2016

THE INTERCONNECTIONS BETWEEN ENTREPRENEURSHIP, SCIENCE, AND THE PATENT SYSTEM

Amy L. Landers

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I. INTRODUCTION

Economic growth in the United States rests on our collective ability to innovate. Such activity creates growth and employment, and provides solutions to our most significant problems.[1] Innovation is particularly critical at this time, given that the nation's recovery from the most recent financial crisis is not assured. Further, budgetary pressures weaken the government's ability to sustain robust levels of funding for scientific research. Additionally, recent data demonstrate that federal funding for research has been decreasing.[2] The National Science Board warns that the United States' "predominance in science and technology . . . [has] eroded further during the last decade."[3]

Added to these circumstances is a comparatively recent trend in patent law that is the subject of this Article. Specifically, this series of changes imposes higher substantive burdens on the ability to obtain patents. Yet this trend, when examined from a multidimensional perspective, has the potential to have a positive impact on innovation and the creation of new knowledge.

Some patent stakeholders have expressed concern that more stringent patentability standards may stymie our technological future. As one source states, now "the validity of thousands of heretofore valuable patents is in question," and "industries are confronted with uncertainty that only serves to dampen the substantial investments needed to develop new technologies."[4] It has been asserted that "many inventions are improperly being denied protection and there is significant uncertainty among patentees and patent applicants as to the breadth of the judicially

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1 *See* Fred Block, *Innovation and the Invisible Hand of the Government*, *in* STATE OF INNOVATION 1, 1–3 (Fred Block and Matthew R. Keller eds., 2011).

2 NAT'L SCI. BD., NAT'L SCI. FOUND., SCIENCE AND ENGINEERING INDICATORS 2014, at 4-11 (2014), http://www.nsf.gov/statistics/seind14/content/etc/nsb1401.pdf [https://perma.cc/5HX6-8PSC].

3 Press Release, Nat'l Sci. Bd., U.S. Lead in Science and Technology Shrinking (Feb. 6, 2014), http://www.nsf.gov/nsb/news/news_summ.jsp?cntn_id=130380 [https://perma.cc/N5JM-9GJH].

4 LAW360, WHERE DO WE STAND ONE YEAR AFTER ALICE (2015), https://www.crowell.com/files/20150617-Where-Do-We-Stand-One-Year-After-Alice-Klapow.pdf [https://perma.cc/U5K6-579X] (quoting David L. Suter); *see also id.* ("The idea that the government can go backwards and destroy such tremendous value with one court opinion will likely have even farther reaching and chilling implications on innovation in general." (quoting Jaime A. Siegel)).

created exclusions from patent eligibility."[5] Perhaps for the first time, there are high-profile invalidations of patents in the medical sector. According to one patent jurist, it is "said that a crisis of patent law and medical innovation may be upon us, and there seems to be some truth in that concern."[6] According to another source, this trend presents a "dark cloud overshadowing thousands of issued and maintained biotechnology patents," which "affect[s] future investment decisions."[7]

To some degree, these criticisms appear to rest on a fictitious separation between foundational science, patents, and innovation.[8] This view assumes that there is a sequential path that begins with raw informational material that subsequently leads to the creation of patentable solutions through the application of human ingenuity.[9] In turn, useful solutions that earn patent protection are positioned to attract financial capital that can be used to transform the invention into an innovative solution.[10] This so-called *linear model of innovation* places patent law as a central but-for connection between basic science and innovation.[11]

Certainly, the linear rubric appears to accurately represent the path to creation for certain types of research. This construct has other advantages. It is theoretically consistent with the stated goals of patent law and much of its doctrine. Yet it is not clear that this model has a universal foundation in fact. Rather, the interaction between science, patents and innovation is complicated, nuanced, and chaotic. The linear model fails to account for the complexity presented by entrepreneurial activity created by spillovers or the fact that companies approach research in a multitude of ways. Reliance on the model obscures important aspects of knowledge creation and overemphasizes the importance of others. Stated simply, these elements do not push on each other in the ways that the linear model contemplates.[12]

This recent restrictive trend in patent law has the potential to maximize available information for entrepreneurship. By contracting patent law's breadth, innovation has free reign to expand without the burden of licensing fees and the threat of litigation, together with its attendant high transaction costs. Creating the

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[5] Brief of Intellectual Prop. Owners Ass'n as Amicus Curiae Supporting Appellants and in Favor of Rehearing En Banc at 7, Ariosa Diagnostics, Inc. v. Sequenom, Inc., 809 F.3d 1282 (Fed. Cir. 2015) (per curiam) (en banc) (Nos. 2014-1139, 2014-1144).

[6] *Ariosa Diagnostics*, 809 F.3d at 1285 (Lourie, J., concurring) (denying a petition for rehearing en banc).

[7] Brief for the Biotechnology Indus. Org. (BIO) & Pharm. Research & Mfrs. of Am. (PhRMA) as Amici Curiae Supporting Appellants and in Favor of En Banc Reconsideration at 3, *Ariosa Diagnostics*, 809 F.3d 1282 (Nos. 2014-1139, 2014-1144).

[8] *See* DONALD E. STOKES, PASTEUR'S QUADRANT: BASIC SCIENCE AND TECHNOLOGICAL INNOVATION 10 (1997).

[9] *See id.* at 10–11.

[10] *See id.*

[11] *See infra* Part IV.

[12] For some examples of research that sheds doubt on the linear model, see Stephen J. Kline & Nathan Rosenberg, *An Overview of Innovation*, *in* THE POSITIVE SUM STRATEGY: HARNESSING TECHNOLOGY FOR ECONOMIC GROWTH 275, 275 (Ralph Landau & Nathan Rosenberg eds., 1986); STOKES, *supra* note 8, at 12–14.

possibility of permissionless innovation can, in turn, focus innovators on solving problems in a manner that leads to more research, rather than less. Stated another way, maximizing the free availability of spillover knowledge fosters entrepreneurship, which in turn facilitates innovation.

There are erroneous aspects of the linear model that must be unwound to fully assess the impact of these recent shifts in patent law. For example, the model draws an artificial distinction between fundamental and applied research despite the fact that in significant cases those activities merge. Moreover, under some circumstances, innovation drives research rather than the other way around. In other words, the linear model simply does not comport with reality and therefore does not justify the full brunt of these pessimistic fears about the future of research.

The recognition that innovation drives the creation of new knowledge is both significant and an underappreciated aspect of patent theory. A full assessment of the impact of this most recent trend in patent law cannot be performed without examining the relationships between science, the patent system, and innovation within a more realistic context. To do so, the system must loosen its hold on the linear model. More broadly, these insights allow us to think about the patent system in ways that do not echo the traditional narrative that places science and innovation at the opposite ends of a continuum. As a practical matter, this more realistic framework suggests that recent shifts in patent law can do much to foster entrepreneurial creativity. The innovation that flows from this work can, in turn, operate in ways that can ultimately drive more scientific inquiry.

II. THE CURRENT CLIMATE: CONCERNS ABOUT THE PACE OF SCIENTIFIC PROGRESS

In the recent past, patent law has promulgated increasingly demanding standards to obtain the right to exclude. These have the impact of narrowing protection or rendering it unobtainable for a greater share of newly generated information.

As some examples, the most recent definiteness standard requires that patentees articulate claims with greater precision.[13] This pushes applicants to commit to clearer boundaries, which typically result in narrower claims. Courts have more rigorously applied the enablement standard to provide sufficient essential information to enable the full claim scope.[14] Together, these standards tend to discourage vague claim boundaries that can lead to overreaching by rights holders. Most recently, the utility doctrine has been implemented to ensure that a patentee does not obtain protection for information in the research phase.[15] Additionally, the written description requirement has been empowered to exclude protection for pure

[13] *See* Nautilus, Inc. v. Biosig Instruments, Inc., 134 S. Ct. 2120, 2129 (2014).

[14] *See, e.g.*, MagSil Corp. v. Hitachi Glob. Storage Techs., Inc., 687 F.3d 1377, 1381–82 (Fed. Cir. 2012).

[15] *In re* 318 Patent Infringement Litig., 583 F.3d 1317, 1323–24 (Fed. Cir. 2009).

scientific research "by giving the incentive to actual invention and not 'attempt[s] to preempt the future before it has arrived.'"[16] As the Federal Circuit has recognized in this context, "claims to research plans . . . impose costs on downstream research, discouraging later invention."[17] As a consequence, patentees must disclose and claim their inventions in ways that focus most sharply on practical, defined implementations. This has the effect of permitting information that does not fit into this category to fall into the public domain.

Newly developed procedures in the U.S Patent & Trademark Office ("USPTO") have enhanced the opportunity to invalidate erroneously issued claims, which effectively raises the bar for issued patents. Specifically, in 2011, Congress passed legislation that expanded procedures to facilitate post-grant challenges for patents. This legislation has created a process that has been criticized because the agency implementing the program has been accused of being "too quick to toss out patents that demonstrate only modest innovation."[18] Although early assessments of these procedures are premature, an early report suggests that this increased scrutiny has resulted in more claim invalidations.[19]

The most significant shift occurred in the patentable subject matter requirement. A series of U.S. Supreme Court cases, *Alice Corp. v. CLS Bank*,[20] *Mayo v. Prometheus*,[21] *Ass'n for Molecular Pathology v. Myriad Genetics*,[22] and *Bilksi v. Kappos*,[23] appreciably expanded the exceptions to patentable subject matter.[24]

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[16] Ariad Pharm., Inc. v. Eli Lilly & Co., 598 F.3d 1336, 1353 (Fed. Cir. 2010) (alteration in original) (quoting Fiers v. Revel, 984 F.2d 1164, 1171 (Fed. Cir. 1993)).

[17] *Id.*

[18] Ashby Jones, *A New Weapon in Corporate Patent Wars*, WALL STREET J. (Mar. 10, 2014, 7:25 PM) (on file with the Utah Law Review), http://www.wsj.com/articles/SB10001424052702304020104579431393308282698 (attributing the statement to former Federal Circuit Chief Judge Randall Radar (ret.)).

[19] Brian J. Love & Shawn Ambwani, *Inter Partes Review: An Early Look at the Numbers*, 81 U. CHI. L. REV. DIALOGUE 93, 94 (2014); *see also* U.S. PATENT & TRADEMARK OFFICE, TRIAL AND APPEAL BOARD STATISTICS 13 (2015), http://www.uspto.gov/sites/default/files/documents/2015-10-31%20PTAB.pdf [https://perma.cc/SD2U-UHAV] (concluding that 1,369 claims had been found invalid under the inter partes review procedure).

[20] 134 S. Ct. 2347 (2014).

[21] 132 S. Ct. 1289 (2012).

[22] 133 S. Ct. 2107 (2013).

[23] 561 U.S. 593 (2010).

[24] *See, e.g.*, *Alice Corp. Pty. Ltd.*, 134 S. Ct. at 2352 (holding that "generic computer implementation" constituted an abstract idea); *Ass'n for Molecular Pathology*, 133 S. Ct. at 2120 (holding that "genes and the information they encode" are not patentable because they are "isolated from the surrounding genetic material"); *Bilski*, 561 U.S. at 604 (discussing the patentability of a business concept for "hedging risk"). In *Myriad*, the Court used an alternative form of reasoning to analyze the products of nature exclusion. Emphasizing the substance's artificial origin, the Court rejected the argument that any inventive activity was necessary for the cDNA to be protected. *Myriad*, 133 S.Ct. at 2117–19.

Today, the Supreme Court requires that the patentee claim an "'inventive concept'—i.e, an element or combination of elements that is 'sufficient to ensure that the patent in practice amounts to significantly more than a patent upon the [ineligible concept] itself.'"[25] This step is targeted to ensure that downstream innovators have a maximized capability to perform the work necessary to create innovative solutions unencumbered by broad patent claims to fundamental principles and scientific information. In other words, knowledge that is not a clearly crystallized inventive solution cannot be patented under the most recent standards.

According to some, the Supreme Court's newly restrictive law of patentable subject matter has created "a quagmire."[26] In an article titled *Nothing Is Patentable*, one scholar asserts "there can be no question that patents are now being aggressively tested and that the penumbra around pure abstract ideas and natural phenomena is growing larger."[27] One patent attorney reports that "the courts invalidated more patents in the 14 months since *Alice*, [than] they did in the five *years* previous to *Alice*."[28] It is inescapable that *Alice*, *Mayo*, *Myriad*, and *Bilksi* impose a more demanding patentable subject matter standard. Information that was historically

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[25] *Alice Corp. Pty. Ltd.*, 134 S.Ct. at 2355 (alteration in original) (quoting *Mayo Collaborative Servs.*, 132 S. Ct. at 1294); *see also Bilski*, 561 U.S. at 606 ("With ever more people trying to innovate and thus seeking patent protections for their inventions, the patent law faces a great challenge in striking the balance between protecting inventors and not granting monopolies over procedures that others would discover by independent, creative application of general principles.").

[26] John M. Golden, *Flook Says One Thing, Diehr Says Another: A Need for Housecleaning in the Law of Patentable Subject Matter*, 82 GEO. WASH. L. REV. 1765, 1776 (2014); Jeffrey A. Lefstin, *The Three Faces of Prometheus: A Post-Alice Jurisprudence of Abstractions*, 16 N.C. J.L. & TECH. 647, 657 n.45, 658–59 (2015) (concluding that in Alice, "the Court has endorsed a framework for patent-eligibility quite different from the frameworks suggested in its earlier cases.").

[27] Michael Risch, *Nothing Is Patentable*, 67 FLA. L. REV. F. 45, 51 (2015).

[28] Robert R. Sachs, *#AliceStorm: The Summertime Blues Continue*, FENWICK & WEST (Aug. 29 2015), http://www.bilskiblog.com/blog/2015/08/alicestorm-summertime-blues-continue.html [https://perma.cc/6EP9-Q4G3]; *see also* Steven Callahan, *Alice: The Death of Software-Related Patents?*, CCRG (May 1, 2015), http://www.ndtexblog.com/?p=3550 [https://perma.cc/UG88-2CNF] (discussing software patents after *Alice*). It is plausible that the sheer numbers of these invalidations will decrease as patent prosecutors, the courts, and the United States Patent and Trademark Office adjust their standards to fit these recent shifts in standards. Moreover, some contrary data points exist that suggest that the change is less draconian than portrayed. For example, one source reports that certain companies have actually experienced an *increase* in patent approvals after the *Alice* decision was issued. Maulin Shah, *Software Patents Are Resilient in the Wake of Alice Corp. vs. CLS Bank*, PATENT VUE (Sept. 9, 2015, 8:30 PM), http://patentvue.com/2015/09/09/software-patents-are-resilient-in-the-wake-of-alice-corp-vs-cls-bank/ [https://perma.cc/7VVA-REYZ]. Another observes that the patent market is healthy as well, including in the software sector. Kent Richardson et al., *The 2015 Brokered Patent Market: A Good Year to Be a Buyer*, IPWATCHDOG (Feb. 8, 2016) (on file with the Utah Law Review), http://www.ipwatchdog.com/2016/02/08/2015-brokered-patent-market/id=65747/.

considered inventive under the former standard is now considered unpatentable under the newer standard. As a result, numerous types of claims that would have been deemed valid and enforceable no longer are. The areas that are the most heavily impacted relate to the foundational science and technology. The ability to seek protection for the so-called "building blocks"—that is, ideas, characteristics, and principles—has been curtailed.

One illustrative case is *Ariosa Diagnostics, Inc. v. Sequenom, Inc.*,[29] a controversial Federal Circuit decision that considered the validity of a method claim directed to a noninvasive procedure to test fetal DNA for abnormalities.[30] The *Ariosa* panel found the invention was a "significant contribution to the medical field" and noted that the research had been cited by a leading medical journal over one thousand times.[31] Yet the claim was rejected as unpatentable. Judge Lourie, concurring in the denial to rehear the case en banc, observed that the method claims described "physical, and not insignificant, steps requiring human intervention," underscoring that "[t]here is nothing abstract about performing actual physical steps on a physical material."[32] Nonetheless, the claims were rejected as "abstract" as the most recent wave of Supreme Court cases use that term.[33]

The change has provoked concern that the Supreme Court has visited "disruption" on the course of innovation, and that tighter patentability standards will cause entities to underinvest in basic research.[34] Now that the higher standard controls, there are questions about information within a new zone of unprotectability—in other words, might such information never have been created absent the promise of a patent? Would Myriad as an entity have elected to commercialize its breast cancer genetic test had the company known of the results of the Supreme Court's future ruling in the *Myriad* case? Under that scenario, would the company Myriad exist at all?

As two scholars point out, the recent patentable subject matter jurisprudence "is wholly isolated from the ultimate audience—the inventing community—to a degree unmatched by other areas of patent law. This separation is cause for concern for the impact it could have on patent law's incentives."[35] Although some of these concerns are unquestionably valid, it is more accurate to say that incumbents are not

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[29] 788 F.3d 1371 (Fed. Cir. 2015).

[30] *Id.* at 1373, 1376.

[31] *Id.* at 1379.

[32] Ariosa Diagnostics, Inc. v. Sequenom, Inc., 809 F.3d 1282, 1286–87 (Fed. Cir. 2015) (Lourie, J., concurring) (per curiam) (en banc) (concurring in the denial of the petition for rehearing).

[33] *Id.* at 1284.

[34] *See* Kevin E. Noonan, *Federal Circuit Denies Rehearing En Banc in* Ariosa v. Sequenom, PATENT DOCS (Dec. 2, 2015, 11:59 PM), http://www.patentdocs.org/2015/12/federal-circuit-denies-rehearing-en-banc-in-ariosa-v-sequenom.html [https://perma.cc/6U9M-XLUG].

[35] Timothy R. Holbrook & Mark D. Janis, *Patent-Eligible Processes: An Audience Perspective*, 17 VAND. J. ENT. & TECH. L. 349, 383 (2015).

the intended beneficiaries for the Court's recent decisions. Rather, these holdings create open space for newcomers who might wish to innovate without confronting a plethora of patents granted under the former, more lax, standards. Further, more total information—particularly that which might be considered foundational—now becomes part of the public domain.

Entrepreneurship is currently viewed as a critical economic driver. As one source summarizes, "[t]he creation and growth of new companies, as well as the closure and shrinkage of existing companies, are at the heart of 'economic dynamism.' Many of the statistics tracked closely by economists, policymakers, investors, and others—such as unemployment, wage growth, and productivity—are driven by entrepreneurial activity." [36] Restraining patentees from protecting information means that, to the extent that such information is not a trade secret, it is available as raw material for entrepreneurial insights. Whether or not acting with intention, this most recent Supreme Court trend appears to favor new entities that are seeking to innovate with minimal interference from broad or vague claims owned by incumbents.

As will be explored later in this Article, to the extent that this trend continues, innovation can, in turn, motivate science in ways that our traditional theories of the progression of knowledge creation do not contemplate. This open space can create public benefits in the form of new products, new technologies, and ultimately investment in new research into fundamental knowledge. In order to view these as likely outcomes, one must consider some emerging perspectives on the interaction between science, the patent system, and innovation. When coupled with the dynamics of entrepreneurship, this trend in patent law may, in fact, have a positive overall impact.

III. INVENTION, SPILLOVERS, AND ENTREPRENEURSHIP

As two well-known legal scholars assert, "[t]here is virtually unanimous agreement that the purpose of the patent system is to promote innovation by granting exclusive rights to encourage invention."[37] This sentiment is echoed in a recent White House Report, which states that a patent "provides a powerful incentive for innovation."[38]

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[36] Dane Stangler, *Foreword*, *in* ROBERT W. FAIRLIE ET AL., THE KAUFFMAN INDEX: STARTUP ACTIVITY NATIONAL TRENDS 3 (2015).

[37] Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1580 (2003). *But see* Gregory N. Mandel, *Proxy Signals: Capturing Private Information for Public Benefit*, 90 WASH. U. L. REV. 1, 10–11 (2012) ("While maximizing innovation by optimizing incentives is not precisely the same as maximizing the social welfare from innovation, it is a commonly used surrogate and sufficient for our purposes at this point.").

[38] EXEC. OFFICE OF THE PRESIDENT, PATENT ASSERTION AND U.S. INNOVATION 2 (2013), https://www.whitehouse.gov/sites/default/files/docs/patent_report.pdf [https://perma.cc/SFN8-UMQM].

These statements do not answer the question of precisely *how* the patent system interacts with innovation. Generally, intellectual property theory considers that patents protect some forms of newly created knowledge. Of those inventions that are patented, a subset becomes commercialized into innovations. Essentially, the law considers innovation a subset of invention.[39]

In contrast, economists define invention as a subset of innovation. For example, one definition considers innovation as the means to create a commercialized product, although not one that is dependent on the existence of an invention, specifically: "the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace."[40] This "newness" is not necessarily the same as the patent law's concept of "inventive." As Schumpeter recognized, innovations "need not necessarily be any inventions at all."[41] Economists consider innovation to include new ways of conducting business, marketing approaches, organizational structures, facilitating previously unexplored modes of communication, and solving social problems. In other words, economists do not rest their definition of innovation on patent law's limited and changing standard of patentable subject matter, novelty, and nonobviousness.[42] One example of an innovation that an economist might view as innovative, but an intellectual property specialist would not, is RC Cola's innovation to package soda in cans.[43] Another is Singer Sewing Machine's creation of consumer installment credit payment plans.[44]

The ability to see innovation as a broad phenomenon that does not follow lock step from invention leads to several insights. Among these is that innovation (using the broader economic definition) can rest on information that is in the public domain.

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[39] Bjørn L. Basberg, *Patents and the Measurement of Technological Change: A Survey of the Literature*, 16 RES. POL'Y 131, 133 (1987).

[40] Anahita Baregheh et al., *Towards a Multidisciplinary Definition of Innovation*, 47 MGMT. DECISION 1323, 1334 (2009). One of the primary attributes of modern definitions of innovation is "newness," which is not necessarily the same as patent law's definition of invention. Outside legal circles, the term innovation reaches activity that includes "the competence of organizing and implementing research and development, bringing forth the new technology and the new product to meet the demands of customers. It involves the new product, the new technology, the new market, the new material and the new combination." Marina du Plessis, *The Role of Knowledge Management in Innovation*, 11 J. KNOWLEDGE MGMT. 20, 21 (2007).

[41] JOSEPH A. SCHUMPETER, THE THEORY OF ECONOMIC DEVELOPMENT: AN INQUIRY INTO PROFITS, CAPITAL, CREDIT, INTEREST, AND THE BUSINESS CYCLE 88–89 (Redvers Opie trans., Harvard Univ. Press 1936).

[42] *Cf.* David J. Teece, *Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy*, 15 RES. POL'Y 285, 286–87 (1986) (considering invention and innovation as a separate activity).

[43] *Id*.

[44] Marcelo Bucheli et al., *Chandler's Living History: The Visible Hand of Vertical Integration in Nineteenth Century America Viewed Under a Twenty-First Century Transaction Costs Economics Lens*, 47 J. MGMT. STUD., 859, 868–69 (2010).

In that sense, an entrepreneurial firm that takes advantage of the spillovers generated from inventing entities has the ability to do so without breaching others' intellectual property rights. The recent shift in patent law facilitates this by refusing protection for the broad, vague claims based on abstract ideas or products of nature. Currently, the law allows more information to fall into the public domain, facilitating richer experimentation with ideas that are more likely to be considered "lawyer free."[45]

A related insight is that the organization that creates new knowledge may never commercialize it.[46] In fact, entrepreneurial firms can be *better* positioned to implement certain kinds of knowledge.[47] According to economist Jennifer Reinganum, entrants are more likely to make larger investments in radical innovation compared with incumbent firms.[48] Although incumbents generally have superior financial resources, distribution mechanisms, and economies of scale, entrants have little to lose and everything to gain by challenging the incumbent's dominance and the status quo. As Reinganum observes, incumbents have weaker incentives to invest in next-generation technology because even if the effort is fruitful, "a successful incumbent merely 'replaces himself,'" and must devote resources from the current business to take the risk.[49] In this same vein, economist Clayton Christensen writes that incumbents fail to appreciate the need for market-disruptive innovation, including those with the ample resources to exploit it.[50] As Bower and Christensen explain, disruptive technologies appear financially unattractive to incumbents because the future scope and profits of such opportunities appear uncertain compared with the existing core business.[51] When presented with an opportunity to engage in disruptive innovation, they state, "managers typically conclude that the technology cannot make a meaningful contribution to corporate

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[45] *See* Lawrence Lessig, *Re-Crafting a Public Domain,* 18 YALE J.L. & HUMAN. 56, 58 (2006).

[46] *See* David Audretsch & Roy Thurik, *A Model of the Entrepreneurial Economy*, *in* ENTREPRENEURSHIP AND ECONOMIC GROWTH 32, 40 (Martin Carree & A. Roy Thurik eds., 2006).

[47] John T. Scott, *Research Diversity Induced by Rivalry*, *in* INNOVATION AND TECHNOLOGICAL CHANGE: AN INTERNATIONAL COMPARISON 132, 137–38 (Zoltan J. Acs & David B. Audretsch eds., 1991); Jonathan B. Baker, *Fringe Firms and Incentive to Innovate*, 63 ANTITRUST L.J. 621, 633–34 (1995); Jennifer F. Reinganum, *Uncertain Innovation and the Persistence of Monopoly*, 73 AM. ECON. REV. 741, 741 (1983).

[48] Reinganum, *supra* note 47, at 745.

[49] *Id.* As Reinganum points out, at the time that the decision is made to invest in a research project, the new entrant has no current business revenue to preserve. *Id.* At that point, the risk of the new endeavor is the entrant's only chance to obtain revenue. *Id.*

[50] *See* CLAYTON M. CHRISTENSEN, THE INNOVATOR'S DILEMMA: WHEN NEW TECHNOLOGIES CAUSE GREAT FIRMS TO FAIL, at xii–xxv (2001); Joseph L. Bower & Clayton M. Christensen, *Disruptive Technologies: Catching the Wave*, HARV. BUS. REV., Jan.-Feb. 1995, at 43; *see also* WILLIAM L. BALDWIN & JOHN T. SCOTT, MARKET STRUCTURE AND TECHNOLOGICAL CHANGE 13 (F.M. Scherer ed., 1987) (discussing a "post-innovation market" and the rewards to innovators).

[51] Bower & Christensen, *supra* note at 50, at 47.

growth and, therefore, that it is not worth the management effort required to develop it."[52]

Where competition is present, incumbents tend to invest more in research and development.[53] Yet as economist Zoltan Acs observed, certain of this knowledge will not be recognized by its creators as commercially valuable.[54] This leaves room for entrepreneurs who can identify commercialization opportunities that the incumbent does not. In this sense, entrepreneurship serves as an important source of economic growth that otherwise remains unaccounted for as entrepreneurs capture the spillovers created by incumbents and turn such opportunities into innovation.[55] As Acs' spillover theory of entrepreneurship holds, nascent firms capture knowledge generated by well-established entities that is not being commercialized by the entity that created it.[56] His theory postulates that new knowledge and ideas created in one context, such as a research laboratory in a large corporation or university, but left uncommercialized or not vigorously pursued by the source can generate entrepreneurial opportunities for others.[57] Under these circumstances, the entrepreneurial act requires an understanding of the relevant information and the ability to connect it to a market need.[58] When this connection is made, the new startup "serves as a mechanism by which knowledge spills over from the source [producing the knowledge] to a new firm in which it is commercialized."[59]

Some examples support Acs' observations that startups foster new innovations that derive from knowledge developed elsewhere. Eight engineers who learned the field at their former employer, Shockley Semiconductor, founded Fairchild Semiconductor, which developed the first commercially viable silicon chip.[60] The first engineers at Tesla were inspired by information obtained from a company called

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[52] *Id.*

[53] Federico Etro, *Innovation by Leaders*, 114 ECON. J. 281, 281 (2004). At the same time, many startups lack sufficient resources to perform significant independent research and development at their start; *see generally* Zoltan Acs et al., *The Missing Link: Knowledge Diffusion and Entrepreneurship in Endogenous Growth,* 34 SMALL BUS. ECON. 105 (2004).

[54] *See* Pontus Braunerhjelm et al., *The Missing Link: Knowledge Diffusion and Entrepreneurship in Endogenous Growth*, 34 SMALL BUS. ECON. 105, 107 (2010).

[55] Audretsch & Thurik, *supra* note 46, at 40.

[56] *Id.* at 40.

[57] *Id.*

[58] Joseph A. Schumpeter, *The Fundamental Phenomenon of Economic Development*, *in* ENTREPRENEURSHIP AND ECONOMIC GROWTH, *supra* note 41, at 56, 56.

[59] Audretsch & Thurik, *supra* note 46, at 40.

[60] *See* CHRISTOPHE LÉCUYER & DAVID C. BROCK, MAKERS OF THE MICROCHIP: A DOCUMENTARY HISTORY OF FAIRCHILD SEMICONDUCTOR 9, 12–14 (2010) (ebook); *History & Heritage*, Fairchild, https://www.fairchildsemi.com/about/history-heritage/ [https://perma.cc/ZWF2-FZEH] (last visited May 27, 2016) (providing the history of the semiconductor and its inventors).

AC Propulsion.[61] Academic researchers who gained experience in a university setting and implemented it in commercial products founded Genentech.[62] Google's researchers began their search engine work within Stanford University.[63] The University of California, Los Angeles was the origin of work that began startups Holmic and Tibogenics.[64] Prometheus Labs relies on research developed by the University of California, Los Angeles.[65] Indeed, the structure and purpose of the Federal Bayh-Dole Act seeks to facilitate the transition of federally funded research that can spill over toward innovative commercialization.[66] In many of these examples, entrepreneurship has operated as a response to opportunities generated by investments in new knowledge made by incumbent firms and organizations.[67]

Entrepreneurial activity that is fully attributable to spillovers owes no royalty or license fee to the generator of the information.[68] One key insight into the more demanding patentability standards is that these increase the well of public domain information available for entrepreneurs to exploit. Thus, this most recent trend in patentability standards encourages those who wish to engage in permissionless innovation. To the extent that this information is available in a "lawyer free" form, entrepreneurs can experiment with this public domain knowledge with minimized risk.[69]

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[61] Drake Baer, *The Making of Tesla: Invention*, *Betrayal, and the Birth of the Roadster*, BUS. INSIDER (Nov. 11, 2014, 12:06 PM), http://www.businessinsider.com/tesla-the-origin-story-2014-10 [https://perma.cc/E9RU-PTQV].

[62] *See* Block, *supra* note 1, at 11.

[63] *See* Sergey Brin & Lawrence Page, *The Anatomy of a Large-Scale Hypertextual Web Search Engine*, COMPUTER NETWORK & ISDN SYSTEMS, Apr. 1998, at 107, 107 (citing origins in Stanford's Computer Science lab); *Our History in Depth*, GOOGLE CO., http://www.google.com/about/company/history/ [https://perma.cc/TD59-292R] (last visited May 27, 2016).

[64] Rebecca Kendall, *National Report Highlights Two UCLA Startups Contributing to Economy in Significant Ways*, UCLA NEWSROOM (Oct. 30, 2013), http://newsroom.ucla.edu/releases/two-ucla-start-ups-featured-in-249175 [https://perma.cc/7ZUU-6N8A].

[65] Prometheus Labs., Inc., *Prometheus Signs Research & Collaboration Agreement with Leading Worldwide Pharmaceutical Company*, PR NEWSWIRE (Feb. 7, 2012, 9:10 AM), http://www.prnewswire.com/news-releases/prometheus-signs-research--collaboration-agreement-with-leading-worldwide-pharmaceutical-company-138846434.html [https://perma.cc/8DXD-XV5U].

[66] The Bayh-Dole Act (P.L. 96-517, Amendments to the Patent and Trademark Act of 1980)—The Next 25 Years: Hearing Before the Subcomm. on Tech. & Innovation, 110th Cong. 4 (2007).

[67] Audretsch & Thurik, *supra* note 46, at 40. Some of these examples include contracts and agreements between the knowledge creator and the entrepreneur.

[68] *See id.* at 39–40 (detailing the process by which innovators adopt new information generated through spillovers).

[69] *See* Robin Feldman, *Patent Demands & Startup Companies: The View from the Venture Capital Community*, 16 YALE J.L. & TECH. 236, 263–65 (2014) (discussing the patent demands on venture-backed startups); Amy L. Landers, *The Antipatent: A Proposal*

The linear model does not account for the dynamics of spillover knowledge. Rather, the model attempts to force patents into the role of an essential conduit between foundational research and finished products. By failing to examine the manner in which unpatented information operates within the larger innovation context, the linear model can tell only a partial (and therefore unreliable) account.

IV. EXAMINING THE LINEAR MODEL OF INNOVATION

Under the linear model, there is a sequential aspect to innovation—that is, scientific research leads to invention, and invention later leads to a commercialized innovation.[70] There is room within this narrative for competition to play a role—for example, patents function throughout the process as competitive differentiators or to attract investment. This construct accommodates the principle that inventors license patents to commercializing entities that incorporate these ideas into an innovative product. In other words, the linear model accepts that patents play practical functions that assist business models, including those that facilitate innovation. Yet this construct includes no comprehensive way to evaluate how patents interact with the process of knowledge creation over time. In other words, it is assumed that patents act as a but-for incentive for invention and therefore play a central role in knowledge creation and ultimately innovation. These beliefs create the concern that the knowledge creation and innovation ecosystem has become undermined by the more stringent patentability standards.

The linear model is so prevalent that it can be difficult to contemplate any other. Perhaps one of the clearest articulations is this statement from Vannevar Bush at the former U.S. Office of Scientific Research in his report to President Franklin D. Roosevelt:

> Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.[71]

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for Startup Immunity, 93 NEB. L. REV. 950, 978–84 (2015) (describing the costs imposed by allegations of patent infringement).

[70] *See, e.g.*, Michael A. Carrier, *Unraveling the Patent-Antitrust Paradox*, 150 U. PA. L. REV. 761, 802 (2002) (discussing the relationship between patent law and anti-trust law); Edith Ramirez & Lisa Kimmel, *A Competition Policy Perspective on Patent Law: The Federal Trade Commission's Report on the Evolving IP Marketplace*, ANTITRUST SOURCE, Aug. 2011, at 1, 1 ("Patents encourage innovation by preventing others from appropriating the value of the patent owner's investment.").

[71] VANNEVAR BUSH, SCIENCE—THE ENDLESS FRONTIER: A REPORT TO THE PRESIDENT ON A PROGRAM FOR POSTWAR SCIENTIFIC RESEARCH 19 (1945); *see also* DANIEL S. GREENBERG, THE POLITICS OF PURE SCIENCE 9 (1999) (observing that the strongest reason to fund basic scientific research "is a belief that utilizable results may ensue").

As described in a 1945 report by the National Patent Planning Commission, an ad hoc body commissioned by President Roosevelt, patents "stimulate new invention and they make it possible for new industries to be built around new devices or new processes. These industries generate new jobs and new products, all of which contribute to the welfare and the strength of the country."[72]

Similarly, reports promulgated by the National Science Foundation ("NSF") were built on linear model assumptions.[73] In seeking to quantify amounts provided in research grants against a measurable output, these reports categorized dollars spent on basic research as the input that fed measurable outputs in the form of patents, which were followed by the production of innovative products.[74] Early on, this approach drew criticism as "too constricted by an input-output framework."[75] As one analyst described, the data was used because it was readily available but "lacks any overall unifying model that makes sense of the connections between science, technology, economy and society."[76] Regardless, the NSF continues to rely on the linear model, placing basic science as the fundamental informational input, patents as an intermediary, and innovation as the key output. For example, the NSF's most recent *Science Indicators* measures research and development funding as the critical inputs, preserving a clear distinction between basic and applied research.[77] The agency has used patent citations and research papers to validate financial support for basic science.[78] Innovation is the ultimate goal of the agency, which notes that, "patent grants and applications can sometimes lead to new or significantly improved products or processes or new methods of organizing productive activities."[79] As a whole, the NSF's reporting methodology considers basic science to be the preliminary input and patents as intermediaries to innovation, which is considered as the final output.

To some degree, patent jurisprudence has integrated the linear model. Supreme Court opinions suggest a one-way flow from science to patentable solution, and

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[72] BUSH, *supra* note 71, at 21.

[73] *See* NAT'L SCI. BD., SCIENCE INDICATORS 1976, at 9–10 (1977) (detailing the indicator highlights as gained through use of the linear model).

[74] *See id.*

[75] U.S. GEN. ACCOUNTING OFFICE, REPORT BY THE COMPTROLLER GENERAL OF THE UNITED STATES: SCIENCE INDICATORS: IMPROVEMENTS NEEDED IN DESIGN, CONSTRUCTION, AND INTERPRETATION 19 (1979).

[76] BENOIT GODIN, MEASUREMENT ON SCIENCE AND TECHNOLOGY, 1920 TO THE PRESENT 112 (2005).

[77] NAT'L SCI. BD., SCIENCE INDICATORS 2016, Chapter 4, 4-9 through 4-11 (2016).

[78] NAT'L SCI. BD., *supra* note 2, O-10 (2014) (noting that patents cite the prior scientific and technological knowledge on which they are built and that "patents are an important output often produced by [science and engineering] research").

[79] *Id.* at O-22 (noting that that together these activities "can have a large impact on innovation and economic growth").

subsequently to innovation.[80] As the Court describes, research yields discoveries that are the "basic tools of scientific and technological work" that will be used to facilitate invention.[81] Within this framework, abstract knowledge, laws of nature, and human understanding of physical phenomena are raw material. Such information cannot be captured in a patent unless "it contains an 'inventive concept' sufficient to 'transform'" the information into patent-eligible subject matter.[82] As a further example, the Supreme Court's *Brenner v. Manson*[83] drew a clear distinction between abstract scientific information that falls "short of the invention of something 'useful.'"[84] The court describes fundamental research as a "hunting license" search that is precedent to the "successful conclusion" in the form of a successful invention.[85] This suggests a continuum from raw information to invention that is the hallmark of the linear model. Further, it is woven into aspects of a discussion of university research in the Federal Circuit's *Ariad Pharmaceuticals v. Eli Lilly and Co.*[86] There, the court pointed out that the written description requirement operates to separate the "basic research, including research into scientific principles and mechanisms of action," from the "practical implications of all such research" that requires "the difficult work of 'invention.'"[87] Consistent with the linear model, the Supreme Court has recognized that, once invention is complete, patents are the medium that encourages innovation.[88]

The linear model has been part of American thinking at least since the mid-twentieth century. Yet universal reliance on this artificial construct is not warranted,

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[80] *See* Alice Corp. Pty. Ltd. v. CLS Bank Int'l, 134 S. Ct. 2347, 2354 (2014) (placing patents between basic science and innovation); Mayo Collaborative Servs. v. Prometheus Labs., Inc., 132 S. Ct. 1289, 1293 (2012) (observing the monopolization of research and abstract ideas in a patent would not promote innovation); Gottschalk v. Benson, 409 U.S. 63, 67 (1972) ("Phenomena of nature, though just discovered, mental processes, and abstract intellectual concepts are not patentable, as they are the basic tools of scientific and technological work.").

[81] *Mayo*, 132 S. Ct. at 1293 (quoting *Gottschalk*, 409 U.S. at 67).

[82] *Alice Corp. Pty. Ltd.*, 134 S. Ct. at 2357 (quoting *Mayo*, 132 S. Ct. at 1294, 1298). *See generally* Pfaff v. Wells Elecs., Inc., 525 U.S. 55, 63 (1998) (recognizing "the interest in motivating innovation and enlightenment by rewarding invention with patent protection"); Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 489 U.S. 141, 146 (1989) (recognizing the "need to promote innovation" as a purpose of the federal patent laws).

[83] 383 U.S. 519 (1966).

[84] *Id.* at 535–36; *see* In re '318 Patent Infringement Litig., 583 F.3d 1317, 1324 (Fed. Cir. 2009) ("The utility requirement also prevents the patenting of a mere research proposal or an invention that is simply an object of research.").

[85] *Brenner*, 383 U.S. at 536.

[86] 598 F.3d 1336 (Fed. Cir. 2010).

[87] *Id.* at 1353 (observing that patents are granted to those willing to invest the resources "to work out the practical implications of all such research").

[88] *See* F.T.C. v. Actavis, Inc., 133 S. Ct. 2223, 2238 (2013) ("The point of patent law is to grant limited monopolies as a way of encouraging innovation.").

particularly today as research methods have evolved. Analysis of the efficacy of the patent system should be based on models that more accurately reflect reality.

V. THE LINEAR MODEL IN HISTORICAL CONTEXT

The difficulty with the linear model of science and innovation is that it fails to account for the various ways that science and innovation interact in fact. History and theory offer alternatives. Although a comprehensive treatment of science and innovation throughout U.S. history is not possible in this piece, the following subsection offers some examples of the manner in which science and innovation have interacted in ways that defy the linear model.

A. The 1800s: The Golden Age of Innovation

In America's early years, science as a discipline was in a nascent state. Regional scientific societies populated by generalists, such as Benjamin Franklin's American Philosophical Society and John Adam's American Academy of Arts and Sciences, were the earliest forms of organized scientific engagement.[89] Research paralleled the economic needs of the growing nation, rather than the pursuit of knowledge for its own sake.[90] For example, the early 1800s brought inquiry into topographical exploration, including the mapping of the nation's coastlines and waterways, weather data, and astronomical observations.[91] At this time, research focused on optimizing trade channels as a federal priority.

During the first half of the nineteenth century, there was little federal governmental support for scientific investigation. Prior to 1850, the U.S. Patent Office was one of the few agencies thought to have an ongoing scientific mission, and therefore it was tasked with such projects as distributing seeds to farmers and acting as a repository for "the vast quantities of plants and seeds sent home by the burgeoning exploring expeditions of the 1840s and 1850s."[92] Yet the agency staffed no scientist qualified with "the knowledge at his command to make the program a genuine success."[93] In fact, Congress did not create an agency with an ongoing scientific investigative purpose until 1884.[94]

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[89] *See* A. HUNTER DUPREE, SCIENCE IN THE FEDERAL GOVERNMENT: A HISTORY OF POLICIES AND ACTIVITIES TO 1940, at 7 (1957).

[90] *See* JOHN DUFFY, FROM HUMORS TO MEDICAL SCIENCE: A HISTORY OF AMERICAN MEDICINE 167 (2d ed. 1993).

[91] DUPREE, *supra* note 89, at 43.

[92] *Id.* at 111.

[93] *Id.*

[94] *Id.* at 164–68. *See generally* REXMOND C. COCHRANE, THE NATIONAL ACADEMY OF SCIENCES: THE FIRST HUNDRED YEARS 1863–1963 (1978) (describing governmental research efforts during the 1800s); Naomi R. Lamoreaux & Kenneth L. Sokoloff, *Inventors, Firms, and the Market for Technology in the Late Nineteenth and Early Twentieth Centuries*, *in* LEARNING BY DOING IN MARKETS, FIRMS, AND COUNTRIES 19, 19–25 (Naomi R.

At this time, the large private in-house research labs that became prevalent during the twentieth century had not yet emerged. Medical research had not yet crystallized into an organized field. Thus, although causative studies began during the 1830s that demonstrated the origins of certain parasites and diseases, American doctors continued to misattribute medical conditions to spontaneous generation or atmospheric origins.[95] It has been reported that U.S. medical schools contributed "virtually nothing to medical research during the second half of the nineteenth century."[96] During this time, the solo inventor was a primary source of new inventions, and it has been said "[i]nventions sprang directly from the empirical observations of practical men, most of them ignorant of contemporary science."[97]

The Civil War prompted the federal government to fund research into metals, medicines, and steam energy. These programs focused on results-based research, including engaging uncompensated advisors trained in the sciences to evaluate weapon proposals and designs for warships submitted by the private sector.[98] In 1863, Congress approved the creation of the National Academy of Sciences to assist with the technological and scientific questions relating to its wartime needs. Yet after the war, the nation's requests to the Academy fell to zero and the group nearly dissolved.[99] During this era, there was little government interest in supporting fundamental science. Instead, during the nineteenth century federal funding was granted for limited, ad hoc projects that delivered identifiable effects on commerce, including surveying the land, investigating shipping routes, and sending teams on exploratory missions.[100]

In the private sector, American industry became a world leader in machining, a field that began in the gun-machining shops that sought to supply the government

Lamoreaux et al. eds., 2007) (ebook) (describing solo inventors as important suppliers of new ideas to firms in the nineteenth century); Naomi R. Lamoreaux & Kenneth L. Sokoloff, *Market Trade in Patents and the Rise of a Class of Specialized Inventors in the 19th-Century United States*, 91 AM. ECON. REV. 39, 39 (2001) (describing the division of labor between commercializing firms on one hand and solo inventors on the other).

[95] DUFFY, *supra* note 90, at 168–69.

[96] *Id.* at 168.

[97] DUPREE, *supra* note 89, at 46; *see also* LEWIS MUMFORD, TECHNICS AND CIVILIZATION 215 (1934) ("The detailed history of the steam engine, the railroad, the textile mill, the iron ship, could be written without more than a passing reference to the scientific work of the period. . . . And though all these inventions would have been the better for science, they came into existence, for the most part, without its direct aid.").

[98] DUPREE, *supra* note 89, at 137.

[99] COCHRANE, *supra* note 94, at 104, 114–15.

[100] *Id.* at 51–58 (describing efforts to survey the eastern coast of the United States); *id.* at 111–12 (describing the Hall expedition to the arctic supported by the U.S. Navy); DUPREE, *supra* note 89, at 109–11 (describing the Navy's efforts to survey and compile information for the oceanic routes, noting that "[i]n terms of the economic interests of the country, the exploring and surveying activities so extensively supported by the federal government told almost entirely in favor of commerce").

with arms.[101] Knowledge gained in the manufacture of guns was subsequently applied throughout the light manufacturing sector.[102] Technological advances were facilitated in part through collective invention, based on knowledge shared by competitors who engaged in interactive information sharing.[103] Learning through these channels led to the creation of new information, incremental improvements, and ultimately improved results within certain industries.[104] A phenomenon first documented by Robert Allen, such activity is characterized by competitors who share information to generate technical advance.[105]

Specialty machine firms within the United States were among those who benefited from collective invention.[106] According to some research, an "open-door policy was common practice among machinery firms across the later nineteenth century; violations of the custom were scored in the trade press," and tours of machine shops were freely provided.[107] These interactions were important to the diffusion of technical and business knowledge. This common practice "involved face-to-face, noncash information exchanges among individuals" that allowed for the transmission of "the odd novel thought about gearing or cutting-tool designs" or "unexpected new angle on a ship or market problem."[108] A similar phenomenon has been documented in the papermaking industry.[109]Although patents were sought and obtained, freely shared spillover information played a significant role.[110]

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[101] Peter Temin, *The Industrialization of New England: 1830-1880*, at 10–11 (Nat'l Bureau of Econ. Research, Working Paper No. 114, 1999).

[102] *Id.* at 10–12. *See generally* Nathan Rosenberg, *Technological Change in the Machine Tool Industry, 1840–1910*, 23 J. ECON. HIST. 414, 428 (1963) (discussing how gun manufacturing affected other economic sectors).

[103] *See* Robert C. Allen, *Collective Invention*, 4 J. ECON. BEHAV. & ORG. 1, 1–2 (1983); Alessandro Nuvolari, *Collective Invention During the British Industrial Revolution: The Case of the Cornish Pumping Engine*, 28 CAMBRIDGE J. ECON. 347, 348–49 (2004); *see also* R. Cowan & N. Jonard, *The Dynamics of Collective Invention*, 52 J. ECON. BEHAV. & ORG. 513, 513–14 (2003) (describing collective invention as taking place when "firms release to their competitors information about the design and efficiency of new plants or technologies; and individual firms devote few resources explicitly to the discovery of new knowledge").

[104] Nuvolari, *supra* note 103, at 347–49.

[105] Allen, *supra* note 103, at 1–3.

[106] PHILIP SCRANTON, ENDLESS NOVELTY: SPECIALTY PRODUCTION AND AMERICAN INDUSTRIALIZATION, 1865–1925, at 30 (1997); Allen, *supra* note 103, at 2 (observing that the U.S. iron industry's development of fast driving for its furnaces was accomplished through collective invention); Naomi R. Lamoreaux, *Rethinking the Transition to Capitalism in the Early American Northeast*, 90 J. AM. HIST. 437, 449 (2003).

[107] SCRANTON, *supra* note 106, at 30.

[108] *Id.* at 30–31.

[109] JUDITH A. MCGAW, MOST WONDERFUL MACHINE: MECHANIZATION AND SOCIAL CHANGE IN BERKSHIRE PAPER MAKING, 1801–1885, at 136–43 (1987).

[110] *Id.* at 141–43, 180–81 (observing the rudimentary level of scientific understanding available to those in the paper-making industry). These examples are not intended to suggest

Despite a lack of widespread foundational scientific knowledge, America attained status as an innovation frontrunner in certain industries by the end of the nineteenth century.[111] These circumstances fly in the face of the linear model of innovation, as "the United States was the world's economic leader in the 1920s, at a time when we were far from being the leading scientific power."[112] Although it is sometimes thought that the United States built its reputation on scientific information developed in Europe, that suggestion does not hold true for every circumstance. As private entities attempted to refine their innovations, questions arose that could not be answered by the existing state of science including that developed in Europe.[113]

In fact, one interesting phenomenon is that, in certain instances, innovation drove scientific advances rather than the other way around. One example took place in the canning industry, with an innovation introduced in the United States by William Underwood around 1810, based on his apprenticeship in this art in London.[114] This field, which predated Pasteur's work on microbiology, was established without any foundational understanding of the relevant science.[115] Its absence led to some arbitrary design choices, although advances continued to take place over the span of the nineteenth century.[116] In 1913, the National Canners Association established a research laboratory staffed with scientists to gain a better scientific understanding of the field.[117] In an example that turns the linear model on its head, the canning arts were based on a series of trial and error without reliance

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that patents were not important within these industries, but only to demonstrate that these rights were not the sole means to incentivize technical advance and innovation.

[111] *See* Richard R. Nelson & Gavin Wright, *The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective*, 30 J. ECON. LITERATURE 1931, 1937 (1992).

[112] Ralph E. Gomory & Roland W. Schmitt, *Science and Product*, 240 SCI. 1131, 1131 (1988).

[113] Kline & Rosenberg, *supra* note 12, at 288.

[114] W. Lyman Underwood, *Incidents in the Canning Industry of New England*, *in* A HISTORY OF THE CANNING INDUSTRY BY ITS MOST PROMINENT MEN 12, 12 (Arthur I. Judge ed., 1914).

[115] *See generally* Martin Brown & Peter Philips, *Craft Labor and Mechanization in Nineteenth-Century American Canning*, 46 J. ECON. HIST. 743, 744 (1986) ("Why this technique was successful in processing foods was poorly understood and subject to common but unanticipated failures."); J.C. Graham, *The French Connection in the Early History of Canning*, 74 J. ROYAL SOC'Y MED. 374, 376 (1981) (observing that one of the leaders in canning technology "understood the need for airtight containers although he did not understand why this was so").

[116] Graham, *supra* note 115, at 378 (noting that a six-pound quantity limitation was imposed and a vent hole design was needed); Underwood, *supra* note 114, at 13 (noting that around 1850 "[m]any unaccountable losses were sometimes met with by the packers in those early times when in certain years their goods would not all keep. Numerous theories were hunted down, in vain effort to learn the cause of these mysterious deteriorations.").

[117] *See* Underwood, *supra* note 114, at 14.

on foundational scientific knowledge. Ultimately, these advances revealed the need for foundational research. At that juncture, resources were devoted to that effort.

Similarly, the development of the steam engine, long considered a major advance of that century, took place prior to the development of thermodynamics. As one historian described, early versions of the steam engine "were essentially successive essays in thermodynamics solved in practice before they were solved in theory."[118] Although steam power benefitted from pneumatics, inventor James Watt disclaimed reliance on other types of theoretical knowledge when he created his most significant advances.[119] Cornot's early theories about thermodynamics began after steam power had already been invented, such that it can be said, "the steam engine did more for science than science did for the steam engine."[120] The telegraph was said to have a parallel effect on the science of electrical measurement, which later influenced the field of electrical engineering.[121] Edison's research focus on a commercially viable light bulb was not built on any robust understanding of the scientific principles of electricity.[122] Although he was considered an expert in the practical aspects of electric power, Edison admitted, "that [he] never did know anything about [the supporting theories]."[123] As his business grew, Edison hired mathematical physicists to research the more difficult questions that arose.[124] As with the steam engine, an initial innovation drove later research.

This brief overview includes several examples that run contrary to the linear model of innovation. Unlike a world in which basic science gives rise to invention, in the nineteenth century innovation gave rise to research incentives. More broadly, the United States obtained prominence as one of the world's innovation leaders, despite the nascent state of science at the time. In some instances, innovations during this time inspired and enabled the study of foundational and theoretical science, rather than the other way around. Some advances owe their origins to shared information, rather than patent incentives. In short, the history of innovation is complicated, nuanced, and impossible to capture in a single, simplistic model.

B. The Twentieth Century to the Present

From a scientific investigation standpoint, the twentieth century was massively different. These years introduced the era of Big Science, vastly increased public and private funding, and worldwide communication systems that facilitated the domestic

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[118] J.D. BERNAL, SCIENCE AND INDUSTRY IN THE NINETEENTH CENTURY 27 (1953).

[119] Milton Kerker, *Science and the Steam Engine*, 2 TECH. & CULTURE 381, 385–86 (1961).

[120] *Id.* at 381, 389.

[121] MICHAEL BRIAN SCHIFFER, POWER STRUGGLES: SCIENTIFIC AUTHORITY AND THE CREATION OF PRACTICAL ELECTRICITY BEFORE EDISON 154 (2008) (ebook).

[122] Bruce J. Hunt, *"Practice vs. Theory": The British Electrical Debate, 1888–1891*, 74 ISIS 341, 355 (1983) (citation omitted).

[123] *Id.*

[124] *Id.*; SCHIFFER, *supra* note 121, at 288.

understanding of scientific principles developed in other countries. This early parts of this era *created* the linear model of innovation. Moreover, basic science has been the foundation of some of the most important innovations of this century. Yet it remains to be seen how sustainable its factual foundations remain as our understanding of research becomes more nuanced and such methods change over time.

During the latter half of the century through the present, numerous political, economic, and societal shifts took place. Entrepreneurship played a significant role. Except in isolated circumstances, private firms reduced their capability for performing purely basic research. Federal support for extremely large-scale projects receded.[125] Although government funding for research remains generally strong, some projects geared to developing fundamental research were cancelled, including the superconducting supercollider, the S6 fractionated spacecraft project, and NASA's plans for further moon exploration. In other sectors, collective invention took on new life, along with research collaborations and large technology acquisitions. In the later years of the century and to the present, the role of the patent system's centrality to the progress of research has been questioned.[126] As one example, one survey of over one thousand early-stage technology companies reported that patents are not a strong incentive to create, develop, and commercialize technology.[127] Unlike the Big Science era, the present era has brought new methods of managing scientifically creative activity in ways that do not mirror the linear model. In addition, theorists have provided alternative ways of thinking about fundamental and applied research that are helpful for assessing the recent changes in the patent system.

1. The Growth of Fundamental Research in the United States

The arc of the development of basic research in the U.S. over the past century has been productive, particularly compared with the prior years. The federal government's engagement in scientific research began to grow around the time of

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[125] *See* Gregory McLauchlan & Gregory Hooks, *Last of the Dinosaurs? Big Weapons, Big Science, and the American State from Hiroshima to the End of the Cold War*, 36 SOC. Q. 749, 750 (1995) (comparing these programs to dinosaurs, stating "[i]t may well be that big states, big weapons, and big science, with all their trappings of modernity, will meet a similar fate").

[126] *See, e.g.*, Landers, *supra* note 69, at 953; Michael J. Meurer, *Inventors, Entrepreneurs, and Intellectual Property Law*, 45 HOUS. L. REV. 1201, 1207 (2008); Lea Shaver, *Illuminating Innovation: From Patent Racing to Patent War*, 69 WASH. & LEE L. REV. 1891, 1897 (2012).

[127] Stuart J.H. Graham et al., *High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey*, 24 BERKELEY TECH. L.J. 1255, 1270 n.45, 1283–87 (2009).

World War I.[128] That work, which involved coordinated efforts with the other Allies, resulted in advances in the chemical arts, new technology for locating submarines, weather sensing solutions, and a renewed understanding of approaches for supplying food.[129] In 1915, the federal government formed the National Advisory Committee for Aeronautics, a small-scale organization that had a budget of only $5,000 per year.[130] This committee, which after several decades evolved into the later National Aeronautics and Space Agency ("NASA"), focused on both the theoretical and practical aspects of flight.[131] The government's war efforts, in collaboration with private firms and university scientists, expanded the foundations of professionalized research within the United States.[132] According to one source, "[t]he end of the war found American industry with a vastly expanded capacity for production, and American science . . . with an enormous research program still for the most part in its early stages."[133] After the war, this work assisted in the development of commercial products, including automobiles, airplanes, and radio.[134]

Around the 1900s, large private firms began to invest more heavily in their internal research capability. Part of this effort was built around the movement toward vertical integration.[135] Edison's 1876 "invention factory," which was viewed as providing a significant competitive advantage, served as an important model for in-house research and development at other companies.[136] These firms, which included General Electric, DuPont, Bell Telephone, Westinghouse, Eastman Kodak, and Standard Oil, started in-house labs during the early part of the twentieth century.[137] Some focused on fundamental long-term research projects, as well as applied

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[128] *See* ALFRED D. CHANDLER, JR., STRATEGY AND STRUCTURE: CHAPTERS IN THE HISTORY OF THE INDUSTRIAL ENTERPRISE 228–33 (Anchor Books 1966); Gerald J. Fitzgerald, *Chemical Warfare and Medical Response During World War I*, 98 AM. J. PUB. HEALTH 611, 612 (2008).

[129] *See* Fitzgerald, *supra* note 128, at 612.

[130] Naval Appropriations Act, Pub. L. No. 63-271, 38 Stat. 928, 930 (1915).

[131] *Id.* ("[I]t shall be the duty of the Advisory Committee for Aeronautics to supervise and direct the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions.").

[132] *See* Richard C. Atkinson & William A. Blanpied, *Research Universities: Core of the US Science and Technology System*, 30 TECH. SOC'Y 30, 33 (2008).

[133] COCHRANE, *supra* note 94, at 233.

[134] Block, *supra* note 1, at 5.

[135] *See* NEIL FLIGSTEIN, THE TRANSFORMATION OF CORPORATE CONTROL 132, 140–44 (1990) (discussing diversification in America's chemical and petroleum industries); *see also* KENDALL BIRR, PIONEERING IN INDUSTRIAL RESEARCH: THE STORY OF THE GENERAL ELECTRIC RESEARCH LABORATORY 7–8 (1957) ("[I]t was World War I which really convinced . . . the United States of the necessity for systematic industrial research. . . . [T]he United States found [itself] cut off from German dyes, chemicals, medicines, and glass.").

[136] *See* BIRR, *supra* note 135, at 7–8; SCHIFFER, *supra* note 121, at 285.

[137] BIRR, *supra* note 135, at 8; Lillian Hoddeson, *The Emergence of Basic Research in the Bell Telephone System, 1875–1915*, 22 TECH. & CULTURE 512, 512–13 (1981).

research used to improve processes or products.[138] Specialized independent firms assisted private firms on particular issues.[139] The need to perform research in this country was reinforced as World War I began and Western Europe and the U.S. entities realized that they could no longer purchase dyes, chemicals, medicines, and glass from Germany.[140]

During these years, Bell, which retained university-trained scientists, institutionalized basic scientific research after the company's initial patents expired and its business strategy shifted toward providing nationwide telephone service.[141] Funded through its monopoly for providing national and local telephone services, Bell's breakthroughs included basic research that ultimately led to the implementation of optical fiber, communication satellites, cellular technology, and the creation of the first transistor.[142] Its work was awarded eleven Nobel prizes, and continues to have a long-lasting impact on technology.[143] Bell, which is a paradigm example for the linear model of innovation, invested in the fundamental research that provided the foundation for its own innovations, as well as generating spillovers that ultimately inured to the benefit of others.

GE's lab serves as another example.[144] As one historian describes, GE lead researcher Irving Langmuir "was able to recognize areas of research and types of experiments that promised knowledge valuable to his employer's commercial interests," based on "'the scientific principles underlying these peculiar effects.'"[145] Although his lab was engaged in basic research projects, over the long term its work fed the company's commercialization pipeline. Another is DuPont, which maintained a division dedicated to fundamental research in molecular structure.[146] Ultimately, this work led to its commercial introduction of rayon and nylon.[147] Additionally, DuPont's introduction of ultracentrifugal and X-ray analysis of particular pigments ultimately inured to the benefit of DuPont's paint line.[148] This era of industrial research provided benefits that, although not all captured by its originators, assisted these firms in carrying out their own technological missions.

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[138] SUZANNE BERGER, MAKING IN AMERICA: FROM INNOVATION TO MARKET 51–52 (2013).

[139] *See* BIRR, *supra* note 135, at 8.

[140] *Id.*

[141] Hoddeson, *supra* note 137, at 520–25, 530–34.

[142] BERGER, *supra* note 138, at 52–53 ("In the case of Bell Labs, AT&T's monopoly and the steady flow of revenue from the local phone companies made it possible to carry on work for years without having any returns.").

[143] *Id.* at 52.

[144] LEONARD S. REICH, THE MAKING OF AMERICAN INDUSTRIAL RESEARCH: SCIENCE AND BUSINESS AT GE AND BELL, 1876-1926, at 122–23 (1985).

[145] *Id.* at 122 (citation omitted).

[146] *See* Augustin Cerveaux, *Taming the Microworld: DuPont and the Interwar Rise of Fundamental Industrial Research*, 54 TECH. & CULTURE 262, 271–77 (2013).

[147] *Id.* at 281–82.

[148] *Id.* at 278–79.

The federal government's support of the sciences reached unprecedented levels during World War II.[149] In 1940, President Franklin D. Roosevelt established the National Defense Research Committee ("NDRC"), which began to develop contracts with universities and private companies to develop weapons.[150] In 1941, Roosevelt created the Office of Scientific Research and Development, which absorbed the NDRC and "became a central organization for all the estates of science" for the wartime effort.[151] The dramatic expansion and capital infusion, including the creation of several federal laboratories, federal collaborations with universities, and the employment of government officers accountable for guiding this work, was unprecedented.[152] Federal research spending went from $100 million in 1940 to $1.6 billion in 1945.[153] The effort resulted in "permanent changes in the government's relation to science" and "deeply affected the universities as well."[154] After the war, Bush was instrumental in advocating for continued federal support for scientific research.[155] For this among other reasons, federal support for scientific and technological research continued throughout the Cold War years up to the present.[156]

2. The Later Years of the Twentieth Century to the Present

Today, the era of Big Science has trailed off and vertical integration became far less attractive to private entities. By the 1980s, many of the in-house labs that had been prolific in fundamental research shifted their focus to application-based projects, were downsized, or ceased operations entirely.[157] Bell's monopoly was dismantled and neither of its successors, AT&T and Alcatel-Lucent, continued Bell's intensive research level. One source reports that today, in general, large company leadership finds that basic research does not sufficiently contribute to

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[149] *See* Block, *supra* note 1, at 45.

[150] DUPREE, *supra* note 89, at 370–71.

[151] *Id.* at 371.

[152] *See* ROGER L. GEIGER, RESEARCH AND RELEVANT KNOWLEDGE: AMERICAN RESEARCH UNIVERSITIES SINCE WORLD WAR II 3–13 (1993) (ebook) (describing several major federal research efforts and collaborations).

[153] DUPREE, *supra* note 89, at 373.

[154] *Id.*

[155] BUSH, *supra* note 71, at x–xxiv.

[156] One of the most significant events occurred in 1958 when the Defense Advanced Research Projects Agency ("DARPA") was founded to facilitate "blue-sky" projects. MARIANA MAZZUCATO, THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE SECTOR MYTHS 75–76 (2013). The agency ultimately funded numerous computer science projects, including work that contributed to others' development of semiconductors and work that established the early stages of the Internet. *Id.*; Block, *supra* note 1, 8–10. Today, the federal government supports science research through a number of mechanisms, including agencies such as the National Science Foundation and through initiatives that include support for alternative energy. Block, *supra* note 1, 12–15.

[157] BERGER, *supra* note 138, at 54–55.

profitability and therefore such investments are not justifiable.[158] Currently, private entities are responsible for most of the overall research and development in the United States, a trend that began during the 1980s.[159] Perhaps not surprisingly, much is categorized as applied research that is geared toward the creation and improvement of products and processes.[160]

On close inspection, companies approach research in innumerable ways that include obtaining new technology through the acquisition of smaller startups, joining collaborations that integrate competencies and share knowledge, or engaging in targeted research with near-term windows toward commercialization.[161] One significant method involves an integrated back and forth that occurs on the path to commercialization. Technology theorists Kline and Rosenberg have characterized this method as an integrated "chain link" relationship between research and innovation.[162] To illustrate the operation of this mode, these theorists explain that entities engaged in the process toward innovation begin with a background understanding of basic scientific principles that exist at the outset of a project.[163] For many, a knowledge roadblock arises that cannot be resolved based on current knowledge.[164] To move forward, foundational research must be performed, or the project must be abandoned.[165] Instead of giving up, the entity finds a way to solve the problem through necessary basic research. If successful, such work may be capable of driving more innovation. Using this chain link method, innovation pushes fundamental research and over time the reverse occurs as well.

Alternatively, companies can combine fundamental and applied research into a single step, merging the research and innovative functions. For example, at Google projects are designed so that "no step [is] required to move beyond study into actual product implementation."[166] This goal combines research and product creation in a way that echoes the early work of the company's founders Larry Page and Sergey Brin. Specifically, the pair developed the algorithm that formed the backbone of the company while the two were at Stanford. At roughly the same time, a computer scientist named Jon Kleinberg was working the same problem while at IBM's

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[158] *Id.* at 55.

[159] NAT'L SCI. BD., *supra* note 2, at 4–9.

[160] *Id.* at 4–15.

[161] *See* BERGER, *supra* note 138, at 55–56; René Rohrbeck et al., *Opening Up for Competitive Advantage—How Deutsche Telekom Creates an Open Innovation Ecosystem*, 39 R&D MGMT. 420, 421 (2009); Achilleas Karamitsios, *Open Innovation in EVs: A Case Study of Tesla Motors* 24 (June 17, 2013) (unpublished Master of Science Thesis, KTH School of Industrial Engineering and Management).

[162] Kline & Rosenberg, *supra* note 12, at 291.

[163] *Id.*

[164] *Id.* ("Only when all stages fail to supply the needed information, as often happens, is a call for the second part of science, research, needed and justified.").

[165] *Id.* Kline and Rosenberg acknowledge that this type of research is more of the applied variety, rather than exploring unknown phenomena. *Id.* at 292.

[166] STEVEN LEVY, IN THE PLEX 64 (2011).

research center.[167] As the three met to discuss their findings, Page and Brin rejected Kleinberg's suggestion to publish their research. As Kleinberg described it, he was trying to solve a very difficult theoretical problem, but Page and Brin "wanted to crawl the whole web and get it on racks of servers that they would accumulate."[168] As one source describes, "Kleinberg was trying to understand network behavior. Page and Brin were *building* something."[169] Notably, Page and Brin's work appears to be both fundamental and applied simultaneously.

This melded approach has been adopted elsewhere.[170] As some examples, Tesla integrates both innovation and research in highly product-focused projects.[171] Edwards Lifesciences has an Advanced Technology Group that includes "early stage marketing, quality, regulatory, clinical and manufacturing teams" that work with outside experts.[172] This structure was set up based on the company's belief that "new product development involves collaboration from the outset between engineers and the physicians who will ultimately use the new product."[173] These firms do not follow a model of linear innovation; rather, they have merged components of each to focus their fundamental research that extends toward commercialization. Outside of firms, grassroots innovation is occurring through a mix of the work of engineers and lay persons, who collaborate to solve everyday problems with a blend of practical and technical knowledge.[174]

The spillover theory of entrepreneurship suggests that new firms can get their start more easily under the most recent state of patent law. To the extent that such firms grow, these entrepreneurs will perform additional research on their path toward innovation.

VI. WHEN PURE AND APPLIED SCIENCE OVERLAP

In addition to the notion that science, the patent system, and innovation do not operate in a linear manner in all cases, there are instances where science and innovation overlap completely. One conceptual difficulty with the patent system is the long-held belief that there is a division between abstract knowledge and its application. Certainly, there are instances where the separation is clean. For example, in *The Telephone Cases*,[175] the Court articulated the distinction between the unpatentable "use of a current of electricity in its natural state as it comes from

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[167] *Id.* at 24.
[168] *Id.* at 26 (quoting Jon Kleinberg).
[169] *Id.*
[170] Cynthia Wagner Weick & Ravi K. Jain, *Rethinking Industrial Research, Development and Innovation in the 21st Century*, 39 TECH. SOC'Y 110, 110 (2014).
[171] *Id.* at 113.
[172] *Id.*
[173] *Id.*
[174] *See* Nitin Maurya et al., *ICTs in Support of Grassroots Innovation*, 10 INFO. TECHS. & INT'L DEV. 21, 21 (2014).
[175] 126 U.S. 1 (1888).

the battery," and the application of the natural phenomenon of electricity to power a specific configuration and for a particular purpose.[176] In this example, foundational knowledge of electricity can be patented only once it is combined with a tangible, useful device that allows voice transmission. These principles are echoed in the court's recent patentable subject matter tests, which seek to separate foundational knowledge from solutions that can be considered inventive.

Yet the line between them can become unclear and in some cases disappears entirely. As Daniel Stokes recognized, Pasteur's work laid out an entire branch of scientific study of the manner in which bacteria grows and cannot be intelligibly separated from the practical nature of his individual projects, which included the improvement of fermentation processes and pasteurization.[177] He points out that the belief that "the categories of basic science and applied research are necessarily separate, is itself in tension with the actual experience of science."[178] In other words, Pasteur's work did not exist on the linear continuum because it was dedicated to understanding microbiology at a fundamental level, but was *equally* dedicated to application through implementation in products and processes.[179] Stokes argues that this is more than a "fuzziness and overlap at the boundaries."[180] Rather, the dual nature of Pasteur's work presents a fatal challenge to the paradigm that attempts to separate pure science from applied research.[181]

Another example is the Manhattan Project, the U.S. government's large-scale project designed to create a nuclear weapon. The effort was focused on an application-specific problem; the result represented a milestone for a basic scientific understanding of controllable nuclear fission. A breakthrough appeared to occur when mathematician John von Neumann began his consultancy and endorsed implosion as the solution. As one source describes, von Neumann's influence derived from his expertise with both theory and practice, which allowed him to "translate[] knowledge of high explosives into the language of mathematics and physical theory."[182] The project was "beset by growing pains and confronted by technical terrain so unexplored that some of the difficulties could not yet even be identified."[183] After others joined the project and computers were added, the project

[176] *Id.* at 534.

[177] STOKES, *supra* note 8, at 12–14.

[178] *Id.* at 12.

[179] *Id.* at 71–72.

[180] *Id.* at 71.

[181] *Id.* (observing that Pasteur's work presents "a conceptual problem that is inherently of a higher dimension"). Notably, Stokes recognizes that some work can fall into one category versus another, such as Edison's work on the light bulb.

[182] CHARLES THORPE, OPPENHEIMER: THE TRAGIC INTELLECT 136 (2006); *see also* 1 RICHARD G. HEWLETT & OSCAR E. ANDERSON, JR., A HISTORY OF THE UNITED STATES ATOMIC ENERGY COMMISSION: THE NEW WORLD, 1939/1946, at 246–47 (1962) (noting that von Neumann's interest in implosion velocities caused others to become interested).

[183] HEWLETT & ANDERSON, *supra* note 182, at 248.

moved toward a prototype.[184] Despite these developments, new shifts in theory and data from new experimentation required frequent redesigns.[185] The project culminated in the Trinity Test, which demonstrated the effectiveness of the application and proof of the theory at a single moment.

Examples of the merger of application and basic research are numerous. Others include Horni's study of the physics of silicon interfaces to create the planar diode.[186] IBM undertook fundamental research to create prototypes of new ultradense semiconductors that rely on silicon-germanium and EUV lithography to etch the chip's features.[187] Sustainability science has been identified as another cross-disciplinary field that encompasses use-inspired basic science that "engage[s] in[] cutting-edge research in areas ranging from complex systems theory to cultural and political ecology."[188] Additional areas of research that fall within this realm include research performed to understand genetic information that can be applied to individualize treatment for heart disease.[189] Work in these areas is "characterized by desire for both a fundamental understanding and a consideration of use, spanning basic and applied research."[190]

Patent law has no metric to grapple with these forms of invention. The current iteration of the patentable subject matter tests attempts to neatly separate fundamental principles, natural phenomena, laws of nature and abstract subject matter from new and useful solutions. The patentable subject matter question defaults to invalidating claims that are conceivably directed to both, erring on the side that places the idea into the public domain.

VII. ENTREPRENEURIAL ACTIVITY, THE PATENT SYSTEM, AND SPILLOVER CREATIVITY

If the patent system represents an important centerpiece of a linear sequence of science and innovation, the recent trend toward tightening patentability requirements presents cause for concern. Heavy reliance on the linear model leads to the

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[184] *Id.* at 248–49.

[185] *Id.* at 249.

[186] LÉCUYER & BROCK, *supra* note 60, at 32.

[187] Sebastian Anthony, *Beyond Silicon: IBM Unveils World's First 7nm Chip*, ARS TECHNICA UK (July 9, 2015, 3:45 AM), http://arstechnica.co.uk/gadgets/2015/07/ibm-unveils-industrys-first-7nm-chip-moving-beyond-silicon/ [https://perma.cc/4TTL-UZXK]; John Markoff, *IBM Discloses Working Version of a Much Higher-Capacity Chip*, N.Y. TIMES (July 9, 2015) (on file with the Utah Law Review), http://www.nytimes.com/2015/07/09/technology/ibm-announces-computer-chips-more-powerful-than-any-in-existence.html.

[188] William C. Clark, *Sustainability Science: A Room of Its Own*, 104 PNAS 1737, 1737 (2007).

[189] Richard I. Levin & Glenn I. Fishman, *The Power of Pasteur's Quadrant: Cardiovascular Disease at the Turn of the Century*, 25 FASEB J. 1788, 1790 (2011).

[190] *Id.* at 1788.

conclusion that this trend will have negative consequences for all technological creators, who are expected to rely on patents as their primary incentive to innovate. Yet this conclusion overemphasizes the role of patents, and propagates reliance on a model that is not universally true. Entrepreneurship depends on spillovers. The recent trend in patent law suggests that entrepreneurs will benefit from a greater amount of research that inures to the public domain.

Certainly the shift presented by *Mayo*, *Bilski*, *Myriad*, *Alice*, and their progeny present valid areas of concern. According to one antibiotic research company, a broad reading of the Supreme Court's *Myriad* case would be entirely unable to protect its $1 billion investment made.[191] Some have expressed concern that the current patentable subject matter standards do not encompass important pharmaceutical solutions that are derived from nature, including antibiotics and certain types of vaccines that are structurally similar to substances that exist in the body.[192] Yet this does not hold true across the board.[193]

The shift in patentability standards at this particular time can be the means to open doors to entrepreneurial activity. Important to economic stability and growth, encouraging innovation at this time is particularly critical. Coupled with rules that limit the availability of injunctions and rein in unsupported damage awards, this trend allows entrepreneurs to take risks. Additionally, limiting patentability standards increases the level of spillover information that can feed entrepreneurial activity.

Of course, there are attendant concerns that must be considered. Notably, these changes have the potential to negatively impact the current business expectations of startups. A robust patent portfolio can be competitively valuable to secure a position against larger incumbents who may have superior production, resources, and distribution methods.[194] Strong patents can secure a position as the exclusive supplier of a product market, which enables the initiator to build up other

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[191] Letter from Thomas DesRosier, Exec. Vice President, Cubist Pharmaceuticals, Inc. to the U.S. Patent & Trademark Office 5 (May 7, 2014) http://www.uspto.gov/sites/default/files/patents/law/comments/mm-e-cubist20140507.pdf [https://perma.cc/DA7H-XNUY].

[192] Benjamin N. Roin, *Unpatentable Drugs and the Standards of Patentability*, 87 TEX. L. REV. 503, 504–07 (2009); Letter from Catriona Hammer, President, Chartered Inst. of Patent Attorneys, to the U.S. Patent & Trademark Office 4 (July 30, 2014), http://www.uspto.gov/sites/default/files/patents/law/comments/mm-a-cipa20140730.pdf [https://perma.cc/K99M-72HP]; Letter from Corey Salsberg, Head Int'l IP Policy, Novartis Int'l AG, to the U.S. Patent & Trademark Office 2 (Mar. 14, 2015), http://www.uspto.gov/sites/default/files/documents/2014ig_e_novartis_2015mar14.pdf [https://perma.cc/2GBG-A5TM].

[193] *See* Amy L. Landers, *Patentable Subject Matter As a Policy Driver*, 53 HOUS. L. REV. 505, 505 (2015) (providing an argument that policy levers should be used to decide these issues).

[194] Teece, *supra* note 42, at 301 ("Large firms are more likely to possess the relevant specialized and cospecialized assets within their boundaries at the time of new product introduction.").

complimentary assets including trademarks, customer loyalty, and a distribution system.[195] The system is not perfect, and enforcement requires time and money, sometimes an extensive amount of each. If successful, these assets can carry the initial entrepreneur after the patents expire.[196] In addition, patents facilitate collaboration, integration, acquisition, and licensing.[197] A company that lacks patents might be hindered in collaborative development, particularly if the proposed collaborator owns strong rights but cannot expect to receive any useful licenses in return.[198] Further, patents facilitate contractual relationships with upstream suppliers and downstream manufacturers, and prevent such partners from converting themselves into competitive adversaries.[199]

The Supreme Court's patentable subject matter decisions have the potential to impact business expectations that depend on broadly available patent protection. Yet historically and with some notable exceptions, many high-technology companies that developed key technologies had very few patents during their earliest years and a significant number hold no patents at all.[200] The most common reason cited by early-stage companies is that the cost of patents is prohibitive.[201] To the extent that entrepreneurs must expend their scant resources defending against allegations of patent infringement, the patent system may present a fatal drain on a startup company's resources.[202] In another context, this author has questioned whether some startups would be better off without the patent system.[203]

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[195] *Id.* (describing the successful strategy of G.D. Searle with respect to its NutraSweet sugar substitute).

[196] *Id.*

[197] *Cf. id.* at 293 (describing advantageous contractual relationships with suppliers, manufacturers, and distributors).

[198] *Cf.* Henry Chesbrough, *Open Innovation: A New Paradigm for Understanding Industrial Innovation*, *in* OPEN INNOVATION: RESEARCHING A NEW PARADIGM 1, 10 (Henry Chesbrough et al. eds., 2006) (observing that intellectual property "flows in and out of the firm on a regular basis, and can facilitate the use of markets to exchange valuable knowledge"); Tamara Loomis, *Cell Break,* IP L. & BUS. (July 2005) (discussing an example for new entrants to the GSM cell phone market that must pay 10-13% royalty amounts, while companies that owned patents paid nothing).

[199] *Cf.* Teece, *supra* note 42, at 294 (observing that licensing can bring about "the added danger that the partner may imitate the innovator's technology and attempt to compete with the innovator").

[200] *See generally* KEVIN G. RIVETTE & DAVID KLINE, REMBRANDTS IN THE ATTIC: UNLOCKING THE HIDDEN VALUE OF PATENTS 39–41 (2000) (identifying Apple and National Semiconductor as some of the exceptions and commenting on "Silicon Valley's early antipathy toward patents"); Graham et al., *supra* note 127, at 1276 ("Substantial numbers of early-stage technology companies appear to be opting out of the patent system altogether . . . . "); Landers, *supra* note 69, at 969–71 (noting that Cisco, Microsoft, and Facebook had few patents in their early years).

[201] Graham et al., *supra* note 127, at 1310–11.

[202] *See* Landers, *supra* note 69, at 963.

[203] *See id.* at 958, 967–68.

The linear model masks the complex interactions between science and innovation. The linear model, although valuable for its empirical insights, has not captured the manner in which innovation drives scientific inquiry. Further, the distinction between basic and applied science, which may be a tenuous distinction for particular kinds of information, is not a sustainable model. In other words, the difference between scientific knowledge and useful solutions is unhelpful for information that represents both.

VIII. CONCLUSION

This Article considers several related points about the recent changes to the patent system and the opportunities for entrepreneurship. The concern about the adverse effect of the recent changes to patent law on innovation may be overstated. As a practical matter, the concept that patents are a necessary input to innovation is built on a model that does not account for the complex relationship between this legal system, science, and innovation. Although it can be expected that there may be some adverse impacts from these decisions, this trend opens up the opportunity for entrepreneurship. By releasing more foundational information into the public domain, there is a real possibility that innovative efforts by new firms will be encouraged. Further, innovation over the long term has positive effects on scientific investigation. In some respects, the practical necessities have led to innovation in the past and, in some instances, inspired new forms of scientific investigation. To the extent that such firms are no longer encumbered by broad, vague patent challenges, such resources can be geared toward additional research and innovative efforts.