightforward; foreign contractors should not receive the benefits of an IP right covering U.S. funded research results. But why is this preference left to the discretion of the agency and subject to substantial review (and thus seemingly difficult to implement), while the domestic industry preference is mandatory (although it can be waived)? Most likely, the IP right is seen as a less lucrative reward given the residual rights of the government, while the exclusive license is considered more substantial and should therefore remain domestic.

Both of these statutory provisions rely on the U.S. patent system to prevent foreign misappropriation.[269] Their effectiveness depends significantly on the extraterritorial enforcement of domestic patent rights. Foreign firms

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267. There is no clear distinction here because imitation is a crucial element of competition.

268. Patent races take place within a derivative innovation market that, for the most part, is less applied than the market for unpatentable derivative innovations. However, the dynamic nature of the innovative process may lead to more basic application estimates for certain firms, depending on their private application estimates prior to inputting the patented innovation. Generally, patenting an innovation raises the risk of innovative process market failures while limiting the risk of foreign free-riding.

269. *See also* National Cooperative Research and Production Act of 1993, 15 U.S.C.A. § 4201 (1993), which allows courts to consider international competition as a factor in antitrust rule of reason analysis.

beyond the reach of this enforcement are still capable of obtaining information disclosed in patents or through other means and competing in derivative innovation markets and patent races.

b. Limited Technical Capacity Within Firms

A less obvious IPMF that may arise in the context of technology transfer is due to limited technical capacity within firms. Some theoretical and empirical research suggests that the grantee-innovator may be an essential participant in derivative research for any chance at successful commercialization.[270] If firms lack the technical capacity to move forward without sufficient involvement and effort by the grantee-innovator, then a licensing arrangement may be a necessary for aligning incentives to avoid moral hazard and adverse selection during technology transfer and derivative research.[271] Again, given the starting point of a patentable innovation, it seems unlikely that the class of derivative innovations for which success depends on grantee-innovator involvement is expansive. Presumably, the patent disclosure enables other researchers "skilled in the art" to practice the invention,[272] and therefore, enabling information could be transferred through other means. Except where a new "art" is created, there will typically be a sufficient number of skilled industry researchers that can carry the derivative research forward. An issue not considered here that may broaden the class of derivative innovations for which grantee-innovator involvement is necessary is whether the patent system is screening properly.[273]

Even where grantee involvement is necessary, using IP to facilitate licensing arrangements seems to be a rather blunt and costly approach, primarily because of reduced pre-patent dissemination, under-utilization of the patented invention, and potential blocking patent problems if derivative innovations are patentable. Grantee involvement may be facilitated more efficiently through contractual terms in the original grant, through cooperative

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270. *See* RICHARD JENSEN & MARIE THURSBY, PROOFS AND PROTOTYPES FOR SALE: THE TALE OF UNIVERSITY LICENSING, (National Bureau of Economic Research Working Paper No. 6698 at 2) (visited Oct. 30, 1999) <http://www.nber.org/papers/w6698>. ("While a licensee-firm must ultimately spend resources to commercialize products based on the invention, further development effort by the inventor is required for *any chance* of commercial success.")

271. *See id.* (discussing the need for an "output-based" payment, e.g., a royalty, in licensing arrangements in order to overcome moral hazard problems).

272. In a sense this obviates adverse selection. However, there is bound to be additional, valuable information held by the grantee that arises during the course of research but is not in the patent claims or specifications. Involving the grantee in subsequent research efforts clearly brings this information to the table.

273. *Cf.* JENSEN & THURSBY, *supra* note 269, at 1-2 (discussing university licensing of "proof of concept" and less applied inventions; discussing moral hazard).

agreements between the government and industry, and perhaps even through a temporary employee loan where the grantee is seconded to the firm.[274]

c. Derivative Innovation Markets That Are Too Competitive

A careful look at how granting an IP right to the grantee attracts private investors returns the analysis to misappropriation risks and reveals an additional, narrow class of innovations for which an *ex ante* reward might be needed. The primary reward that firms receive through an exclusive license (and the resulting lead time advantage in the derivative innovation market) is an enhanced lead time advantage in eventual product markets or in the race for derivative IP rights. In the "race to innovate," firms working under an exclusive license have a tremendous head start. Thus, an exclusive license may be necessary to encourage firms to invest in derivative research when technology transfer is stifled because the derivative innovation market is too competitive.

It is difficult to fashion a rational justification for using an exclusive license (as a policy tool) to cool down competition in the race for derivative IP rights and thereby attract private investors.[275] The patent race is generally seen as a source of social waste because of duplicative efforts rather than deterred investment.[276] The prize at the end of the race, i.e., the patent, is sufficient to attract investors.

However, in the race for innovations that fall short of patentable criteria or for which qualification is merely uncertain, the perceived prize is natural lead time. It may be that misappropriation risks deter private investment where IP rights are unexpected and natural lead time is too short, perhaps because all firms are beginning at the same point with publicly disseminated information and without secrecy. However, for patented research generated at universities, most of the licenses between university researchers and industry involve "proof of concept" results or similar basic research.[277] It seems that while justified to encourage derivative research that is unlikely to produce patentable results, grantee licensing in practice involves a much broader class of innovations.

In sum, there are three possible sources of innovation market failure, namely foreign misappropriation, inadequate technical capacity in firms (and

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274. CRADAs can involve this type of arrangement.

275. Except, of course, where risks of foreign misappropriation deter domestic investors, discussed *supra* Part IV.C.2.i.a.

276. *See generally* Scotchmer, *supra* note 89.

277. JENSEN & THURSBY, *supra* note 269, at 2 (discussing university licensing of "proof of concept" and less applied inventions).

the resulting need for grantee involvement in technology transfer and subsequent R&D), and misappropriation in derivative innovations markets. These sources may hamper efficient technology transfer from government-funded researchers to industry and therefore justify some form of corrective mechanism.

ii. Socially Efficient?

If exclusive licensing through the IP right does improve private investment into certain narrow classes of socially desirable research, the associated social benefits must be weighed against the costs of granting an IP right and compared with alternative mechanisms. The framework developed in the Introduction and Part I and the analysis in this subsection provide guidance for efficiency analysis, although a detailed explanation along these lines is left for future work.

Overall, Bayh-Dole relies heavily on the effectiveness of the IP institution (and the underlying market mechanism) for correcting exclusionary market failure and promoting efficient downstream coordination of research efforts. The primary impetus justifying continued government intervention in the innovative process after grant funding is the risk of foreign free-riding. This concern generally arises for innovation projects with application estimates concentrated at the private goods end of the spectrum where the justification for direct government financing is limited to innovative process market failures.[278] Public investments in innovation aimed at stimulating private investment run into misappropriation risks much like those faced by firms in the naked market. Of course, the benefits of using IP to protect against foreign misappropriation are limited by the reach of domestic IP enforcement.

The need for grantee-patentee involvement in subsequent research efforts is plausible for a narrow class of innovations, but incurring the social costs of IP seems to be unnecessary when compared with alternative mechanisms such as cooperative research relationships and secondment of personnel. Moreover, where a personal stake in downstream outcomes is necessary to alleviate moral hazard, it may be possible to shift the reputational and traditional norms of the research community to recognize technology transfer and downstream success as a measure of professional success without introducing profit motives through the IP institution.

278. However, government research aimed at supplying a public good may also give rise to foreign misappropriation risks, e.g., national defense.

Bayh-Dole was explicitly targeted at facilitating technology transfer by enabling grantees to obtain patents and issue exclusive licenses to firms. As discussed above, this implies that the derivative innovation market is too competitive and that a lead time advantage is necessary to encourage firms to continue the research. However, this implication is only valid for derivative research that is expected to produce unpatentable innovations for which natural lead time is inadequate to secure a satisfactory return. For this narrow class of innovations, IP seems to be a rather blunt and costly instrument that rewards both grantees and licensees more than necessary at the public's expense.[279] Again, cooperative research, perhaps at earlier stages to develop privately held expertise, and/or secondment of personnel seem to be preferable alternatives.

Bayh-Dole seeks to limit the social costs of IP, particularly where spillovers into public goods production are present. However, the deadweight social costs of IP remain intact–pre-patent under-dissemination and post-patent under-utilization persist; therefore, blocking patents regimes may arise. Weighing the costs and benefits of Bayh-Dole is a tremendous task that depends significantly on empirical research of, *inter alia*, the actual rates of foreign misappropriation of federally-funded research (not simply foreign competition) and a counterfactual measure of deadweight costs from under-utilization. Preliminary theoretical analysis has indicated serious doubts as to whether the Act is likely to be efficient and whether the justifications for uniformly introducing IP into the grant system are valid.

The IP institution modifies the grant system in a more complex (and perhaps more costly) manner than it modifies the naked market. Simply compare *a priori* the grant system with the naked market and then their IP-enhanced counterparts. For example, consider the modification of researchers' incentives.[280] When the opportunity to secure IP rights in research results is made available to the grantee, there are two significant incentive-based changes in the grant system. First, the discretionary control over the project exercised by the grantee becomes more worrisome. The researcher now has a direct financial interest tied to the outcome of the project. Under the grant regime, the production risks were borne by the government and the discount rate reflected society's willingness to invest for the long term, but when modified with IP, the regime shifts such that private risk preferences and discount rates subtly affect the course of research. Despite the possible tempering effect of research community norms,[281] the

279. The "public pays twice" through taxes supporting the research and then through higher prices as a result of the IP royalties and exclusive license. *See* Eisenberg, *supra* note 2, at 1666.

280. *But see* Rai, *supra* note 122 (discussing tempering influence of scientific community norms).

281. *See id.* These norms may change with time as will likely be the case when profit incentives

definition of "successful research" embodies imported commercial interests that were previously outside the scope of researchers' employment.[282] Second, dissemination to the public is likely constrained to the IP mechanism because of fears of misappropriation, statutory bars, etc., and the statutory provisions that reinforce these fears. Researchers' incentives to publish are tempered by incentives to patent.

A more efficient corrective mechanism that would avoid the social costs of IP entails direct technology transfer through cooperative efforts between government and industry and selective tax incentives used specifically to promote derivative research efforts springing from government-funded research. Cooperative research builds project-specific technical capacity within firms and thereby supplies them with a private lead time advantage. Although these programs abound in the federal government, they have not displaced Bayh-Dole or the "first dibs" rights of government-funded researchers. Tax incentives tied directly to development of government research also benefit domestic firms by reducing production costs and offsetting misappropriation (or other) risks. Moreover, they would limit the social costs to dollars spent on derivative research (plus administrative costs).

Foreign misappropriation remains the sole issue for which mixing IP with the grant system may be economically justified. IP may be necessary to prevent foreign firms and governments from misappropriating federally-funded research results. Empirical research should be directed at this issue to explore the extent to which foreign competition in derivative innovation markets arising from federally-funded research exists.

CONCLUSIONS

The intellectual foundations upon which current U.S. science and technology policy is based are in need of significant reform. Innovation theory must integrate an understanding of public goods, decision-making performed under uncertain terms, and the dynamic nature of the innovative process. The model of innovation developed in this paper is a step in this direction. Moreover, the path towards comparative institutional analysis and coordination of science and technology policy has been laid.

Although some might argue that the linear model is a sufficient approximation to guide science and technology policy, this paper

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are introduced where they had not been before.

282. The innovation project under the grant system may have been concentrated on commercial innovations, but the upside and downside risks were borne by the government, and pre-Bayh-Dole, researchers were insulated from these risks while exercising their discretion.

demonstrates some of the problems that arise with its use. In particular, it is simply not enough to say that the government should fund basic research up to some point, at which firms may pursue more applied projects, because firms will not fund basic research. The government must choose between basic research projects to fund because of limited resources and, at the same time, must fund various applied projects that serve public goods ends. Similarly, firms choose between a range of basic to applied projects based on the returns they expect to appropriate over time. The justifications for government funding of basic commercial research are not sufficiently spelled out under the linear model. In addition, the linear model gives the government no direction as to how it should subsidize basic commercial research.

Under the linear model, it is unclear at what point government funding of basic research should give way to private investment. The Bayh-Dole Act draws the exit point at a patentable innovation. In other words, the government funds basic research to the point that a patentable result is churned out; subsequent research investment is then left to the private sector. Even within the linear framework, this depiction seems flawed. The promise of a patent is presumably sufficient to induce private investment. Therefore, the exit point could be earlier in the course of research and the government seems to be over-investing. Yet, the linear model frames the problem poorly because it does not distinguish between classes of research or illuminate the types of market failure that may inhibit technology transfer. As seen in the last Part, there may be problems that arise during technology transfer that present viable reasons for using IP in the grant system. Empirical research into foreign misappropriation is needed to evaluate this justification.

For want of an omniscient social planner, society must rely on both public and private decision makers to evaluate research projects and allocate limited resources. Government institutions are mechanisms through which allocation decisions are influenced. The traditional innovation model provides no guidance on institutional comparison. Comparing institutions and evaluating mixed institutional settings begins with the recognition that institutions (ought to) correct market failures that arise because of the public goods nature of innovation and the dynamic nature of the innovative process, and that the choice between market-based and government-based institutions turns, for the most part, on which operative decision maker is best suited (e.g., possesses better information, skills, and incentive structures). This choice also determines the degree of government intervention.

The intellectual property system and tax incentives involve less government intervention in the innovation market than direct subsidization. They are indirect subsidies given to private actors. The government uses IP and tax incentives to attract private resources into a class of commercial research that satisfies (or is likely to satisfy) the qualification criteria it sets.

This cabins private firms' discretion, yet sufficient latitude is left for firms to operate and use their superior information, skills, etc. The government and firms share the production costs of the research giving the firm an incentive to use its private information and allowing the government to funnel private resources toward (what it perceives to be) socially desirable investment.

Tax incentives may be an under-utilized tool in the area of commercial research that the government wishes to encourage, for example, in derivative R&D resulting from government-funded research. If qualification criteria are appropriately drafted into the tax law, the government can correct market failures that it perceives without completely subsuming the decision making function. For example, in the Bayh-Dole regime, tax incentives may be a more appropriate form of subsidy than intellectual property. A tax credit could be extended to domestic firms engaging in derivative R&D springing from government technology transfer. In this fashion, tax incentives would avoid the distorting effects on grantees' incentives as well as the traditional deadweight losses attributable to the IP right.

It may be that government funding of commercial research is the result of entrenched interest groups. Although the public choice aspect of government decision making is beyond the scope of this paper, it seems that one reason the linear model persists despite its fallacies might be political. Government funding of commercial research is a subsidy, a transfer of wealth from the general public to researchers. The argument that the government should fund basic commercial research because firms will not out of fear of misappropriation should be viewed with some suspicion. Generally, industry is best situated to determine the attractiveness of commercial research, yet the government is expected to choose amongst the basic commercial projects presented to it, presumably by private firms. In the absence of government subsidy, joint research ventures between private entities are likely to arise if the research is attractive enough. On one hand, the government may fund a project that would otherwise go forward, resulting in an unnecessary wealth transfer. On the other hand, the government may select a project that should not go forward, resulting in economic waste. Still, in other cases, there may be a valid justification for government intervention. Without a doubt, the public does benefit substantially from some government-funded commercial research, but not all, and at what cost is unknown. Evaluation of science and technology policy and comparison and coordination of institutions must take into account the public choice dimensions of government decision making.

A number of additional issues were avoided or glossed over in this paper for expositional reasons. A significant number of other institutions affect science and technology policy, including antitrust law, international trade, and environmental regulation to name a few. A comprehensive framework must integrate these institutions for consideration. Also, a narrow subset of the

Bayh-Dole regime within which the framework developed can be applied more concretely is the university setting. Introducing profit incentives into the university context may affect academic community norms over time. Some empirical economic research has focused on university research and might serve as a basis for testing the effectiveness of Bayh-Dole.[283]

It is undisputed that innovation profoundly affects the economy and public welfare, yet the significance of the current "mix" of federal institutions, particularly in antitrust law, intellectual property law, international trade law, and government finance (appropriation, procurement, and subsidization), on the promotion and production of innovation is only beginning to be understood. Despite an abundance of economic and legal literature on innovation within a variety of fields, there does not seem to be a coherent interdisciplinary treatment of the issues. Integrating the disparate treatments of innovation theory within different fields is crucial to a systematic coordination of science and technology policy. The framework developed in this paper has laid some of these foundations.

283. *See generally* REBECCA HENDERSON ET AL., UNIVERSITIES AS A SOURCE OF COMMERCIAL TECHNOLOGY: A DETAILED ANALYSIS OF UNIVERSITY PATENTING *1965-1988*, (National Bureau of Economic Research Working Paper No. 5068) (visited Oct. 30, 1999) <http://www.nber.org/papers/w5068.pdf.>. *See also* JENSEN & THURSBY, *supra* note 269, at 1 (exploring changes in university patenting behavior between 1965 and 1988).