ACCESS-TO-ERROR[♦]

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Abstract

Access to knowledge is a crucial part of the innovation paradigm, and its significance for development and progress is well recognized. Conversely, the role of errors, failures, and additional types of negative information in the dynamics of innovation is insufficiently explored in law and policy scholarship. This Article focuses on errors as drivers of innovation, and explores new ways for facilitating access to error.

Drawing on multidisciplinary research—ranging from philosophical accounts of progress through studies of complex systems to accumulating reflections from diverse scientific communities—this Article demonstrates that, counterintuitively, errors and innovation are inextricably linked. Yet, the principal legal, institutional, and social structures that regularly incentivize the diffusion of knowledge discourage rather than encourage the diffusion of errors. Intellectual property law, the primary mechanism for stimulating the dissemination of knowledge goods, is inherently limited in its ability to promote the dissemination of negative knowledge. The scientific establishment—whose reputational rewards and institutional funding schemes complement and sometimes substitute intellectual property incentives—offers no equal rewards when it comes to negative findings or falsifications. The result is insufficient access to negative knowledge,

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with acute and proven harms for innovation and progress.

Against this analysis, this Article frames "access-to-error" as a pressing goal for innovation law and policy. It proposes a preliminary typology of negative information, and explores concrete policy measures to support an access-to-error paradigm concentrating on three possible mechanisms: adjustments to the intellectual property regime, top-down regulation, and a state-supported commons-based approach.

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INTRODUCTION

"Men are greedy to publish the successes of efforts, but meanly shy as to publishing the failures." This quote is attributed to Abraham Lincoln, whose own failures have attracted public attention for decades.[1] Whatever its source, this saying captures a fundamental truth: people are very much reluctant to share their errors with others.[2] Yet, surprisingly, errors are not merely a source of humiliation and disgrace; they are also crucial tenets of innovation and progress. The inextricable links between error and innovation are the focus of this Article.

Legal scholarship in the field of innovation has long recognized that access to knowledge is vital for technological advance, human creativity, and scientific growth.[3] Information, data, and knowledge are the raw materials of technological and cultural innovations. Access to knowledge is therefore a key to development and progress, and its

1 Scott Sandage, *I Have Never Been Up: The Persistent Powerful Meme of Abraham Lincoln as a "Failure at Fifty"*, SLATE (May 28, 2014, 3:34 PM), http://www.slate.com/articles/business/how_failure_breeds_success/2014/05/abraham_lincoln_failure_at_50_why_the_myth_is_so_persistent_and_powerful.html (examining the cultural myth of "Lincoln's Failures").

2 As more fully explained below, I use the term "errors" in this Article in a rather generic manner to cover various failures, mistakes, and additional types of negative information. *See infra* notes 26–27 and accompanying text.

3 *See, e.g.*, Yochai Benkler, *The Idea of Access to Knowledge and the Information Commons: Long-Term Trends and Basic Elements*, *in* ACCESS TO KNOWLEDGE IN THE AGE OF INTELLECTUAL PROPERTY 217, 217 (Gaëlle Krikorian & Amy Kapczynski eds., 2010) [hereinafter Benkler, *The Idea of Access to Knowledge*] ("[T]he constituent elements of human welfare and development depend on information and knowledge."); Madhavi Sunder, *IP*^{3}, 59 STAN. L. REV. 257, 310 (2006) (highlighting the relationship between knowledge and development); Lea Bishop Shaver, *Defining and Measuring A2K: A Blueprint for an Index of Access to Knowledge*, 4 I/S: J. L. POL'Y FOR INFO. SOC'Y 235, 253–56 (2008) (discussing access to various "knowledge goods" such as books, broadcasts, pharmaceuticals, and seeds); Peter Lee, *Toward a Distributive Commons in Patent Law*, 2009 WIS. L. REV. 917 (emphasizing the importance of access to successful medicines). *See also* Part III.C *infra*, notes 207–208 and accompanying text.

importance in the contemporary world is ever-increasing.[4] Following this broad recognition, the term access-to-knowledge (or "A2K") has become an influential cultural meme and has grown to denote a significant social movement.[5]

However, existing literature (just like the A2K movement itself), concentrates on access to the *positive* aspects of knowledge and its various embodiments.[6] Access to errors, failures, and additional types of negative knowledge is almost absent from legal discourse about innovation.[7] Parting with conventional literature, this Article focuses on errors as an essential feature of innovation and progress and proposes to frame access-to-error as an integral part of the access-to-knowledge paradigm. In furtherance of this proposal, it systematically explores the incentive structure for the dissemination of negative knowledge and demonstrates that the current legal, social, and institutional mechanisms discourage rather than encourage such dissemination. The result is insufficient access to error with proven harms for innovation and progress. This Article then highlights a substantial and pressing gap—not merely in the legal scholarship but in the innovation ecosystem itself—and provides a conceptual framework for devising possible solutions.

Relying on multi-disciplinary literature—ranging from philosophical accounts of progress through studies of complex systems to internal reflections from diverse scientific communities—the analysis demonstrates that access to error plays a fundamental role in the dynamics of innovation. Briefly, errors expose the fallibility of scientific hypotheses and extant technologies. By so doing they provide innovators with robust and high-quality knowledge (about what does *not* work) that can guide innovation efforts toward viable solutions

4 Amy Kapczynski, *Access to Knowledge: A Conceptual Genealogy*, *in* ACCESS TO KNOWLEDGE IN THE AGE OF INTELLECTUAL PROPERTY 17, 19 (Gaëlle Krikorian & Amy Kapczynski, eds., 2010) [hereinafter Kapczynski, *A2K Genealogy*] (discussing the increasing role of knowledge as a source of productivity in today's world); Sunder, *supra* note 3, at 269 ("social and economic power . . . derive more and more from access to knowledge . . . .").

5 Sunder, *supra* note 3, at 266–68 (2006); Kapczynski, *A2K Genealogy*, *supra* note 4, at 17 (describing the emergence of access-to-knowledge as a social movement).

6 *See supra* notes 3–5.

7 For prominent exceptions, *see* John T. Cross, *Dead Ends and Dirty Secrets: Legal Treatment of Negative Information*, 25 J. MARSHALL J. COMPUTER & INFO. L. 619 (2009) (observing the absence of legal mechanisms for incentivizing disclosure of negative information); Charles Tait Graves, *The Law of Negative Knowledge: A Critique*, 15 TEX. INTELL. PROP. L.J. 387 (2007) (criticizing the protection of negative knowledge under trade secret law); Amy Kapczynski & Talha Syed, *The Continuum of Excludability and the Limits of Patents*, 122 YALE L.J. 1900, 1923–28 (2013) (highlighting the difficulty of excluding the use of negative information through patent protection); Amir Khoury, *The Case Against the Protection of Negative Trade Secrets: Sisyphus' Entrepreneurship,* 54 IDEA 431 (2014) (taking a similar position); Sean B. Seymore, *The Null Patent*, 53 WM. & MARY L. REV. 2041 (2012) (proposing the creation of a "null patent" mechanism as a means for encouraging the disclosure of negative information). For further discussion of this scholarship, *see infra* Parts II–III.

while minimizing waste.[8] In addition, errors spark paradigm shifts, which are an unusual yet valuable type of progress, thereby igniting radical inventions and technological breakthroughs.[9] Furthermore, errors in complex innovation ecosystems tend to accumulate undetected until they eventually cause cascading failures and serious harms. The exposure of small and moderate errors in such systems is therefore crucial for preventing larger catastrophes.[10] Finally, errors and mistakes are drivers of artistic creativity.[11]

This Article further demonstrates that despite the essential role of errors in promoting innovation, the principal legal and social institutions that encourage the diffusion of positive knowledge do not adequately incentivize the disclosure and sharing of errors. First, intellectual property (IP) law, the primary legal mechanism for incentivizing the creation and dissemination of knowledge goods, is largely based on exclusion—namely on the ability of IP owners to prevent unauthorized uses of the IP-protected subject matter. Yet, negative knowledge is generally non-excludable; often, there is no simple way to effectively limit its use by third parties.[12] The intellectual property system is therefore unlikely to provide satisfactory incentives for the dissemination of this type of knowledge. Secondly, the scientific establishment—whose reputational rewards and institutional funding schemes complement and sometimes substitute IP incentives—offers no equal rewards when it comes to negative results, failures, or falsifications. Scientists face substantial difficulties to publish negative findings, and even when published, such information produces less impact than positive information.[13] Similarly, state-funded grants strongly prefer projects that seek to attain positive findings to projects that focus on replication and falsification.[14]

This general absence of incentives to disclose and disseminate negative knowledge, coupled with prevalent cultural perceptions of error as shameful and disparaging, yields a "file-drawer effect": errors and negative findings are often shelved, concealed, or guarded under a veil of secrecy.[15] The result is insufficient access to negative knowledge with acute and proven harms for innovation and progress. These include distortions of the "big picture" in scientific and technological domains,

8 *See infra* notes 30–40 and accompanying text.
9 *See infra* notes 40–50 and accompanying text.
10 *See infra* notes 51–61 and accompanying text.
11 *See infra* notes 62–66 and accompanying text.
12 *See* Kapczynski & Syed, *supra* note 7, at 1923–28 (2013) (maintaining that not all innovations are equally excludable and explicitly discussing negative information as an example for low-excludability). For an elaborate discussion of this point, *see infra* Part II.A.
13 *See infra* Part II B.
14 *See infra* Part II B.
15 *See infra* Part II.B, notes 129–130 and accompanying text.

valuable resources being poured into dead ends, and innovators being steered away from potentially groundbreaking projects.[16] In some cases, the difficulties to disseminate and access negative knowledge may even risk lives: flawed scientific hypotheses "live on" and create health hazards,[17] non-effective drugs with dubious safety may find their way to the market,[18] and undetected errors in complex projects accumulate "under the surface" until abruptly causing disastrous outcomes.[19]

Against this analysis, this Article aims to start up a conversation about access to error as an essential part of the access to knowledge paradigm. While not purporting to provide a comprehensive solution, it explores and evaluates three principal directions for intervention by policy makers.

First, while intellectual property law is not the ideal vehicle for incentivizing the dissemination of negative knowledge, the analysis does suggest that certain adjustments to specific IP doctrines—in particular, patent law's disclosure requirements and the exceptions to intellectual property protection—could promote access to error. Most prominently, these proposed adjustments are designed to lower access barriers and facilitate the exposure of errors in existing technologies without risking IP infringement.[20]

Second, in some cases, direct and top-down regulation of innovation ecosystems can promote access to error by mandating the disclosure of negative information.[21] While this type of intervention has significant drawbacks as a general solution, it may be apt where disclosure pertains to the safety of an innovation and regulatory schemes are already in place. A recent amendment to FDA regulation which instructs the disclosure of "adverse events" that are part of clinical trial results is one such example.[22] More generally, illuminating the nexus between errors and innovation can alert regulators to the significance of negative knowledge and assist them in calibrating their regulatory policies accordingly.

Finally, the most promising direction for promoting the diffusion of negative knowledge may be locating access-to-error within the larger paradigm of access-to-knowledge.[23] The norms of sharing cultivated by the access-to-knowledge movement can serve as a useful model for an

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16 *See infra* Part II.C, notes 130–135 and accompanying text.
17 *See infra* Part II.C, notes 136–139 and accompanying text.
18 *See infra* notes 140, 182–184 and accompanying text.
19 The Fukushima nuclear disaster in 2011 is a case in point. For a discussion of this and additional examples, *see infra* notes 51–61, 141–142 and accompanying text.
20 *See infra* Part III.A.
21 *See infra* Part III.B.
22 *See infra* notes 179–180 and accompanying text. For additional examples, *see* discussion *infra* Part III.B.
23 *See infra* Part III.C.

access-to-error paradigm. Such conceptualization can encourage, for example, the formation of commons-based schemes that would allow scientists, professionals, and other stakeholders to share failures, refutations, and additional types of negative data and to benefit from similar data contributed by their peers. Several recent commons-based initiatives that focus on access to error—such as the emergence of journals dedicated to negative results, or grass-root replication schemes—indicate that this could be a promising route.[24]

This Article further suggests that the proposed theoretical framing should be coupled with a variety of measures on behalf of policy makers to facilitate commons-based schemes and nudge bottom-up initiatives of access-to-error. These include, for example, providing infrastructure for the formation and maintenance of errors-repositories, adopting and supporting voluntary **"**near-miss**"** schemes for reporting errors, the allocation of designated funds for scientific and technological projects that focus on replications and refutations, and more broadly, the promotion of an educational agenda that embraces error rather than conceals it.[25]

Before delving into the world of errors, a few clarifications are in order. I use "error" in this Article in a rather broad manner to include mistakes, failures, refutations, blind alleys, misconceptions, negative results, and additional types of negative information. Although there are differences between these various kinds,[26] this Article is interested in all such instances, and its principal insights do not depend upon a detailed taxonomy of errors. Yet, some of the particular problems and specific solutions addressed along the way may benefit from broadly outlining prominent types of negative knowledge. I therefore delineate the following four groups: (i) failures to validate one's own hypotheses, including insignificant experimental results, "null" findings, or blind alleys; (ii) refutations and falsifications of existing hypotheses (of others); (iii) errors pertaining to safety or health hazards; and (iv) negative information which is in close proximity to positive knowledge. Although these categories are not designed to constitute a formal typology and are not mutually exclusive, they highlight particular aspects of the access-to-error conundrum, and I return to them throughout the analysis.

While the first three groups are very much self-explanatory, the

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24 *See infra* notes 233–234 and accompanying text.

25 *See infra* Part III.C.

26 *See, e.g.*, MARIO LIVIO, BRILLIANT BLUNDERS 6 (2014) (discussing the difference between "mistakes" and "major scientific blunders"); KATHRYN SCHULZ, BEING WRONG: ADVENTURES IN THE MARGIN OF ERROR 10, 12, 23 (2011) (referring to "slips and lapses and mistakes, errors of planning and errors of execution, errors of commission and errors of omission, design errors and operator errors, endogenous errors and exogenous errors" but recognizing that errors may be "a coherent category of human experience," where we "[see] the world as it is not").

fourth category may warrant some explanation. Negative information is not always clearly distinguishable from positive information. At times, the line between failure and success is blurry, and some negative findings are so intertwined with positive knowledge that the two can be virtually indistinguishable. In those instances, knowing that one possibility is false immediately points toward a viable, and positive, answer ("if not A, then B"). I refer to this point more fully below[27] but should clarify at the outset that my general focus in this Article is *not* on those cases. Rather, I concentrate on the myriad of failures, errors, and negative findings that do not lead to an immediate positive solution. As shall be demonstrated throughout this Article, it is in these latter instances that the challenge of access-to-error significantly diverges from traditional analyses of intellectual property and innovation theory and justifies the exploration initiated herein.

Part I demonstrates the nexus between errors and innovation by drawing on diverse and multidisciplinary literature. Part II explores the access-to-error conundrum. It discusses the inherent limitations of the intellectual property system in incentivizing the dissemination of negative knowledge. It further demonstrates that institutional and social structures that traditionally supplement or replace IP incentives fail to offer adequate incentives for the disclosure and diffusion of negative knowledge. It then examines the significant social costs of insufficient access-to-error. Part III proceeds to investigate possible mechanisms for promoting access-to-error, concentrating on three principal directions: adjustments to the IP regime, top-down regulation, and a state-supported commons-based approach.

I. On Errors and Innovation

We regularly connect innovation with scientific discoveries, popular technological inventions, successful new products, or creative designs. We rarely associate it with errors, mistakes, and failures.[28] Not only do we fail to perceive a relationship between error and innovation, but our culture often links error with intellectual inferiority, fear, shame, and defeat.[29] Yet, errors are intricately linked to innovation and progress in more than one way.

First, errors steer innovation away from dead ends and guide it toward viable solutions.[30] By so doing, they fulfill a crucial part in the

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27 *See infra* notes 175, 220 and accompanying text.

28 Scott A. Sandage, Born Losers: A History of Failure in America 265 (2005) [hereinafter Sandage, Born Losers] (observing the close cultural analogy between entrepreneurship and success).

29 Schulz, *supra* note 26, at 5; Sandage, Born Losers, *supra* note 28, at 251 (indicating that failures and errors are culturally perceived as character flaws).

30 *See* Livio, *supra* note 26, at 10.

development of scientific and technological enterprises. The most renowned philosophical articulation of this point is that of Karl Popper, who described progress as a process of trial and error, or "conjectures and refutations."[31] Popper famously regarded the falsifiability of a scientific theory as the ultimate mark for its scientific (rather than pseudo-scientific) nature and actually denied the verification of any positive knowledge.[32] Popper's philosophical account illuminates a critical point for our purposes, even without embracing the Popperian view in its entirety: knowledge grows not only by the accumulation of positive findings but also by subtraction of negative ones.[33] Such negative knowledge exposes the blind alleys on the map of science and technology and "lift[s] the fog" through which innovation inevitably progresses.[34] As Popper elegantly put it, "we learn from our mistakes."[35]

Moreover, negative knowledge supplies innovators with *high-quality* information: the knowledge that an engineering design does *not* work, that a technology fails, or that a scientific assumption is incorrect is often more rigorous than positive hypotheses which may still be disproved at a later stage.[36] Simply put, "[s]omeone who did not find something is providing others with knowledge, *the best knowledge*, that of absence."[37] And interestingly, these insights about the reliability of negative knowledge find support in recent statistical analyses which indicate that the accuracy of negative findings is substantially higher in comparison to positive ones.[38]

Indeed, progress in scientific and technological fields regularly relies on lessons learned from previous failures. For example, the

31 KARL R. POPPER, CONJECTURES AND REFUTATIONS (1962).

32 *Id.* at 52, 60.

33 KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY 19 (1959). For more contemporary writing reflecting similar insights, *see* NASSIM NICHOLAS TALEB, ANTIFRAGILE: THINGS THAT GAIN FROM DISORDER 57 (2012) ("errors and their consequences are information").

34 LIVIO, *supra* note 26, at 11. *See also* HENRY PETROSKI, TO ENGINEER IS HUMAN: THE ROLE OF FAILURE IN SUCCESSFUL DESIGN 51 (1992) (discussing the important contribution of failures to subsequent innovations in the field of engineering); SCHULZ, *supra* note 26, at 32 (maintaining that the actual falsifiability of a scientific hypotheses marks "the success of science, not its failure"); Cross, *supra* note 7, at 620 (stressing the importance of blind alleys for scientific progress).

35 POPPER, CONJECTURES AND REFUTATIONS, *supra* note 31, at vii.

36 *See* POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY, *supra* note 33, at 19 (discussing the "asymmetry" between the two types of knowledge); PETROSKI, *supra* note 34, at 51 ("[A] failure would . . . contribute more to uncovering error than all the successful 'verifications' of the incorrect hypothesis.").

37 TALEB, *supra* note 33, at 79 (emphasis added and omitted).

38 *See Unreliable Research: Trouble at the Lab*, ECONOMIST (Oct. 19, 2013), http://www.economist.com/news/briefing/21588057-scientists-think-science-self-correcting-alarming-degree-it-not-trouble (relying on statistical tools to conclude that "negative results are much more trustworthy" than positive ones); *cf.* John P.A. Ioannidis, *Why Most Published Research Findings Are False*, 2 PLOS MEDICINE 696 (2005) (using statistical models to demonstrate an increasing concern that most *positive* research findings are false).

successful design of the Brooklyn Bridge, one of the greatest engineering innovations of the nineteenth century, was the result of negative knowledge attained from the many failures of suspension bridges during that period.[39] Likewise, the repeated failures to replicate a study that introduces a new approach to overcoming transplant rejection can signal to researchers that the proposed solution is in fact a blind-alley and can induce them to shift their efforts to other potential avenues in the search for a viable solution.[40]

Second, and relatedly, errors are especially important for inducing paradigm shifts. Paradigm shifts are an unusual yet important kind of innovation: one that is not cumulative but challenges the conventions of a scientific or technological domain and reconstructs some of its theoretical foundations.[41] Paradigm shifts, by definition, identify faults in previous paradigms and offer alternatives that discard some of these misconceptions. Moreover, these shifts are often triggered by detecting such errors and inconsistencies. The history of science indicates that the recognition that a paradigm is flawed and the adoption of a new paradigm in its stead are commonly preceded by the gradual exposure of inconsistencies, counter-instances, anomalies, and incommensurable results under the prevalent paradigm.[42] The accumulation of those errors "loosens the stereotypes" of the existing paradigm and encourages innovators to search for alternatives.[43] To some extent, then, success encourages repetition while failure encourages novel shifts in innovation ecosystems.[44]

To illustrate, Charles Darwin's revolutionary theory on the "Origin of Species" was partly triggered by his failure to reconcile the design of certain species with the conventions of the then-prevalent creationist paradigm.[45] More recently, the scientific breakthrough concerning the

39 PETROSKI, *supra* note 34, at 106–09.

40 The example is based on a recent account by medical researcher David Vaux. *See* David Vaux, *Why I Retracted My Nature Paper: A Guest Post from David Vaux About Correcting the Scientific Record*, RETRACTION WATCH (June 19, 2013, 9:30 AM), http://retractionwatch.com/2013/06/19/why-i-retracted-my-nature-paper-a-guest-post-from-david-vaux-about-correcting-the-scientific-record/ (the author describes how his team's research agenda was influenced by a seemingly revolutionary study concerning overcoming transplant rejection, until the repeated and accumulating failures redirected their research path).

41 The term "paradigm shift" was coined by philosopher and historian of science Thomas Kuhn in his seminal treatise. THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS (4th ed. 2012). For a recent examination of the interrelations between paradigm shifts and intellectual property law, *see* Michal Shur-Ofry, *Nonlinear Innovation*, MCGILL L. J. (forthcoming 2016), http://ssrn.com/abstract=2666871.

42 KUHN, *supra* note 41, at 52–76.

43 *Id.* at 89.

44 *Cf.* Ian Hacking, *Introductory Essay*, *in* KUHN, *supra* note 41, at xxvi ("discovery comes not when something goes right but when something is awry"); PETROSKI, *supra* note 34, at 62 ("No one wants to learn by mistakes, but we cannot learn enough from successes to go beyond the state of the art.").

45 JANET BROWNE, DARWIN'S ORIGIN OF SPECIES 45 (2006).

function and structure of the DNA molecule pronounced erroneous the preceding notion that the genetic material is comprised of proteins.[46] Moreover, the success of James Watson and Francis Crick, who identified the double helix structure of DNA, resulted in part from the detection of several significant errors in a previous model for the DNA molecule offered by the renowned biochemist Linus Pauling.[47] Likewise, in the social sciences, the paradigm shift of behavioral economics was prompted to some extent by the exposure of various "anomalies" and "failures" in standard economic theory.[48]

Admittedly, paradigm shifts are uncommon in comparison to regular and incremental innovations, but their impact on scientific and technological progress is particularly broad. Such shifts open up new research avenues, ignite a multitude of follow-on inventions, and can completely alter scientific domains.[49] Deciphering the role and structure of DNA, for example, prompted the design of new treatments for serious diseases, opened the door to new ways for prolonging human life, shed light on the origin of life, heralded major progress in forensic science, and created a platform for innumerous additional innovations—some of which we cannot yet appreciate.[50] The encounter with errors, then, extends the boundaries of science and technology and paves the way for particularly valuable innovations.

Third, an inextricable (but largely overlooked) part of innovation is preserving the robustness of complex innovation systems and planning against disaster. The detection of errors plays a crucial role in this context. Complex technological systems are commonly comprised of various interdependent networks, such as human networks, telecommunication networks, electricity and transportation networks, and interactive technologies.[51] The multiple interactions of the components comprising these networks and the interdependencies among them inject these systems with embedded unpredictability and vulnerability.[52] Due to these interdependencies, errors in complex systems can yield nonlinear responses that seriously impact the entire

46 LIVIO, *supra* note 26, at 102.

47 *Id.* at 140 (describing how Pauling's blunder "served as the catalyst" to the eventual success of Watson and Crick).

48 Daniel Kahneman, *Experiences of Collaborative Research*, 58 AM. PSYCHOLOGIST 723, 728 (2003) (recounting how Richard Thaler's detection of "obvious failures" and "anomalies" in standard economic theory played a significant role in the development of behavioral economics).

49 KUHN, *supra* note 41, at 66–68; Hacking, *supra* note 44, at xxix.

50 LIVIO, *supra* note 26, at 153–54. For additional examples, *see* Shur-Ofry, *Nonlinear Innovation*, *supra* note 41.

51 *See generally* Michal Shur-Ofry, *IP and the Lens of Complexity*, 54 IDEA 55, 94–101 (2013) (describing the networked nature of innovation ecosystems).

52 *Id.* at 96. *See also* TALEB, *supra* note 33, at 57 (discussing the unpredictability of complex systems).

system.[53] In other words, in networked innovation systems, small-size errors do not necessarily result in small-scale problems. Instead, unexposed errors may accumulate "under the surface" for long periods of time and eventually cause abrupt and large-scale catastrophes.[54]

Indeed, analyses of the collapses of bridges[55] and the crashes of airplanes[56] suggest that such calamities are frequently preceded by accumulating small-scale failures. The Fukushima nuclear disaster of 2011 is another case in point. Although the debacle at the nuclear power plant was generated by a combination of an earthquake and a tsunami, the independent investigation commission appointed by the Japanese government explicitly pronounced it a "manmade" disaster resulting from the accumulation of a "multitude of errors" over the decades preceding the catastrophe.[57] These included "errors in design," "deficiencies in the response," "errors in mindset," and, importantly, a practice of covering up small-scale failures whose accretion eventually resulted in a major collapse.[58]

The above cases demonstrate that access to error is particularly crucial in innovation ecosystems where safety is a major concern.[59] In such systems, the exposure of errors and failures helps sober up from the illusion of predictability, allows one to learn from the mistakes revealed, enables the design of more robust infrastructures, and constitutes an important measure for preventing more severe tragedies.[60]

53 For the vulnerability of interdependent networks, *see, e.g.*, Vittorio Rosato et al., *Modelling Interdependent Infrastructures Using Interacting Dynamical Models*, 4 INT'L. J. CRITICAL INFRASTRUCTURES 63 (2008) (demonstrating how failures in the power grid network in Italy caused cascading failures in multiple interdependent systems, including telecommunication networks, the railway network, and the healthcare and the financial systems); Amir Bashan et al., *The Extreme Vulnerability of Interdependent Spatially Embedded Networks*, 9 NATURE PHYSICS 667 (2013) (demonstrating that higher dependency between networks increases their vulnerability to abrupt cascading failures).

54 Rosato et al., *supra* note 53; Bashan et al., *supra* note 53. *See also* TALEB, *supra* note 33, at 101; HENRY PETROSKI, TO FORGIVE DESIGN: UNDERSTANDING FAILURE 5 (2012) ("[a]ccidents may occur quickly, but they often follow long periods of normal or near-normal behavior."); SCHULZ, *supra* note 26, at 303 (indicating that the collection of minor errors can be "collectively catastrophic").

55 PETROSKI, *supra* note 34, at 93–95 (analyzing the collapse of the Mianus Bridge in Connecticut and the Point Pleasant Bridge in Ohio).

56 *Id.* at 95–96 (analyzing the crash of a DC-10 airplane in Chicago).

57 *The Official Report of The Fukushima Nuclear Accident Independent Investigation Commission*, *Executive Summary*, NAT'L DIET OF JAPAN, 9 (2012), http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/wp-content/uploads/2012/09/NAIIC_report_lo_res10.pdf.

58 *Id.*

59 *See, e.g.*, PETROSKI, *supra* note 34, at 52 (observing that making mistakes in engineering is "forgivable," while catching such mistakes is "imperative"); Jane Carthey et al., *The Human Factor in Cardiac Surgery: Errors and Near Misses in a High Technology Medical Domain*, 72 ANNALS THORACIC SURGERY 300 (2001); Samer A. M. Nashef, *What Is a Near Miss?*, 361 LANCET 180, 180–81 (2003) (discussing the importance of exposing errors and failures in medical processes and treatments).

60 PETROSKI, *supra* note 34, at 235 (stressing the importance of locating "the next anonymous glitch before it can do any harm"). *See also* Bettina B. F. Wittneben, *The Impact of the*

In fact, complexity theorists suggest that detecting and experiencing some level of error may have a stabilizing effect over complex innovation systems and can increase their anti-fragility.[61]

Lastly, while this Article concentrates on the significance of negative information for scientific and technological advancement, errors are also drivers of creativity in the arts. Recognizing one's own mistakes can be a difficult psychological experience.[62] Yet, it is also an experience that cultivates flexibility, shows us the world from previously unseen angles, and allows us to imagine new realities or generate new narratives—all of which constitute the building blocks of creativity.[63] Errors are intertwined in art, poetry, and humor. Creativity in these domains is very much based on the human capability to conjure up the world not only exactly as it is, but also as it is not. [64] In fact, the ability of art to elicit an emotional response very much relies on this gap between reality and its perceptions.[65] As poet Anne Carson astutely observed:

> that what we are engaged in when we do poetry is error,
> the willful creation of error, the deliberate break and complication of
> mistakes
> out of which may arise
> unexpectedness.[66]

The foregoing discussion unraveled the close nexus between error and innovation and the significance of negative knowledge for progress in various domains. This analysis also reveals that the enormous benefits of negative knowledge for innovation depend very much on "access to error," namely on the recognition, acknowledgement, exposure, and dissemination of negative information. Errors that are not detected and negative information that does not see daylight are unlikely to advance innovation. In fact, they are likely to hinder and

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Fukushima Nuclear Accident on European Energy Policy, 15 ENVTL. SCI. & POL'Y 1, 1 (2012) (describing how the failures in the Fukushima nuclear plant led other countries to reevaluate and update their nuclear safety policies).

61 TALEB, *supra* note 33, at 85.

62 *See infra* notes 122–125 and accompanying text.

63 SCHULZ, *supra* note 26, at 328 (maintaining that the human capacity to err is "inseparable from our imagination."). *Cf.* JULIE E. COHEN, CONFIGURING THE NETWORKED SELF 16–19 (2012) (emphasizing the role of "tinkering" and "play" in the flourishing of human creativity). *See also* Jason S. Moser et. al, *Mind Your Errors: Evidence from a Neural Mechanism Linking Growth Mindset to Adaptive Posterror Adjustments*, 22 PSY. SCI. 1484 (2011) (evidence from a neural experiment suggesting a positive link between a "growth mindset" and the ability to adapt and learn from mistakes).

64 SCHULZ, *supra* note 26, at 323–30.

65 *Id.* at 217, 319.

66 ANNE CARSON, *Essay on What I Think About Most*, *in* MEN IN THE OFF HOURS 30, 35 (2000).

delay it.[67] The next Part proceeds to demonstrate that the principal legal, institutional, and social structures that regularly incentivize the diffusion of positive knowledge do not adequately promote access to error.

II. The Access-to-Error Conundrum

The intellectual property system is the primary legal mechanism delegated with the explicit mission of encouraging innovation through the grant of exclusive rights.[68] Yet, innovation scholarship has long recognized that the grant of private intellectual property rights is not the sole method for stimulating innovative activity. The reputational awards and prizes offered by the scientific establishment, as well as direct state funding, can supplement and sometimes substitute IP incentives.[69] However, a close look reveals that all these mechanisms have significant constraints when it comes to promoting the diffusion of negative knowledge.

A. *IP and Its Constraints*

According to conventional wisdom, the grant of exclusive rights in the form of patents or copyrights is a principal tool for overcoming public goods problems and incentivizing creators and inventors.[70] Contemporary IP theory further recognizes that the intellectual property regime should not merely motivate innovators to engage in innovative activity but should also provide incentives for commercializing and diffusing innovations.[71] In addition, conventional wisdom maintains that

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[67] *See infra* Part II.C.

[68] U.S. CONST. art. I, § 8, cl. 8 (Congress is empowered "[t]o promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries.").

[69] For prominent scholarship discussing prizes and state-supported funds as means for promoting innovation, *see* Brian D. Wright, *The Economics of Invention Incentives: Patents, Prizes, and Research Contracts*, 73 AM. ECON. REV. 691 (1983) (analyzing the choice between patents, prizes, and direct contracting for research services as means for promoting innovation); Joseph E. Stiglitz, *Economic Foundations of Intellectual Property Rights*, 57 DUKE L.J. 1693 (2008) (discussing prizes and state-supported research as substitutes to the patent system); Steven Shavell & Tanguy van Ypersele, *Rewards Versus Intellectual Property Rights*, 44 J.L. & ECON. 525 (comparing intellectual property incentives with government awarded rewards as means for stimulating innovation); Kapczynski & Syed, *supra* note 7, at 1952 (discussing peer-review systems as means for promoting non-excludable research); Rebecca S. Eisenberg, *Proprietary Rights and the Norms of Science in Biotechnology Research*, 97 YALE L.J. 177, 183–84 (1987) (discussing scientific rewards that are based on "recognition" and "esteem"); *Cf.* Daniel J. Hemel & Lisa Larrimore Ouellette, *Beyond the Patents—Prizes Debate*, 92 TEX. L. REV. 303, 310–321 (2013) (discussing the role of R&D-related tax incentives in incentivizing innovation).

[70] *See, e.g.*, WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 20–21 (2003); Kenneth W. Dam, *The Economic Underpinnings of Patent Law*, 23 J. LEGAL STUD. 247 (1994).

[71] *See, e.g.*, F. Scott Kieff, *Property Rights and Property Rules for Commercializing Inventions*, 85 MINN. L. REV. 697 (2001) (emphasizing the role of the patent system in facilitating commercialization of nascent inventions); Ted Sichelman, *Commercializing Patents*, 62 STAN. L. REV. 341 (2010) (calling for a reform in patent law to encourage substantial commercialization of

intellectual property policy should balance between the need to encourage innovation and the social costs imposed on users, competitors, and follow-on innovators who need to access and use IP protected subject matter—a balance commonly described as "the incentive-access" paradigm.[72] As part of this balance, intellectual property doctrine sets out various exceptions and limitations to the scope of IP rights and further requires inventors to disclose sufficient information about their inventions in return for the grant of exclusive rights.[73]

However, these fundamental insights about IP's incentive structure have limited value when it comes to negative knowledge. First, intellectual property as an "incentive to create" is largely irrelevant with respect to the negative. In many instances, negative knowledge is not intentionally created but is rather a byproduct of an attempt to produce positive knowledge. Consider, for example, information that transpires in the course of drug development showing that a certain pharmaceutical composition is *not* efficient.[74] In other instances, errors unintentionally occur as an inevitable part of technological endeavor in diverse fields, from the building of boats[75] to the design of nuclear plants[76] or electricity networks.[77] Simply put, errors are embedded in every human activity.[78] Providing a legal incentive to create them is unnecessary and undesirable. As the foregoing discussion indicates, the principal challenge with errors and negative information is not incentivizing their creation but incentivizing their exposure, dissemination, and diffusion.

But in this respect, too, IP is unlikely to play a significant role. The exclusionary basis underlying intellectual property rights is largely dysfunctional with regard to negative information. Amy Kapczynski

new inventions); *cf.* Gaia Bernstein, *In the Shadow of Innovation*, 31 CARDOZO L. REV. 2257 (2010) (calling for promoting the diffusion of new technologies); Camilla A. Hrdy, *Commercialization Awards*, 2015 WIS. L. REV. 13 (maintaining that patents under-reward commercialization).

72 On the "incentive-access" paradigm as the prevalent paradigm in intellectual property discourse, *see*, *e.g.*, LANDES & POSNER, *supra* note 70, at 66.

73 *See, e.g.*, SHELDON W. HALPREN, ET AL., FUNDAMENTALS OF UNITED STATES INTELLECTUAL PROPERTY LAW: COPYRIGHT, PATENT, TRADEMARK 197–203 (3d ed. 2011). Notably, disclosure of inventions is often perceived as one of the justifications of the patent system. *See, e.g.*, Wendy J. Gordon, *Intellectual Property*, *in* THE OXFORD HANDBOOK OF LEGAL STUDIES 617, 632 (Peter Can & Mark Tushnet eds., 2003) ("The incentive to disclose theory suggests that a patent is granted to encourage . . . disclosure of the invention . . . .").

74 For examples of negative findings that transpired in the process of drug development, *see infra* notes 182–184 and accompanying text.

75 PETROSKI, *supra* note 54, at 329–30 (discussing errors in ship construction that were exposed after the sinking of the Titanic).

76 *See supra* notes 57–58 and accompanying text.

77 Rosato et al., *supra* note 53.

78 *Cf.* PETROSKI, *supra* note 34, at 9 ("Because man is fallible, so are his constructions, however."). For further discussion of this point, *see infra* notes 250–257 and accompanying text.

and Talha Syed have recently conceptualized this point by introducing the notion of a "continuum of excludability."[79] Under this conceptualization, some information products are more difficult to exclude than others and are therefore less disposed to the set of incentives offered by the IP system.[80]

Negative information is a paradigmatic case of low excludability.[81] Much like positive information goods, negative information is easy to duplicate. Yet, unlike positive knowledge, negative knowledge does not easily translate into material objects, and it is extremely difficult to trace and control its unauthorized use by third parties.[82] For example, information that a certain biological mechanism is *not* efficient in overcoming transplant rejection, or that a certain factor has *no* link to autism, may be an important step on the way to deciphering the mechanism of transplant rejection or understanding the causes of autism.[83] Yet, at the end of those blind alleys there awaits no tangible product, and this negative information does not directly translate into a drug, method, or device.[84] As a result, it is often impossible to identify third parties who actually absorbed and utilized such negative knowledge and to distinguish them from others who avoided the wrong path for various other reasons.[85] Therefore, parties in possession of negative information will often be unable to internalize its benefits through dissemination.[86] Put differently, intellectual property incentives that are based on exclusion, coupled with the low excludability of negative knowledge, make the intellectual property system an unsuitable vehicle for incentivizing the diffusion of such knowledge.

To a large extent, patent law reflects this reality and does not purport to protect the negative. Negative information, as such, is neither a "process, machine, manufacture, or composition of matter," nor translates into a "useful" and operative object.[87] For example, the

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79 Kapczynski & Syed, *supra* note 7, at 1906.

80 *Id.* at 1904–06.

81 *Id.* at 1923–25.

82 *Id.* at 1920 (observing that the more a good can be deployed without necessary connection to identifiable material goods, the less excludable it will be); *cf.* Graves, *supra* note 7, at 411 (discussing the difficulty to show "non-use" of negative knowledge in trade secret infringement claims).

83 The examples are based on the cases discussed in Part II.B, *infra* notes 108–115 and accompanying text.

84 *Cf.* Carol M. Rose, *Scientific Innovation and Environmental Protection: Some Ethical Considerations*, 32 ENVTL. L. 755, 764 (2002) ("[R]ational economic decision-making favors investments in scientific investigation . . . where the end-product can be turned into property.").

85 Kapczynski & Syed, *supra* note 7, at 1916 (observing that when "use" involves merely absorbing the information into thought, it may be technically impossible to monitor and prevent).

86 *Cf.* TALEB, *supra* note 33, at 66 ("Sadly, the benefits of errors are often conferred on others . . . .").

87 For the eligibility requirements for patent protection, *see generally* the Patent Act, 35 U.S.C. § 101 *et seq.*; PAUL GOLDSTEIN & R. ANTHONY REESE, COPYRIGHT, PATENT, TRADEMARK AND RELATED STATE DOCTRINES 397–492 (6th ed. 2010).

information that a certain mechanism for the protection a nuclear power station does *not* work would itself be ineligible for patent protection, even if it is new, nonobvious, and valuable.

IP's focus on positive knowledge is not confined to the side of incentives but also extends to the side of access. First, as more fully discussed below,[88] the various IP doctrines that set out limitations to the scope of IP rights are designed against the narrative of access to positive information and are not equally concerned with facilitating access to negative knowledge. The case of reverse engineering is one illustration: while several IP doctrines allow the reverse engineering of IP protected products, some of these exceptions are explicitly confined to reverse engineering for the purpose of achieving "interoperability"—i.e., for accessing positive information that is necessary for the development of a new software or device that would be compatible with the original product.[89] Conversely, the reverse engineering of technologies for the purpose of exposing fallibilities, flaws, and errors may constitute intellectual property infringement. This almost exclusive focus on access to positive knowledge implies that in some cases, the intellectual property system may actively bar access to error by pronouncing such access IP infringement.

Secondly, as part of its access-incentive paradigm, the patent system instructs the disclosure of patented inventions to the public.[90] Yet, patent law's disclosure requirements are confined to the disclosure of positive information that will enable competitors to reproduce the invention after patent expiration or to carry out follow-on inventions.[91] The obligation to disclose does not extend to information such as failures or blind alleys accumulated on the way to the invention that will often remain confidential.[92]

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88 *See infra* Part III.A.

89 *See, e.g.*, Digital Millennium Copyright Act, 17 U.S.C. § 1201(f):

> Reverse engineering.—(1) . . . a person who has lawfully obtained the right to use a copy of a computer program may circumvent a technological measure that effectively controls access to a particular portion of that program *for the sole purpose of identifying and analyzing those elements of the program that are necessary to achieve interoperability of an independently created computer program with other programs* . . . .

(emphasis added); *cf.* Directive 2009/24/EC of the European Parliament and of the Council of 23 April 2009 on the Legal Protection of Computer Programs, art. 6(1), 2009 O.J. (L 111) 16 ("The authorisation of the rightholder shall not be required where reproduction of the code and translation of its form . . . *are indispensable to obtain the information necessary to achieve the interoperability of an independently created computer program with other programs*, provided that the following conditions are met . . . .") (emphasis added); *cf.* Sega Enterprises Ltd. v. Accolade, Inc., 977 F.2d 1510, at 1520 (9th Cir. 1993) (holding that the reverse engineering of a computer program in order to make a "compatible" product constitutes fair use, but noting that these circumstances are non-exhaustive).

90 Patent Act, 35 U.S.C. § 112(a); HALPREN et al., *supra* note 73, at 197–203.

91 HALPREN et al., *supra* note 73, at 199.

92 *See, e.g.*, Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and*

Finally, negative know-how can sometimes qualify for trade secret protection.[93] However, unlike patent and copyright protection, trade secret protection incentivizes enclosure, not disclosure.[94] Thus, the protection afforded to negative knowledge under trade secret law does not encourage broad diffusion of negative information. Rather, it facilitates its concealment under a veil of secrecy and further hinders access by third parties.

The foregoing discussion highlights the embedded shortcomings of the intellectual property system as a mechanism for incentivizing the exposure and dissemination of negative knowledge. The following sub-Part proceeds to examine whether additional institutions that regularly advance the diffusion of knowledge may be better suited for fostering the diffusion of errors.

B. *Alternatives to IP and Their Constraints*

Scholarship in the field of innovation has long acknowledged that intellectual property rights are not the only method for incentivizing innovation and diffusing knowledge. Reputational awards and prizes offered by the scientific establishment, as well as direct state funding in the form of research grants, often supplement and sometimes substitute IP incentives.[95] In fact, when it comes to knowledge diffusion we often regard the scientific establishment as the opposite of the intellectual property system: while IP is based on exclusion, progress in science is based on a culture of sharing information, subjecting such information to peer review, and allowing scientists to build upon the experiences of their peers.[96]

Experimental Use, 56 U. CHI. L. REV. 1017, 1029 n.52 (1989) (referring to a practice of patent applicants who withhold information from patent specifications and continue to protect their know-how as trade secrets); R2 Medical Systems, Inc. v. Katecho, Inc., 931 F. Supp. 1397, 1420 (N.D. Ill. 1996) (trade secrets may cover information that lies outside the disclosure requirements of the claimed invention).

93 UNIFORM TRADE SECRETS ACT § 1 cmt. 5 (NAT'L CONF. OF COMM'RS ON UNIFORM STATE LAWS, amended 1985) ("The definition [of a trade secret] includes information that has commercial value *from a negative viewpoint* . . . .") (emphasis added). *See also* Deepa Varadarajan, *Trade Secret Fair Use*, 83 FORDHAM L. REV. 1401, 1410 (2014) (referring to the protection of negative know-how under trade secret law); Graves, *supra* note 7, at 389 (criticizing the protection of negative knowledge as a trade secret).

94 Eisenberg, *supra* note 69, at 194–95 (explaining how trade secrecy conflicts with disclosure); Varadarajan, *supra* note 93, at 1419 ("[Trade secrets are] premised on secrecy rather than disclosure.") (footnote omitted).

95 *See supra* note 69.

96 Eisenberg, *supra* note 69 (exploring the gap between the norms and incentives of research science and those of intellectual property); Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 89–92 (1999) (discussing traditional norms of science that promote a "communal" culture of freely available scientific information and unimpeded access to research results); Robert P. Merges, *Property Rights Theory and the Commons: The Case of Scientific Research*, 13 SOC. PHIL. & POL'Y 145 (1996); Peter Lurie & Allison Zieve, *Sometimes the Silence Can Be Like the Thunder: Access to*

Yet, a closer look at these alternatives reveals that they, too, suffer from significant constraints when it comes to the diffusion of negative knowledge. A large and rapidly developing body of literature from diverse scientific fields indicates that despite the romantic view of science as objective, impartial, and self-correcting, scientists actually face significant obstacles in publishing negative results.[97] Scientific culture commonly analogizes "high-impact" with "positive", whereas experimental outcomes that do not display a positive, statistically significant effect often do not pass peer-review systems.[98] This bias against publishing negative findings has been documented across numerous scientific disciplines, including biology,[99] medicine and public health,[100] behavioral sciences,[101] and economics.[102] Although the prejudice against negative results has been known to exist for decades, empirical evidence suggests that the problem has increased in recent years.[103]

Pharmaceutical Data at the FDA, 69 LAW & CONTEMP. PROBS. 85, 85 (2006) (stressing that science's narrative of progress is based on the free publication of study results and data, in contrast to the commercial sector); *but cf.* Jorge L. Contreras, *Data Sharing, Latency Variables, and Science Commons*, 25 BERKELEY TECH. L.J. 1601, 1603–06 (2010) (warning that the ethos of scientific data sharing is becoming vulnerable).

97 For prominent discussions of this phenomenon, *see* Natalie Matosin et al., *Negativity Towards Negative Results: A Discussion of the Disconnect Between Scientific Worth and Scientific Culture*, 7 DISEASE MODELS & MECHANISMS 171 (2014) (maintaining that scientific culture is significantly biased against negative results); Jonathan Schooler, *Unpublished Results Hide the Decline Effect*, 470 NATURE 437 (2011) ("[W]e do not generally have access to 'negative results' . . . . "); Kay Dickersin, *How Important Is Publication Bias? A Synthesis of Available Data*, 9 AIDS EDUC. & PREVENTION 15 (1997) (discussing editorial bias against negative results); Daniele Fanelli, *Do Pressures to Publish Increase Scientists' Bias? An Empirical Support from US States Data*, 5(4) PLOS ONE (2010), at 1 (presenting empirical evidence for this bias); Jens B. Asendorpf et al., *Recommendations for Increasing Replicability in Psychology*, 27 EUR. J. PERSONALITY 108, 113 (2013) (discussing the reluctance of editors in the field of psychology to publish null findings or results that run counter to initial hypotheses).

98 Matosin, *supra* note 97. For a recent discussion of this phenomenon in legal scholarship, *see* Seymore, *supra* note 7, at 2052–53 (explaining how the peer review system discriminates against negative findings).

99 Ryan D. Csada et al., *The "File Drawer Problem" of Non-Significant Results: Does It Apply to Biological Research?*, 76 OIKOS 591 (1996) (documenting an anti-negative publication bias in biology).

100 Dickersin, *supra* note 97 (discussing the publication bias in the fields of medicine and public health); Panayiotis A. Kyzas et al., *Almost All Articles on Cancer Prognostic Markers Report Statistically Significant Results*, 43 EUR. J. OF CANCER 2559 (2007) (documenting a similar effect in cancer research).

101 Robert Rosenthal, *The "File Drawer Problem" and Tolerance for Null Results*, 86 PSYCHOL. BULLETIN 638 (1979) (discussing the bias against publication of "null results" in psychology); Asendorpf et al., *supra* note 97.

102 Daniele Fanelli, *Negative Results are Disappearing from Most Disciplines and Countries*, 90 SCIENTOMETRICS 891, 894–95 (2011) (presenting empirical evidence for a strong decline in negative results reported in economics and business management literature).

103 *See id.* (analyzing 4,600 papers from various disciplines and countries and concluding that the proportion of reported negative results dropped from thirty percent to fourteen percent between 1990 and 2007). *See also* Annie Franco et al., *Publication Bias in the Social Sciences: Unlocking the File Drawer*, SCIENCE 1504 (Sept. 19, 2014) (analyzing 221 studies in the social

Importantly, this bias is not confined to failures to validate one's *own* hypotheses that lead to insignificant results or null findings.[104] It subsists even when such negative results refute or falsify findings that were previously published by others.[105] In other words, scientists may fail to publish falsifications and refutations of existing hypotheses, or they may have to compromise on less influential publication platforms.[106] Furthermore, even when such negative information eventually comes to light, it generally has less impact, receives fewer citations, and attracts less academic and public attention than positive information.[107]

One of the prominent illustrations of this phenomenon concerns a 1998 study that suggested a causal link between the MMR child vaccine and autism.[108] That controversial study was followed by at least twenty other studies by different investigators, spanning across numerous countries and employing a multitude of epidemiological and statistical methods, all of which discovered no link between the vaccine and autism.[109] Yet, despite the accumulation of refutations, the retraction of the original study by the prestigious journal in which it was originally published,[110] and the disqualification of its principal investigator from practicing medicine in the UK,[111] this significant negative information failed to attract the same level of public attention as the original, seemingly-positive-and–subsequently-retracted, study.[112]

Another example was recently documented by medical researcher David Vaux after the repeated failures of his research team to replicate a study with positive findings that suggested a paradigm-changing solution to organ transplant rejection.[113] Although the original study was

sciences conducted between 2002 and 2012, and reporting that "few null results are published").

104 According to the distinctions introduced earlier, such cases belong to the first category of negative information. *See supra* notes 26–27 and accompanying text.

105 Under this Article's proposed distinctions, these cases belong to the second category. *Id.*

106 *See, e.g.*, Matosin et al., *supra* note 97, at 171 (explaining that correcting the literature is "an uphill battle," and that "'high impact' journals . . . might as well have a bold statement in the submission form: *negative results are not accepted*").

107 Matosin et al., *supra* note 97, at 172; Daniele Fanelli, *Positive Results Receive More Citations, But Only in Some Disciplines*, 94 SCIENTOMETRICS 701 (2013) (finding evidence for a citation bias in favor of the positive in Neuroscience & Behavior, Molecular Biology & Genetics, Clinical Medicine, and Plant and Animal Science, but not in other disciplines).

108 AJ Wakefield et al., *Ileal-Lymphoid-Nodular Hyperplasia, Non-Specific Colitis, and Pervasive Developmental Disorder in Children*, 351 LANCET 637 (1998); retraction in 375 LANCET 445 (2010).

109 Jeffrey S. Gerber & Paul A. Offit, *Vaccines and Autism: A Tale of Shifting Hypotheses*, 48 CLINICAL INFECTIOUS DISEASES 456 (2009) (reviewing the methodologies and the results of the original study and the refuting studies).

110 *Supra* note 108.

111 John F. Burns, *British Medical Council Bars Doctor Who Linked Vaccine With Autism*, N.Y. TIMES (May 24, 2010), http://www.nytimes.com/2010/05/25/health/policy/25autism.html.

112 Matosin et al., *supra* note 97, at 171.

113 Vaux, *supra* note 40.

published in *Nature*, with Vaux himself as one of the reviewers, both *Nature* and *Nature Medicine* ultimately rejected Vaux's negative findings.[114] The refuting paper was eventually accepted for publication in another journal, but it attracted significantly fewer citations than the original, seemingly positive, paper, which led Vaux to wistfully conclude: "Little did we know that instead of providing an answer to transplant rejection, these experiments would teach us a great deal about editorial practices and the difficulty of correcting errors once they appear in the literature."[115]

Negative information faces similar difficulties in securing academic grants and state funding. Funding schemes, too, prefer research proposals that aim to produce positive results over research that aims to refute—or replicate—existing findings.[116] Leaders of funding programs confirm that research proposals seeking to replicate (and possibly falsify) previous results are "not . . . at or near the top of their priority lists,"[117] and "in all likelihood would be turned down."[118] Moreover, policy guidelines of major grants require that grant recipients publish "*significant*" (namely positive) findings but impose no parallel duty to disclose falsifications and negative results.[119] Policies of other funding schemes provide that grant recipients are expected to share their research data only after publication of their findings occurs, which implies that research with negative findings that might never reach publication may very well remain in the file drawer.[120]

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114 *Id.*

115 *Id.*

116 *See, e.g.*, Beryl Lieff Benderly, *Medical Research Needs A Collaborative Funding Model*, DISCOVER MAGAZINE (May 14, 2013), http://discovermagazine.com/2013/june/06-medical-research-needs-a-collaborative-funding-model (maintaining that negative findings are "crucial but less grant-worthy" and are discouraged by the current funding schemes); Nathaniel C. Smith, Jr., *Replication Studies: A Neglected Aspect of Psychological Research*, 25 AM. PSYCHOL. 970 (1970) (discussing the absence of replication studies in psychology and listing "lack of funding" as a potential reason); *Unreliable Research*, *supra* note 38 (describing the reluctance of major grants to fund replications); Asendorpf et al., *supra* note 97, at 115 (calling for a change of policy among funding agencies to support replication studies in psychology).

117 *Unreliable Research*, *supra* note 38 (quoting James Ulvestad, head of the division of astronomical sciences at the National Science Foundation).

118 *Unreliable Research*, *supra* note 38 (quoting Helga Nowotny, former president of the European Research Council); *but cf.* Francis S. Collins & Lawrence A. Tabak, *NIH Plans to Enhance Reproducibility*, 505 NATURE 612, 613 (2014) (announcing a forthcoming change in NIH policies on funding replications).

119 *See The National Science Foundation, Proposal and Award Policies and Procedures Guide*, Part II, at VI-8 (effective Jan. 18, 2011), http://www.nsf.gov/pubs/policydocs/pappguide/nsf11001/nsf11_1.pdf ("Dissemination and Sharing of Research Results. Investigators are expected to promptly prepare and submit for publication, with authorship that accurately reflects the contributions of those involved, *all significant findings* from work conducted under NSF grants.") (emphasis added).

120 *See The National Institute of Health—Grants Policy Statement*, § 8.2.3.1–Data Sharing Policy at IIA-88, http://www.udel.edu/research/pdf/nih-policy.pdf ("NIH endorses the sharing of final research data . . . and expects and supports the timely release and sharing of final research data from NIH-supported studies for use by other researchers. 'Timely release and sharing' is

The emerging picture is clear: the primary institutional and social structures that supplement, and sometimes substitute, the intellectual property system as mechanisms for the diffusion of knowledge do not present viable alternatives when it comes to incentivizing the diffusion of errors.

Multidisciplinary literature offers various explanations for this preference of positive knowledge over negative knowledge. Briefly, philosophers of science emphasize human attraction to the positive and the inclination to connect it with "truth" and "progress"—in the words of Francis Bacon, "to the nature of the mind of all men it is consonant for the affirmative or active to effect more than the negative or privative."[121] Psychologists highlight confirmation bias, namely the human tendency to seek confirmation of current beliefs and disregard contradictory evidence, and explicitly observe that this bias does not skip scientists.[122] Psychological literature further provides that the human aversion to doubt and uncertainty hinders the recognition of error,[123] while research in neuroscience indicates that admitting one's own errors can be a painful and traumatic experience.[124] Innovators and scientists, again, are no exception.[125]

Intertwined with all of these factors are prevalent cultural perceptions that regard error and failure as disgraceful, distasteful, and humiliating.[126] Thus, negative results in science are often considered a "taboo" that might negatively reflect on the scientists who attained them.[127] Likewise, in commercial settings, failed entrepreneurs receive

defined as "*no later than the acceptance for publication of the main findings* from the final data set.") (emphasis added).

121 FRANCIS BACON, OF THE PROFICIENCE AND ADVANCEMENT OF LEARNING, DIVINE AND HUMAN 49 (1605). *See also* POPPER, CONJECTURES AND REFUTATIONS, *supra* note 31, at 5–8 (critically describing the human inclinations to concentrate on "knowledge" and to believe that truth is "manifested").

122 DANIEL KAHENMAN, THINKING, FAST AND SLOW 63 (2011) ("Contrary to the rules of philosophers of science who suggest testing hypotheses by trying to refute them, people *(and scientists, quite often)* often seek data that are likely to be compatible with the beliefs they currently hold.") (emphasis added).

123 SCHULZ, *supra* note 26, at 164–70 (discussing "the allure of certainty" and the aversion of uncertainty as potential causes of "wrongness" and its denial).

124 ROBERT A. BURTON, M.D., ON BEING CERTAIN: BELIEVING YOU ARE RIGHT EVEN WHEN YOU'RE NOT 86–101 (2008) (presenting evidence from research in neuroscience that the sensation of "being right" is psychologically similar to addiction, which possibly explains the difficulty to admit error); *cf.* KAHENMAN, *supra* note 122, at 219–20 (2011) (discussing psychological findings about the reluctance to admit one's own errors); LIVIO, *supra* note 26, at 218 (noting that the experience of being wrong in a major enterprise is psychologically traumatic); SCHULZ, *supra* note 26, at 191–94 (maintaining that realizing one's wrongness is a "psychological construction site").

125 LIVIO, *supra* note 26, at 96, 99.

126 SCHULZ, *supra* note 26, at 27; SANDAGE, BORN LOSERS, *supra* note 28, at 87, 251 (2005) (discussing the public image of failure as a "character deficiency").

127 Matosin et al., *supra* note 97, at 171–72.

little or no credit, and "what is worse, [get] no respect."[128]

C. *The Social Costs*

Whatever its sources, the institutional and social disfavor of negative knowledge, coupled with the absence of intellectual property incentives to disseminate it, hinder innovation and produce significant social costs. Many scientific and technological disciplines suffer from a "file drawer effect," according to which positive knowledge gets published but "the file drawers back at the lab are filled with the 95% of the studies that show non-significant . . . results."[129] Failed experiments, negative findings, and refuted hypotheses are shelved-off and never see daylight. As a result, the information available for interpretation by the scientific community is inherently deficient, which in turn distorts the "big picture" in various scientific and technological fields.[130]

The fact that refutations, insignificant results, and negative findings never see daylight provides a partial explanation to the troubling and accumulating evidence that a significant portion of papers reporting positive outcomes are actually erroneous.[131] For example, industry scientists who tried to reproduce fifty-three "landmark studies" in the field of cancer research reported success in only eleven percent of the cases;[132] a recent large-scale replication effort in psychology was successful in less than forty percent of the cases,[133] while researchers who attempted to replicate studies in empirical economics concluded that "inadvertent errors in published empirical articles are a commonplace rather than a rare occurrence."[134]

128 TALEB, *supra* note 33, at 79.

129 Rosenthal, *supra* note 101, at 638 (coining the term "file drawer problem"). *See also* Jeffrey D. Scargle, *Publication Bias (The "File-Drawer Problem") in Scientific Inference*, 14 J. SCI. EXPLORATION 91 (2000); Matosin et al., *supra* note 97, at 171; Seymore, *supra* note 7, at 2051–54 (discussing the "file drawer" problem); ALIZA Y. GLASNER ET AL., FACILITATING MEDICAL PRODUCT DEVELOPMENT THROUGH VOLUNTARY DATA SHARING: A LOOK AT THE LEGAL ISSUES 7 (Oct. 1, 2014), http://ssrn.com/abstract=2535480 (indicating that negative results "never see the light of day").

130 Schooler, *supra* note 97 (observing that due to under-dissemination of errors, many scientifically discovered effects seem to diminish with time, a phenomenon dubbed "the decline effect"); Franco et al., *supra* note 103, at 1502 (highlighting the difficulty to assess the state of knowledge in a field or on a particular topic "because null results are largely unobservable to the scholarly community"); Ioannidis, *supra* note 38, at 698–99 (arguing that "most published research findings are probably false" and listing the aversion for negative results as one of the primary causes).

131 Ioannidis, *supra* note 38.

132 Glen Begley & Lee M. Ellis, *Raise Standards for Preclinical Cancer Research,* 483 NATURE 531 (2012).

133 Open Science Collaboration, *Estimating the Reproducibility of Psychological Science*, 349 SCIENCE 943 (2015) (reporting the results of a large scale reproducibility study in psychology according to which out of 100 prominent papers only 39 were unambiguously replicated).

134 William G. Dewald et al., *Replication in Empirical Economics: The Journal of Money, Credit and Banking Project*, 76 AM. ECON. REV. 587, 587 (1986). For a recent study in economics that reached a similar conclusion, see Andrew C. Chang & Phillip Li, *Is Economics Research*

In addition to this distortive effect, the current incentive structure in the innovation ecosystem drives entrepreneurs and scientists away from potentially groundbreaking effort. Commercial firms investing in research and development would naturally favor research that is likely to yield positive outcomes, which could eventually translate into IP-protected products. Scientists in academic settings, too, may prefer to direct their efforts to familiar research paths and avoid engaging in high-risk projects with substantial likelihood of failure.[135]

In some cases, the difficulty to access and disseminate negative information creates significant hazards and may even risk lives. This can happen when flawed scientific hypotheses "live on" despite multiple refutations and may affect public behavior in harmful manners.[136] The story of the vaccination studies is again illustrative. The multiple studies that refuted the link between child vaccination and autism attracted substantially less public attention than the subsequently retracted single study which had originally suggested such a link.[137] Concomitantly, a decrease in child immunization occurred, both in the United States and elsewhere,[138] leading to rising concerns for the reemergence of endemic diseases with proven substantial harms.[139] In other instances, selective publication of clinical trial results—with positive results being published and negative results being shoved into the file drawer—can yield adverse health consequences.[140] In yet other cases, the accumulation of non-exposed errors can lead to sudden

Replicable? Sixty Published Papers from Thirteen Journals Say "Usually Not" FINANCE AND ECONOMICS DISCUSSION SERIES 2015-083. WASHINGTON: BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM, http://dx.doi.org/10.17016/FEDS.2015.083 (reporting a replication study of 60 economic papers that was successful in less than fifty percent of the cases, and concluding that "economics research is generally not replicable").

135 Schooler, *supra* note 97.

136 *Unreliable Research*, *supra* note 38, at 6 (observing that such flawed papers "may develop a bad reputation among those in the know . . . [b]ut to outsiders they will appear part of the scientific canon.").

137 *Supra* notes 108–112 and accompanying text.

138 Matosin et al., *supra* note 97 at 171; V. A. A. Jansen et al., *Measles Outbreaks in A Population With Declining Vaccine Uptake*, 301 SCI. 804 (2003) ("Although all of the claims of serious side effects have been refuted, there has been a decline in the uptake of the MMR vaccine in the United Kingdom leading to a growing pool of susceptible individuals."); Michael J. Smith et al., *Media Coverage of the Measles-Mumps-Rubella Vaccine and Autism Controversy and Its Relationship to MMR Immunization Rates in the United States*, 121 PEDIATRICS 836 (2008) (documenting a significant increase in non-receipt of the MMR vaccination in the US, in close proximity to the publication of the Wakefield study, yet maintaining that the decrease is unlikely related to extensive media coverage of the issue).

139 Jansen et al., *supra* note 138, at 804 (documenting the risk of the "re-establishment of endemic measles and accompanying mortality").

140 Erick H. Turner et al., *Selective Publication of Antidepressant Trials and Its Influence on Apparent Efficacy*, 358 NEW ENG. J. MED. 252 (2008) (investigating the publication of negative and positive clinical trial results of antidepressants and concluding that unlike positive results, negative results were often not published or were published in a way that conveyed a positive outcome). For further discussion of health hazards due to negative results about drugs being withheld from the public eye, *see* Part II.B *infra*, notes 182–184 and accompanying text.

cascades with tragic outcomes.[141] Analyses of the collapse of bridges, the crash of airplanes, and the failure of nuclear plants suggest that accumulating small-scale failures that are undetected or ignored frequently precede such catastrophes.[142]

Finally, and importantly, it is difficult to learn from our collective mistakes if these mistakes never see daylight. The insufficient access to negative knowledge results in errors being repeated and valuable innovation resources being poured into blind alleys.[143] For example, the heads of the NIH have recently expressed a concern that the difficulty of detecting failures in preclinical research pointlessly directs valuable funds to costly but futile clinical trials in humans.[144] The inadequate access to error, in other words, creates substantial waste.

Altogether, the analysis in this Part demonstrates that the primary mechanisms that incentivize the diffusion of positive knowledge—namely intellectual property rights, reputational rewards, and state-supported funding schemes—have limited value in promoting the dissemination of negative knowledge. It also highlights a serious and pressing need to improve the diffusion of negative information. Can innovation policy resolve this conundrum and adopt measures that would facilitate access to error? The following Part proceeds to explore this question.

III. TOWARD A PARADIGM OF ACCESS-TO-ERROR

To a considerable extent, the challenge of access-to-error can be framed as a collective action problem.[145] Cooperation in the disclosure and sharing of negative knowledge will significantly increase joint social welfare and in many cases will also benefit the relevant stakeholders (scientists, innovators, and even industry players). Yet, in light of the current incentive structure, most players fail to cooperate. Instead, they adopt a self-interest oriented approach and adhere to a

141 *See* discussion in Part I *supra*, notes 54–61 and accompanying text.

142 *Id.*

143 *See* Thomas O. McGarity & Sidney A. Shapiro, *The Trade Secret Status of Health and Safety Testing Information: Reforming Agency Disclosure Policies*, 93 HARV. L. REV. 837, 845 (1980); Richard S. Fortunato, Note, *FDA Disclosure of Safety and Efficacy Data: The Scope of Section 301(J)*, 52 FORDHAM L. REV. 1280, 1285 (1984) (discussing waste resulting from insufficient disclosure of negative clinical trials data); Graves, *supra* note 7, at 388–89 (noting that trade secret protection of negative knowledge requires firms to wastefully replicate mistakes in order to avoid liability for infringement); Khoury, *supra* note 7, at 477 (noting that trade secret protection of negative information yields "Sisyphus-type" undertakings); Seymore, *supra* note 7, at 2054 (discussing the costs to science as a result of non-disclosure of failed experiments).

144 Collins & Tabak, *supra* note 118, at 613.

145 On collective action problems and cooperation dilemma, *see generally* Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243 (1968) (an influential model of a collective action problem in the use of common resources); ELINOR OSTROM, GOVERNING THE COMMONS, THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 1–7 (1990) (discussing the principal theoretical models of collective action dilemma).

policy of enclosure that relegates negative information to the file drawer.[146] This Part, therefore, begins by discussing the classical solutions to problems of collective action: allocation of private rights—in our case, in the form of intellectual property rights—on the one hand, and top-down state intervention on the other hand.[147] It then proceeds to explore a third, commons-based, approach for solving the access-to-error conundrum.

A. *Adjustments to IP Doctrine*

Privatization is often perceived as the primary solution to problems of collective action. Yet, the preceding discussion illuminates its limited value as a means for incentivizing the diffusion of negative knowledge.[148] The analysis further indicates that these shortcomings of intellectual property rights are largely inherent: exclusive rights on non-excludable subject matter are likely to encounter significant difficulties of enforcement and monitoring.[149] It is implausible that we could efficiently overcome these difficulties through the expansion of current rights or the design of new exclusive rights, and this Article does not prescribe either.

However, even if IP is an inadequate vehicle for incentivizing the diffusion of negative knowledge, it can still play a part in promoting access to error by facilitating the side of access. The preceding analysis indicates that the intellectual property regime can hinder access to negative knowledge through various access-barriers.[150] IP can therefore adjust its doctrines so as to lower these barriers. The following paragraphs identify two principal areas for such adjustments. *First*, I propose to calibrate patent law's disclosure requirements to better support an access-to-error policy. *Second*, and relatedly, I suggest crafting the exceptions to IP protection in an error-friendly manner that would allow exposing errors in IP-protected technologies without risking IP infringement.

Several scholars have recently observed that the information disclosed in patent documents is a source of technological literature that, akin to scientific publications, should serve to inform scientists and innovators in relevant technological fields.[151] However, the current

146 In game-theory parlance, this gap between the socially desired result and the players' risk-averse preferences seems to fit the model known as "the assurance game": players will not cooperate to achieve the desired result unless they are assured that most other players would cooperate too. *See* DOUGLAS G. BAIRD ET AL., GAME THEORY AND THE LAW 271 (1998).

147 OSTROM, *supra* note 145, at 8–12.

148 *Supra* notes 79–86 and accompanying text.

149 *Id*. These difficulties also cast significant doubts on a scholarly proposal to initiate an exclusivity-based royalty system for distributing negative knowledge. *See* Cross, *supra* note 7, at 623.

150 *Supra* notes 89–94 and accompanying text.

151 Sean B. Seymore, *The Teaching Function of Patents*, 85 NOTRE DAME L. REV. 621 (2010)

patent regime does not sufficiently allow third parties to detect errors and failures in the disclosed materials. As described earlier, the disclosure requirements under the Patent Act are confined to positive information and do not mandate disclosing errors, mistakes, or other negative knowledge accumulated on the way to the invention.[152] Even more troubling, actual disclosure practices allow patentees to blur positive and negative knowledge in a manner that can hinder identifying the latter. Although patent doctrine explicitly provides that patent specifications must enable "any person skilled in the art . . . to make and use [the invention]"[153] "without undue experimentation,"[154] these provisions are not strictly enforced during patent examination proceedings. In practice, patentees enjoy a presumption in favor of enablement and are not required to reduce their invention to practice and demonstrate that it actually works as claimed in the patent documents.[155]

As a result of this lax disclosure threshold, many patent specifications are not only "intentionally . . . ambiguous"[156] and "obfuscate[] the invention"[157] but may also actually include components that do *not* work.[158] Indeed, Lisa Larrimore Oullette recently presented empirical evidence that many researchers view patents as non-reproducible, some of whom believe that the invention might never even have worked as claimed.[159]

The problem is particularly evident with respect to complex patents in the chemical and pharmaceutical fields, where patent applications are often structured as "cascading claims": the first claims introduce large groups of compounds, narrowing progressively to smaller groups, only one of which represents the actual active ingredient or the actual formulation used by the patentee.[160] In such cases, valuable positive information may be drowned in a long list of compounds that

[hereinafter Seymore, *Teaching Function*] (discussing patent's role in communicating knowledge through disclosure); Lisa Larrimore Ouellette, *Do Patents Disclose Useful Information?*, 25 HARV. J.L. & TECH. 531 (2012) (presenting empirical evidence that many researchers in the field of nanotechnology rely on patents as a source of technical literature).

152 Part II.A *supra*, notes 91–92 and accompanying text.

153 Patent Act, 35 U.S.C. § 112(a).

154 Benjamin N. Roin, Note, *The Disclosure Function of the Patent System (or Lack Thereof)*, 118 HARV. L. REV. 2007, 2017–23 (2005) (discussing the enablement requirement and its application by the courts).

155 Seymore, *Teaching Function*, *supra* note 151, at 630, 638–39 (critically describing the presumption of enablement and the absence of a "reduction to practice" requirement).

156 *Id.* at 638.

157 Larrimore Ouellette, *supra* note 151, at 564.

158 Seymore, *Teaching Function*, *supra* note 151, at 632 (indicating that, with respect to claims for future uses, "there is a real danger that . . . the invention will not work") (footnote omitted).

159 Larrimore Ouellette, *supra* note 151, at 579.

160 HALPREN et al., *supra* note 73, at 250. *See also* Teva Canada Ltd. v. Pfizer Canada Inc., 3 S.C.R. 625, 630 (2012) (Canadian Supreme Court case describing the practice of cascading claims).

were not found to work effectively, or, even worse, were found *not* to work.[161] One recent illustration for blind alleys included in a patent application as "red herrings" concerns a patent for Viagra that was the center of litigation in Canada.[162] Although the patent in that case was eventually invalidated, the outcome was case-specific.[163] As a general matter, disclosure that injects errors into the positive description of the invention will not necessarily risk patent validity.[164] The current disclosure regime therefore generates patent literature that might display negative information as positive knowledge, which impedes the ability of researchers and additional third parties to detect errors in patented technologies.

The situation is aggravated since limitations and exceptions to the scope of intellectual property rights largely ignore the social need to access negative information. The common law "experimental use" exception to patent infringement is extremely narrow and does not apply where there is "a slightest commercial implication,"[165] even if experimentation is performed in an academic setting.[166] Therefore, testing a technology in order to detect errors contained in the patent claims may itself constitute patent infringement.

Likewise, reverse engineering a technology for the purpose of detecting errors may attract liability for patent infringement[167] and—with respect to software products—also for copyright infringement.[168] Patent law lacks any explicit reverse engineering exception,[169] while copyright law's reverse-engineering exceptions concentrate on achieving "interoperability" between software products.[170] Reverse engineering for the purpose of detecting mistakes, errors, and failures

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161 *Teva Canada*, 3 S.C.R. at 634.

162 *Id.* at 634. *See also* the trial court's decision—Teva Canada Ltd. v. Pfizer Canada Inc. 2009 F.C. 638 ("[M]any of other claims and compounds in the patent are 'red herrings,' i.e. they are for claimed compounds which have been found not to work . . . .").

163 *Teva Canada*, 3 S.C.R. at 654 ("I would not make too much of the fact that Claim 1 included over 260 quintillion compounds. The practice of cascading claims . . . is a common one that does not necessarily interfere in every case with the public's right to disclosure.").

164 Atlas Powder Co. v. E.I. Du Pont de Nemours & Co. 750 F.2d 1569, 1576–77 (Fed. Cir.1984) (court acknowledging that an invention could contain "inoperative" claims); Seymore, *Teaching Function*, *supra* note 151, at 632, n.54 ("[C]laims are not necessarily invalid if they encompass inoperative embodiments . . . .").

165 Madey v. Duke Univ., 307 F.3d 1351, 1362 (Fed. Cir. 2002), *cert. denied*, 539 U.S. 958 (2003).

166 *Id.*; Yochai Benkler, *Commons-Based Strategies and the Problems of Patents*, 305 SCI. 1110, 1111 (2004) [hereinafter Benkler, *Strategies*] (describing the research exemption as "illusory" in light of the decision).

167 Jeanne C. Fromer, *Patent Disclosure*, 94 IOWA L. REV. 539, 558–60 (2009) (explaining that reverse-engineering an invention involves "a severe risk of liability for patent infringement").

168 *See supra* note 89 and accompanying text.

169 Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1663 (2003) (discussing the absence of a reverse engineering exception in patent law).

170 *See supra* note 89 and accompanying text.

may well remain outside the scope of these exceptions. Finally, while trade secret laws give leeway to reverse engineering a properly obtained product,[171] trade secret doctrine does not contain a general fair use exception that may enable access to negative knowledge in circumstances beyond reverse engineering.[172]

The foregoing analysis yields two principal policy recommendations for adjustments in intellectual property doctrine. *First*, it supports the recent calls to improve patent law's disclosure requirements and provides them with an additional, and convincing, justification.[173] *Second*, it supports the expansion and recalibration of certain exceptions to intellectual property rights so as to allow certain socially beneficial uses that involve access to negative knowledge.

As with any reform to IP doctrine, the issue of internal tradeoffs deserves attention. In our case, the concern is that the disclosure of negative information that was accumulated as part of R&D activities may allow competitors to benefit from the effort and investment expended by the party possessing the negative knowledge, and more generally, that greater public access to *negative* knowledge would undermine innovators' incentives to produce *positive* knowledge.[174] This concern carries particular weight when negative and positive knowledge are closely intertwined, so that positive solutions can be easily derived from the disclosure of the negative information.[175]

Indeed, the impact on incentives varies across industries and doctrines and is generally uncertain.[176] This Article does not purport to sketch specific doctrinal amendments pertaining to each of the doctrines discussed in this sub-Part, but incentive considerations should be addressed, as a general matter, when crafting particular amendments. For example, mandating a patentee to actively disclose negative information that led to her invention may possibly disrupt the incentive-access balance underlying patent law. In contrast, preventing the deliberate inclusion of errors as part of the description of the invention in the patent application will unlikely yield such an adverse effect. More

171 DONALD S. CHISUM ET AL., UNDERSTANDING INTELLECTUAL PROPERTY LAW 240 (2d ed. 2011) (reverse engineering trade secrets from products obtained by proper means "is a complete defense to a claim of trade secret misappropriation").

172 Varadarajan, *supra* note 93 (advocating the introduction of a fair use exception into trade secret law to allow socially beneficial uses).

173 For recent scholarly calls to strengthen the disclosure regime, *see* Fromer, *supra* note 167, at 544; Larrimore Ouellette, *supra* note 151, at 574; Seymore, *Teaching Function*, *supra* note 151, at 641–46.

174 *Cf.* Larrimore Ouellette, *supra* note 151, at 574 (addressing the concern that stronger patent disclosure would negatively impact incentives); Varadarajan, *supra* note 93, at 49 (considering the influence of the introduction of a trade-secret fair use exception on owners' incentives).

175 According to the distinctions proposed earlier, these cases belong to the fourth category ("if-not-A-then-B" cases). *See supra* notes 26–27 and accompanying text.

176 Shur-Ofry, *supra* note 51, at 96–101 (demonstrating that the impact of IP reforms in complex innovation systems is often nonlinear).

generally, it is important to remember that insufficient access to error harms innovation in various manners.[177] Hence, on balance, careful adjustments to IP doctrine to remedy the current disregard of access to error will likely benefit innovation and social welfare.

B. *Regulation*

A second possible solution to the access-to-error problem is direct, top-down regulation. If market-based intellectual property mechanisms fail to induce sufficient dissemination of negative knowledge, then state intervention mandating such disclosure may be called for.[178] Regulatory intervention may be particularly apt in areas involving immediate safety concerns, where oft-times regulatory schemes are already in place. In such cases, the regulation of the negative can be embedded with relative ease and efficiency in extant regulation of the positive activities in the relevant field.

One prominent illustration for regulation that explicitly targets negative knowledge is an amendment to the FDA regulatory scheme that requires those engaged in clinical trials to disclose to publicly-available databases certain drug trial results including "adverse events," "in a manner and form that is useful and not misleading to patients, physicians, and scientists."[179] Failure to comply can result in the loss of government grants as well as substantial fines.[180] A database containing the disclosed negative information was made available to the public after the amendment.[181] This regulatory involvement was preceded by several infamous cases where negative results about pharmaceuticals were withheld from the public eye.[182] The best known example concerned the effectiveness of SSRI antidepressants in children and adolescents, where studies with negative results about drug efficacy and adverse effects were neither published nor disclosed.[183] Most likely, the suppressed negative information in that case would have changed the

177 *See supra* Part II.C.

178 *See* ROBERT BALDWIN, ET AL., UNDERSTANDING REGULATION: THEORY, STRATEGY, AND PRACTICE 41 (2d ed. 2012) (explaining that regulation's purpose is "to achieve certain publicly desired results in circumstances where . . . the market would fail to yield th[em]"). For a recent discussion of the use of "sticks" (such as fines and sanctions) for inducing innovation, *see* Ian Ayres & Amy Kapczynski, *Innovation Sticks: The Limited Case for Penalizing Failures to Innovate*, 82 CHI. L. REV. 1781 (2015)

179 Food and Drug Administration Amendments Act of 2007, Pub. L. No. 110-85, § 801, 121 Stat. 823 (2007).

180 For a review of the amendment's principal terms, *see* Alastair J.J. Wood, M.D., *Progress and Deficiencies in the Registration of Clinical Trials*, 360 NEW ENG. J. MED. 824 (2009).

181 CLINICALTRIALS, http://www.ClinicalTrials.gov (last visited Apr. 10, 2016).

182 *See* Marc J. Scheineson & M. Lynn Sykes, *Major New Initiatives Require Increased Disclosure of Clinical Trial Information*, 60 FOOD & DRUG L.J. 525, 533–34 (2005).

183 Lurie & Zieve, *supra* note 96, at 86 (explaining that in addition to negative findings concerning efficacy, the results suggested a possible increase in suicidal thinking).

regulatory profile of the drug.[184]

Regulatory disclosure requirements of this type, it should be clarified, are different from liability rules that impose liability for damages resulting from errors and failures (for example, in cases of negligence). Indeed, liability rules may constitute "sticks" that induce parties to take greater care in order to avoid failures and mistakes. Yet, this Article's primary focus is not on incentives for minimizing errors, but rather on promoting their disclosure and dissemination once they occur. From this perspective liability rules may prove a double-edge sword: encouraging precautionary measures to minimize errors on the one hand, but also increasing the incentive to conceal mistakes once they occur, on the other hand. Therefore, the potential role of liability rules in promoting an access-to-error paradigm is far from obvious, and deserves separate exploration.[185] The discussion in this sub-part, then, concentrates on direct regulatory requirements that instruct the *disclosure* of negative information.

Indeed, much like the intellectual property regime, regulatory schemes need to consider the impact of mandatory disclosure requirements on incentives in the regulated industry.[186] As noted earlier, in commercial settings, the disclosure of negative information revealed during R&D activities may allow free-riding on part of competitors, result in loss of lead-time or jeopardize first-to-market advantage.[187] While the actual impact of mandatory disclosure on incentives is unclear and varies across industries,[188] regulatory schemes are not completely exempt from considering it.

Yet interestingly, in regulated environments, these concerns may carry less weight. First, in innovation systems that are characterized by repeat players (such as the pharmaceutical industry or the financial innovation industry), over time the playing field may level-out; the advantages lost due to mandatory disclosure of negative information by one player might be set off against benefits obtained from the mandatory disclosure of comparable information by others.

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184 *Id.* For additional examples, *see* Scheineson & Sykes, *supra* note 182, at 534–35.

185 One potential direction which could be considered in this context is a tort regime that regards error disclosure as a factor which shields from, or mitigates, liability for damages. However, exploring the possible consequences of various liability regimes in different innovation-related contexts involves a complicated cost-benefit analysis, which exceeds the scope of this Article.

186 *See* McGarity & Shapiro, *supra* note 143, at 838, 849–52 (noting that broad mandatory disclosure of health and safety information may reduce incentives for research and development of new drugs); Gerrit M. Beckhaus, *A New Prescription to Balance Secrecy and Disclosure in Drug-Approval Process*, 46 U. MICH. J.L. REFORM 135, 136 (2012) (discussing the incentive-access balance in the context of regulatory disclosure of pharmaceutical information).

187 *See supra* notes 174–175 and accompanying text. *See also* McGarity & Shapiro, *supra* note 143, at 849–52; Beckhaus, *supra* note 186, at 136.

188 McGarity & Shapiro, *supra* note 143, at 852 (noting that it is "uncertain" whether disclosure requirements affect incentives for innovation in the pharmaceutical field).

Moreover, in some cases, regulators may be able to devise schemes that would mandate the disclosure of negative knowledge on the one hand while also providing some form of compensation to the disclosing party on the other hand.[189] One illustration is regulatory "exclusivity periods" that will allow the discloser of negative information to exclusively use that information for a certain period of time, thus preserving some R&D lead time.[190] Unlike market players, regulators may be in a position to effectively monitor and enforce such exclusions through their regulatory control over the field. For example, regulators may be able to release the data disclosed only after a certain period of time, or award "lead time" through their capacity to approve or bar market entry.[191] The detailed consideration of such incentive schemes is beyond the scope of this Article. The important point for our purposes is that at times, regulators may be in a better position than the intellectual property system to incentivize disclosure of negative information by awarding it some measure of excludability.

Another example for promoting access to error through regulation concerns the mandatory adoption of "near-miss" policies in high-risk innovation industries, such as the nuclear, chemical, and medical domains.[192] These programs require the relevant players to disclose and document errors, mistakes, and accidents that came close to happening but did not result in detrimental harm.[193] By so doing, near-miss policies encourage the adoption of a systematic approach to detecting errors

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189 *Id.* at 875–76 (discussing various schemes of "compensated disclosure"); *cf.* IAN AYRES, CARROTS AND STICKS, 55–57 (1st ed. 2010) (discussing the use of a mixture of "carrots and sticks" for incentivizing desirable behavior); Ayres & Kapczynski, *supra* note 178, at 20 (indicating that combining "carrots and sticks" may sometimes serve as a useful method for promoting innovation).

190 McGarity & Shapiro, *supra* note 143, at 875–83 (recommending a full disclosure of clinical trials information that will be balanced against exclusive-use periods of the information disclosed by the submitter); *cf.* Beckhaus, *supra* note 186 (proposing an "auction" scheme for sensitive data after drug approval).

191 One example of a successful regulatory-controlled exclusion is set out in the Drug Price Competition and Patent Term Restoration Act of 1984, Pub. L. No. 98-417, 98 Stat. 1585 (codified as amended in 21 U.S.C. § 355 (2012)), commonly known as the "Hatch-Waxman Act." The Act awards a 180-day market exclusivity period to the first generic company that files a generic drug for FDA approval and challenges the patents protecting the innovator's ("brand-name") drug. This exclusivity period can be easily enforced because drug companies must obtain FDA approval before entering the market. *See* Michael A. Carrier, *Payment After Actavis*, 100 IOWA L. REV. 7, 8–11 (2014).

192 The term "near-miss" originates in the aviation industry. *See* Nashef, *supra* note 59, at 180; SCHULZ, *supra* note 26, at 214–16. For discussions of "near-miss" schemes in the medical and chemical domains *see, e.g.*, Jeannie L. Callum et al., *Reporting of Near-Miss Events for Transfusion Medicine: Improving Transfusion Safety*, 41 TRANSFUSION 1204, 1205 (2001); Carthey et al., *supra* note 59, at 301.

193 Nashef, *supra* note 59, at 180; Carthey et al., *supra* note 59, at 301 ("an accident sequence was initiated and then either by chance or by the actions of an individual, team, or organization it was averted before negative consequences occurred.").

before they cascade into catastrophes,[194] enable the formation of error-databases, draw a picture of the weaknesses and fallibilities in the regulated system's defenses,[195] and facilitate learning from collective mistakes.

Regulation, however, does not present an ultimate solution to the access-to-error conundrum. Regulatory intervention may be appropriate where the necessity of disclosing errors is evident due to pressing safety concerns. Under this Article's proposed distinctions, these cases belong to the third group of errors.[196] In such cases, regulatory schemes are usually already in place and expanding them to include negative information will unlikely impose significant costs. Mandatory disclosure of errors is less apt (and less effective) in other domains—those that are not subject to constant regulatory intervention, such as academic research that does not yield significant results. In such cases, the costs of regulation and enforcement may well exceed the benefits,[197] and the mere coercive intervention by the state may crowd out the willingness of the players to voluntary share their negative knowledge.[198]

Thus, this Article does not propose to extend regulation to every field in which errors accumulate (which is virtually each and every aspect of human endeavor). Nor does it recommend detailed regulatory arrangements that are obviously context and industry specific. Yet it does aim to alert regulators of innovation ecosystems to the significance of negative information. It further contends that when regulatory schemes are already in place, regulators cannot confine themselves to the positive aspects of their regulated fields but must also devote regulatory efforts to the detection, exposure, and dissemination of negative information.

194 For the tendency of undetected errors to accumulate and cause large and abrupt harms, *see* discussion in Part I, *supra* notes 53–61 and accompanying text.

195 Carthey et al., *supra* note 59, at 301–02.

196 *See supra* notes 26–27 and accompanying text.

197 *Cf.* Ayres & Kapczynski, *supra* note 178, at 15 (stressing that imposing fines on researchers that fail to innovate seems "ill advised").

198 For general literature documenting the "crowding out" effect, whereby people may lose their internal motivation to engage in a desirable activity in the presence of external sanctions or rewards, see, for example, Edward L. Deci et al., *A Meta-Analytic Review of Experiments Examining the Effects of Extrinsic Rewards on Intrinsic Motivation*, 125 PSYCHOL. BULL. 627 (1999); Daphna Lewinsohn-Zamir, *The Importance of Being Earnest: Two Notions of Internalization*, 65 TORONTO L. J., 37, 58-59 (2015) (explaining that incentives that "control", rather than merely support, behavior, tend to crowd out intrinsic motivations); Yuval Feldman & Orly Lobel, *The Incentives Matrix: The Comparative Effectiveness of Rewards, Liabilities, Duties, and Protections for Reporting Illegality*, 88 TEX. L. REV. 1151, 1194–95, 1202–1203 (2010); *Cf.* Rai, *supra* note 96 (suggesting that regulating innovation through private rights may crowd-out norms of information sharing prevalent in scientific communities).

C. *From Access-to-Knowledge to Access-to-Error*

The discussion so far has explored the two traditional approaches to cooperation dilemma: (intellectual) property rights and top-down state intervention. The analysis indicates that despite certain virtues, these two institutions are limited as *general* frameworks for promoting the diffusion of negative knowledge. IP incentives may play a certain role when negative information lies in very close proximity to positive knowledge.[199] Top-down regulation may be suitable when negative information involves immediate safety concerns.[200] Yet, none of these schemes is adequate for promoting the diffusion of vast amounts of null results, blind alleys, failed hypotheses, falsifications, and unsuccessful experiments, all of which accumulate in both scientific and industry settings. Under this Article's proposed distinctions, these "hard cases" belong primarily to two categories: the first concerns failures to validate one's own hypotheses including, for example, insignificant experimental results, 'null' findings and blind alleys. The second concerns refutations of others' hypotheses.[201]

Notably, there are certain differences between these two groups of negative information: while people's incentive to publish and disseminate their own "self-generated-failures" is generally lacking, scientists and industry players in competitive settings may still have an incentive to publish refutations of others' hypotheses.[202] In addition, while self-generated failures, as well as many refutations, are unintentional and ancillary to the effort to produce positive knowledge,[203] some refutations (such as large-scale replication studies) are deliberate,[204] and they may require designated resources. These distinctions may have policy implications, and I return to them shortly. However, the important insight at this stage is that these two types of negative information are hardly susceptible to the solutions of privatization and top-down regulation. As such, they are at the heart of the access to error conundrum.

Yet, the dichotomy of privatization versus regulation does not exhaust the solutions to collective action problems. As Nobel Laureate Elinor Ostrom demonstrated in her seminal work, communities can sometimes self-organize to achieve effective collaboration in their use

199 According to this Article's categorization these limited cases belong to the fourth category of negative information. *See supra* notes 26–27 and accompanying text. For further discussion of this point, see *infra* note 220 and accompanying text.

200 *See supra* note 196 and accompanying text.

201 *Supra,* notes 26-27 and accompanying text.

202 One should keep in mind, however, that securing a suitable publication platform for refutations is often problematic. *See supra,* notes 104–107 and accompanying text.

203 *Supra,* notes 74-78 and accompanying text.

204 *See, e.g.,* the replication studies in the field of cancer research, economics and psychology described *supra* notes 132–135 and accompanying text.

of common resources.[205] While Ostrom's original studies focus on natural resources, her subsequent work with Charlotte Hess explicitly explores self-organized collaboration and sharing of information as a response to collective action problems in the use of knowledge resources.[206]

Against this background, this sub-Part explores a third and promising direction for innovation policy. It suggests to locate access-to-error within the broader paradigm of access-to-knowledge and to adopt a variety of policies that will facilitate and support commons-based mechanisms for the dissemination of negative information.

1. Access-to-Error and the Commons

Commons-based schemes for knowledge sharing are increasingly recognized as a significant means for promoting innovation.[207] Building on Ostrom's work and on the values of the access-to-knowledge movement, an expanding strand of scholarship in the field of innovation law maintains that voluntary sharing of knowledge can effectively foster innovation in the domains of science, technology, and culture.[208] The strength of this approach is manifested by the significant number of ventures that promote innovation based on a commons-paradigm. Prominent examples for such enterprises include the Registry of Standard Biological Parts that provides a shared tool-box of biological functional units for the design of biological systems;[209] the Rare Diseases Clinical Research Network—an NIH initiative to develop infrastructure for rare diseases clinical research through a network of

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205 OSTROM, *supra* note 145.

206 CHARLOTTE HESS & ELINOR OSTROM, UNDERSTANDING KNOWLEDGE AS COMMONS 3 (2007). This notion was further developed in recent innovation scholarship. *See infra* notes 207–208.

207 BRETT M. FRISCHMANN ET AL., *Introduction* to GOVERNING KNOWLEDGE COMMONS ix, x (Brett M. Frischmann, et al., eds., 2014) [hereinafter FRISCHMANN ET AL., GOVERNING KNOWLEDGE COMMONS].

208 *See, e.g.*, Michael J. Madison et al., *Constructing Commons in the Cultural Environment*, 95 CORNELL L. REV. 657, 691–92 (2010) [hereinafter Madison et al., *Constructing Commons*] (discussing information commons as "solutions to collective action, coordination, or transactions cost problems"); FRISCHMANN ET AL., GOVERNING KNOWLEDGE COMMONS, *supra* note 207; James Boyle, *Foreword: The Opposite of Property?*, 66 L. & CONTEMP. PROBS. 1, 2 (2003) (discussing means to avoid the "tragedy of the commons" in cultural systems, without private ownership); Benkler, *Strategies*, *supra* note 166, at 1110 (demonstrating that social mechanisms not based on exclusion serve an important role in promoting science); Amy Kapczynski, *The Cost of Price: Why and How to Get Beyond Intellectual Property Internalism*, 59 UCLA L. REV. 970 (2012) [hereinafter Kapczynski, *Cost of Price*] (discussing collaborative, self-organized production as a significant approach for promoting innovation); Contreras, *supra* note 96, at 1610 (2010) (examining commons-based approaches for sharing scientific data); Lee, *supra* note 3 (discussing commons-based schemes for increasing access to patented technologies).

209 iGEM, *Registry of Standard Biological Parts*, http://parts.igem.org/Main_Page (last visited Apr. 10, 2016); JAMES BOYLE, THE PUBLIC DOMAIN: ENCLOSING THE COMMONS OF THE MIND 171–78 (2008) (describing the aims and operations of the Registry).

research consortia;[210] the reCAPTCHA algorithm that uses the multiple human inputs to the "CAPTCHA" web feature in order to digitize printed materials;[211] the Linux open source operating system;[212] and Wikipedia.[213] This non-exhaustive list illustrates the capacity of self-organized initiatives that rely on collaboration and sharing to play a significant role in the creation and dissemination of knowledge. It also suggests that commons-based enterprises are not necessarily confined to amateur users but can also appeal to sophisticated commercial players in innovation ecosystems.[214]

Commons-based schemes may be particularly appealing when their object is negative information, for two principal reasons. The first is the very limited ability of the intellectual property system to provide an effective mechanism for internalizing the value of negative information.[215] In other words, oft-times an innovator who considers joining a commons scheme for the sharing of negative knowledge will not need to weigh this option against an attractive IP dissemination mechanism based on exclusion, simply because the latter is not a viable alternative.

The second is that, as elaborated earlier, in many instances the creation of negative knowledge is not intentional but ancillary to efforts to produce positive knowledge, or stems inadvertently from diverse human activities.[216] In most cases, innovators do not dedicate substantial resources to creating errors, and the independent value of distinct pieces of negative information is generally low. This trait makes negative information particularly suitable for commons schemes that frequently rely on integrating contributions with low independent value

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210 Katherine Strandburg et al., *The Rare Diseases Clinical Research Network and the Urea Cycle Disorders Consortium as Nested Knowledge Commons*, *in* GOVERNING KNOWLEDGE COMMONS, *supra* note 207, at 155–56.

211 CAPTCHA, the acronym that stands for "Completely Automated Public Turing test to tell Computers and Humans Apart," is a web-security feature that distinguishes between human and nonhuman users by asking people to type distorted letters. For a description of the commons-based reCAPTCHA project, *see* Luis von Ahn et al., *reCAPTCHA: Human-Based Character Recognition via Web Security Measures*, 321 SCI. 1465 (2008).

212 Benkler, *The Idea of Access to Knowledge*, *supra* note 3, at 226–28 (describing the success of Linux); *cf.* Kapczynski, *A2K Genealogy*, *supra* note 4, at 32 (referring to the "free software" movement as a prominent example of a collectively governed commons-based institution).

213 Benkler, *Strategies*, *supra* note 166, at 1110; FRISCHMANN ET AL., GOVERNING KNOWLEDGE COMMONS, *supra* note 207, at x (referring to Wikipedia as a paradigmatic example of knowledge commons).

214 *Cf.* Benkler, *The Idea of Access to Knowledge*, *supra* note 3, at 226–28 (describing how Linux's success yielded cooperation with commercial players such as IBM); Amy Kapczynski, *The Access to Knowledge Mobilization and the New Politics of Intellectual Property*, 117 YALE L.J. 804, at 810–11 (2008) [hereinafter Kapczynski, *A2K Mobilization*] (arguing that the access-to-knowledge movement can create areas of agreement among commercial and non-commercial players).

215 *Supra* Part II.A.

216 *See supra* Part II.A, notes 74–77 and accompanying text.

from many low-intensity collaborators.[217]

These particular properties of negative knowledge also address, to some extent, the concern of commons-skeptics that cooperative regimes cannot provide a viable alternative to IP exclusionary mechanisms in innovation settings that require high capital investment and involve high asset value.[218] Even under these assumptions, commons-based schemes can still play a fundamental role in the context of negative information, where the creation is often inadvertent and does not involve direct investment, where the value of each contribution to the commons is frequently low, and where exclusion through intellectual property is at best partial. Moreover, given the voluntary nature of commons-based institutions, these schemes raise fewer concerns about harming incentives to engage in innovative activities, in comparison to the mandatory measures previously discussed.[219]

Indeed, there may be a particular subset of circumstances that will not fit this description. I am referring again to cases where negative information is in very close proximity to positive knowledge so that access to the negative effectively provides access to the positive ("if not A, then B" cases). For the sake of illustration, imagine there are only two potential formulations for effectively producing a certain pharmaceutical. The information that one of these formulations does *not* work immediately points out to the other one as the effective solution. Put more generally, in capital-intense settings, when negative information is virtually indistinguishable from valuable positive information, it may be unreal to expect its release to commons-based schemes.[220] Rather, parties in possession of such information would likely prefer a strategy of enclosure—namely maintaining the negative information confidential—and the subsequent release of a product based on the positive information (a drug, in our example) that would be protected under the intellectual property regime. Yet, as indicated earlier, in these cases the regular, IP-based, set of incentives for the dissemination of knowledge would largely function. Thus, they are not the core of the problem that is addressed by this Article. Our discussion illustrates that in most cases, negative and positive information are not so closely intertwined. The crux of the access-to-error problem concerns the myriad insignificant results, blind alleys, refuted hypotheses, and

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217 *Cf.* Benkler, *Strategies*, *supra* note 166, at 1111 (calling scientists to join peer-production enterprises that integrate contributions from many low-intensity collaborators); Jonathan M. Barnett, *The Illusion of the Commons*, 25 BERKELEY TECH. L.J. 1751, 1755 (2010) (maintaining that non-exclusionary regimes may function in settings involving low capital intensity and low asset value, but not in other settings).

218 Barnett, *supra* note 217 (maintaining that some form of restraint of access is a key to supporting capital intensive forms of innovation).

219 *See supra* Part III.B, notes 186–188 and accompanying text.

220 *Cf.* Graves, *supra* note 7, at 413 (making a similar distinction in the context of trade secrets).

unsuccessful experiments with low independent value, which highly fit a commons-scheme profile.

The proposal to frame access-to-error as part of the access-to-knowledge paradigm begs some clarification. Access-to-knowledge is sometimes perceived as a rejectionist movement, a counter-reaction to intellectual property's expansion.[221] Whether or not the rejectionist account is still a vital part of A2K's conceptualization,[222] it is certainly not vital for conceptualizing access-to-error. If IP is inherently limited as a means for encouraging the dissemination of negative knowledge, then embracing commons-based-solutions to promote this end is neither hostile to intellectual property nor does it involve rejecting any of its key premises.

Despite this nuance, positing access-to-error as part of the access-to-knowledge paradigm carries substantial benefits. Most importantly, it provides access-to-error with a conceptual frame. Such framing builds on the memetic power of "access-to-knowledge." The mere use of the phrase "access-to-error" immediately highlights the problem and invokes notions of sharing, access, commons, and collaboration as potential solutions without the need for elaborate explanations.[223] Moreover, as the experience of access-to-knowledge demonstrates, the existence of a common frame can illuminate and form alliances between seemingly disparate groups in the innovation ecosystem.[224] In our case, the frame of access-to-error can alert scientists, industry players, and public institutions to their common interest in disseminating negative knowledge, which, in turn, can foster collaborations among these diverse groups and increase the success prospects of commons-based initiatives.[225]

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221 *See, e.g.*, Kapczynski, *A2K Genealogy*, *supra* note 4, at 17 (describing A2K as a reaction to the structural expansion of intellectual property); Boyle, *supra* note 208, at 3, 12 (critically discussing the expansion of intellectual property).

222 *Cf.* Ahmed Abdel Latif, *The Emergence of the A2K Movement: Reminiscences and Reflections of a Developing-Country Delegate*, *in* ACCESS TO KNOWLEDGE IN THE AGE OF INTELLECTUAL PROPERTY 99, 118 (Gaëlle Krikorian & Amy Kapczynski, eds., 2010) (maintaining that A2K is "not the antithesis of intellectual property"); FRISCHMANN ET AL., GOVERNING KNOWLEDGE COMMONS, *supra* note 207, at xi (stressing that knowledge commons is an independent affirmative means for producing innovation that is not opposed to intellectual property).

223 *Cf.* Kapczynski, *A2K Genealogy*, *supra* note 4, at 30–34 (referring to the concepts of "commons," "access," and "sharing" as prominent memes of the A2K movement); Abdel Latif, *supra* note 222, at 110–12 (describing the origin of the term A2K and the process of framing it as a concept).

224 Kapczynski, *A2K Mobilization*, *supra* note 214, at 806–11. *See also* Gaëlle Krikorian, *Access to Knowledge As a Field of Activism*, *in* ACCESS TO KNOWLEDGE IN THE AGE OF INTELLECTUAL PROPERTY 57, 78 (Gaëlle Krikorian & Amy Kapczynski, eds., 2010) (maintaining that the conceptualization helps stakeholders "to perceive the world differently").

225 *Cf.* Kapczynski, *A2K Mobilization*, *supra* note 214, at 844–46 (maintaining that interpretive frames can be used to foster collective action). The discussion in this sub-Part also highlights the advantages of an access-to-error commons-based paradigm in comparison to a recent proposal to

Lastly, and importantly, the frame of access-to-error can serve as a guiding principle for innovation policy. As such, it can clarify the tight connections between a wide array of policy measures—from the formation of error repositories, through the enhanced funding of replication studies, to the promotion of voluntary near-miss schemes—which I now turn to discuss.

2. Access-to-Error and Innovation Policy

The role of policymakers in promoting the access-to-error paradigm deserves attention. Indeed, commons-based schemes are not subject to top-down regulation, and their success largely relies on self-organization and voluntary collaboration. Yet, the state can supply a variety of nudges to spark, facilitate, and disseminate bottom-up initiatives of access-to-error.[226] Moreover, innovation scholarship points out that commons-based schemes include diverse, sophisticated projects that extend far beyond merely throwing materials into the public domain.[227] Rather, successful commons projects frequently rely on sets of rules, make use of certain infrastructure, and have some form of governance.[228] Policymakers can therefore significantly support errors-commons by providing the infrastructure required for their operations.

The following paragraphs illustrate how policy interventions and state-supplied nudges can promote access to error by exploring four concrete proposals: 1) initiating and facilitating errors repositories; 2) calibrating state funding schemes to support the access-to-error paradigm; 3) nudging voluntary near-miss programs; and, 4) advancing a change in our cultural perception of error.

The pressing need for digital errors-repositories is one of this Article's principal insights. Such databases would allow scientists, industry researchers, and other stakeholders to voluntarily contribute

create a "null patent" regime to accommodate negative knowledge within the patent office databases. Seymore, *supra* note 7. A scheme which is part of the patent system is unlikely to yield the same notions of collaboration and sharing and may crowd out parties such as academics, economists, psychologists, and other social scientists that do not regularly interact with the patent system. For a discussion of crowding-out concerns, see *supra* note 198 and accompanying text.

226 I use "nudges" here to denote measures that can "alter people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives." *See* RICHARD THALER & CASS SUNSTEIN, NUDGE: IMPROVING DECISIONS ABOUT HEALTH, WEALTH, AND HAPPINESS 6 (2008). For the power of nudges to generate collective behavior, *see id.* at 53 ("Sometimes massive social changes, in markets and politics alike, start with a small social nudge."). Notably, however, while the nudges proposed by Thaler and Sunstein largely rely on harnessing people's cognitive biases to initiate change, most policy interventions proposed in this sub-Part are not based on utilizing psychological biases.

227 *See supra* notes 209–212 and accompanying text; Contreras, *supra* note 96, at 1628–53 (discussing various commons-based initiatives for sharing of scientific data); Kapczynski, *Cost of Price*, *supra* note 208, at 1019 (reviewing a variety of practices that fall under commons based production).

228 Madison et al., *Constructing Commons*, *supra* note 208, at 703–06; Contreras, *supra* note 96, at 1629.

negative and insignificant results and to access similar information contributed by their peers.[229] In order to be useful, commons-based repositories need to be formed in a standardized, easily searchable, and usefully structured manner.[230] The state can initiate the creation of error-repositories, plan their architecture, supply the digital resources required for their operation, and support their maintenance. One possibility worth consideration is the design of error repositories in a manner that would allow contributors to remain anonymous *vis-a-vis* the public while maintaining certain transparency *vis-a-vis* the repository coordinators. Such architectures might help potential contributors overcome concerns about adverse reputational effects resulting from the exposure of their failures.[231] Another simple but effective nudge would be to use the state's information networks to spread the word about the availability of errors-commons (whether or not initiated by the state) among the relevant communities.[232]

Emerging grassroots enterprises in several scientific domains suggest that this could be a productive path. Platforms dedicated to the publication of negative findings—such as the Journal of Negative Results in Biomedicine[233] and the Journal of Negative Results in Ecology and Evolutionary Biology[234]—evidence increasing awareness on the part of scientific communities that the problem of access-to-error requires urgent attention. The rise in discussions of this topic in high-profile scientific journals is another such indication.[235] This rising attention of the scientific community provides a ripe atmosphere for the proposed policy intervention. Therefore, a few thoughtful nudges to promote error repositories may well generate a general movement that could bring to light the enormous scientific capital of negative results that lies in the file drawers of each and every scientific institution.[236]

229 *Cf.* Charlotte Hess & Elinor Ostrom, *A Framework for Analyzing the Knowledge Commons*, *in* UNDERSTANDING KNOWLEDGE AS COMMONS 41, 54–56 (Charlotte Hess & Elinor Ostrom ed., 2007) (discussing digital repositories as forms of commons).

230 *Id.*

231 *Supra* note 127 and accompanying text.

232 *Cf.* THALER & SUNSTEIN, *supra* note 226, at 66 (explaining that informing people about what others are doing can be an effective way for generating shifts in social behavior).

233 *About*, JOURNAL OF NEGATIVE RESULTS IN BIOMEDICINE, http://www.jnrbm.com/about (last visited Apr. 10, 2016) ("The journal invites scientists and physicians to submit work that illustrates how commonly used methods and techniques are *unsuitable* for studying a particular phenomenon . . . and invites the publication of clinical trials *that fall short of demonstrating an improvement* over current treatments.") (emphasis added).

234 JOURNAL OF NEGATIVE RESULTS, ECOLOGY AND EVOLUTIONARY BIOLOGY, http://www.jnr-eeb.org/index.php/jnr (last visited Apr. 10, 2016).

235 *See, e.g.*, Begley et al., *supra* note 133; Collins & Tabak, *supra* note 118; Fanelli, *supra* note 107; Franco et al., *supra* note 103; Matosin, et al., *supra* note 97; Parish, *supra* note 106; Open Science Collaboration, *supra* note 133; Unreliable Research, *supra* note 38; Vaux, *supra* note 40. Each of these papers and comments was published between 2012 and 2015.

236 For the term "scientific capital," *see* PIERRE BOURDIEU, SCIENCE OF SCIENCE AND REFLEXIVITY 55 (2004).

And such trend need not be confined to academics. Industry stakeholders too might be motivated to share certain negative information. The recent "Principles for Sharing Clinical Trials Data" adopted by the Pharmaceutical Industry Research and Manufacturers of America (PhRMA) and their explicit reference to the sharing of negative results illustrate that commercial players may be willing to take some part in errors-commons schemes.[237]

A second policy proposal is calibrating the state's funding programs to support the access-to-error paradigm. One simple adjustment should be conditioning the receipt of state funding upon comprehensive disclosure of all the results of the funded projects, including negative results that may never reach publication.[238] Another significant step would be the allocation of designated grants to support replication studies and technological projects that focus on refutations.[239] The latter measure is particularly significant since—unlike inadvertent negative information—deliberate large scale refutations can be costly to produce, and may require direct monetary support.[240] An encouraging development in this area is the fact that NIH directors have recently made clear statements regarding the agency's intent to actively incentivize reproducibility studies.[241] Hopefully additional major funds will follow suit.

State support for reproducibility research may raise the scientific profile of replication studies, and by so doing may strengthen several emerging projects that are devoted to replications and refutations. Two prominent illustrations are the new "Reproducibility Initiative" that encourages scientists to have their work independently validated while providing a platform for publishing validation studies,[242] and the "Center of Open Science" (COS) in the social sciences that aims "to increase openness, integrity, and reproducibility of scientific research" through various measures,[243] including bottom-up initiatives and interactions among communities.[244]

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237 *See Principles for Responsible Clinical Trial Data Sharing*, PHRMA (Jul. 18, 2013), http://www.phrma.org/sites/default/files/pdf/PhRMAPrinciplesForResponsibleClinicalTrialDataSharing.pdf ("All company-sponsored clinical trials should be considered for publication in the scientific literature *irrespective of whether the results of the sponsors' clinical trials are positive or negative*") (emphasis added).

238 For current funding policies that do not explicitly require the sharing of negative results, see *supra* notes 119–120 and accompanying text.

239 For the current lack of support to replication studies by grants and funding schemes, see *supra* notes 117–118 and accompanying text.

240 *See* the analysis *supra*, notes 201–204 and accompanying text.

241 Collins & Tabak, *supra* note 118, at 613.

242 *See Reproductability Initiative*, SCI. EXCH. NETWORK (2014), http://validation.scienceexchange.com/#/reproducibility-initiative.

243 *COS Mission*, CENTER FOR OPEN SCIENCE, http://centerforopenscience.org/about_mission/ (last visited Apr. 10, 2016).

244 *See COS Communities*, CENTER FOR OPEN SCIENCE, http://centerforopenscience.org/

A third direction for innovation policy is supporting *voluntary* near-miss programs to nudge the disclosure of errors.[245] In order to encourage such schemes policy makers could, for example, adopt error-reporting programs as optional default choices in public systems,[246] or provide institutions in the innovation ecosystem with a reporting infrastructure that includes useful error-taxonomies.[247] Unlike the regulatory near-miss schemes that were discussed earlier, non-mandatory programs completely depend on stakeholders' willingness to collaborate and share mistakes and errors. Yet, the emergence of several voluntary, bottom-up, near-miss initiatives in the area of medical treatments is a promising sign,[248] and their success indicates that state-supplied nudges to encourage such programs could be a worthy effort.

Voluntary near-miss programs share many of the advantages of mandatory programs: they provide a structural and more robust picture of the system's weaknesses that allows learning from collective mistakes. But beyond that, the adoption of voluntary error-reporting policies buttresses an organizational culture of openness, signals an institutional commitment to transparency, and no less important, conveys a cultural message that recognizes and embraces human fallibilities.[249]

This illuminates a final yet significant point. To some extent, an access-to-error paradigm requires a shift in our social perception of error. It can be a difficult task to nurture the dissemination of negative knowledge in an environment that equates innovation with success,[250] treats failure as a character trait,[251] and perceives errors as defeats that are relegated to the file drawer.[252] Indeed, various stakeholders in the innovation ecosystem—including directors of state funding programs, editors of scientific journals, and high-tech entrepreneurs—have recently been calling for a change of perception.[253]

communities/ (last visited Apr. 10, 2016). For a recent large scale replication study carried out by COS, *see* Open Science Collaboration, *supra* note 133.

245 For a discussion of mandatory "near-miss" schemes, see *supra* Part III.A, notes 192–193 and accompanying text.

246 For the effectiveness of default choices as nudges, see THALER & SUNSTEIN, *supra* note 226, at 35.

247 For the importance of error taxonomies for the success of near-miss schemes, *see* Carthey et al., *supra* note 59, at 302.

248 *See, e.g.*, Callum et al., *supra* note 192, at 1204, 1210 (describing the "Serious Hazards of Transfusion" program, a voluntary near-miss scheme for detecting errors in blood transfusion); SCHULTZ, *supra* note 26, at 303 (discussing a successful program implemented by the Beth Israel Deaconess Hospital that included deliberate and frank publication of medical errors).

249 *Cf.* SCHULTZ, *supra* note 26, at 303 (discussing the importance of an organizational culture in which members are encouraged to report mistakes).

250 SANDAGE: BORN LOSERS, *supra* note 28, at 265.

251 *Id.* at 251.

252 *Supra* notes 126–128 and accompanying text.

253 *See* Collins & Tabak, supra note 241, at 613 (heads of NIH recognizing the need for a "cultural revolution" within science); Written Testimony of Bruce M. Alberts, Editor-in-Chief of

Transforming social norms of this type is essentially a bottom-up process, and the grassroots initiatives explored throughout this Part constitute important steps along the way.[254] Yet here, too, policymakers can support grassroots processes through a variety of nudges. These include, for example, providing platforms to openly discuss and contest scientific findings;[255] adjusting public education programs to illuminate the links between errors, innovation, and progress[256] and to provide a more realistic account of successful innovators and their fallibilities;[257] and more broadly, promoting an educational agenda that embraces error rather than conceals it.

CONCLUSION

Counterintuitively, negative information and innovation are closely intertwined, and access-to-error is a crucial tenet of creativity and progress.

This Article's systematic focus on negative knowledge illuminates a significant gap in our innovation infrastructure. The principal legal, social, and institutional mechanisms concerned with innovation and progress discourage, rather than incentivize, the exposure and dissemination of negative knowledge. The result is a huge metaphorical file-drawer that keeps vast amounts of negative findings, falsifications, insignificant results, failures, and errors away from the public eye. The adverse consequences for innovation and progress are substantial.

The foregoing analysis further indicates that innovation law and policy cannot remain oblivious to the pressing need to promote access to negative information. This Article does not offer a comprehensive solution but aims to conceptualize access-to-error as a vital part of the access-to-knowledge paradigm and as an important goal for innovation

Science Magazine, *in* Congressional Hearing on "Scientific Integrity and Transparency" (March 5, 2013), https://brucealberts.ucsf.edu/publications/Testimony.pdf (calling for the a shift in the scientific value system, toward public acknowledgement of one's mistakes); Claire Martin, *Wearing Your Failures on Your Sleeve*, N.Y. TIMES (Nov. 8, 2014), http://www.nytimes.com/2014/11/09/business/wearing-your-failures-on-your-sleeve.html (describing initiatives in the high-tech industry to encourage start-up entrepreneurs to openly discuss their failures).

[254] *Cf. Strategic Plan*, CENTER FOR OPEN SCIENCE (Sept. 18, 2013), https://docs.google.com/document/d/17OTxjE5zl34VcXiAORayFOCDIkyRCiefh1ZBN1qEBUc/edit?pli=1, at 2 ("Cultural revolutions are more likely to persist if they emerge from the community rather than being forced on to the community.").

[255] The new "PubMed Commons," an online forum launched by the NIH as a platform for open discourse about published articles, is one such example. *See PubMed Commons*, NCBI, http://www.ncbi.nlm.nih.gov/pubmedcommons/ (last visited Apr. 10, 2016).

[256] *Cf.* PETROSKI, *supra* note 34, at 91 (arguing that failures should be "a permanent part of the engineering literature"); Jo Boaler, *The Mathematics of Hope* (2014), http://www.youcubed.org/wp-content/uploads/The-Mathematics-of-Hope-5.pdf (describing the importance of a learning environment in which mistakes are valued rather than punished, for the learning of mathematics).

[257] *See, e.g.*, LIVIO, *supra* note 26 (providing a fascinating account of "brilliant blunders" by the most iconic innovators, including, *inter alia*, Darwin, Pauling, and Einstein).

policy. It proposes a preliminary typology of negative information. It further suggests several directions for policy intervention, while highlighting their relations to the different types of negative information. These include calibrating the intellectual property system to support the access-to-error paradigm; alerting regulators to the significance of error disclosure; and nudging various commons-based schemes dedicated to the dissemination of negative knowledge. Hopefully, these proposals will be further developed in future research, and their combination will advance the opening of a significant bottleneck in the innovation ecosystem.

Finally, access-to-error will greatly benefit from a certain change in social perceptions. This Article began with an observation attributed to Lincoln about the reluctance to publish one's own errors. One hundred fifty years later, this insight is still very true. But in some parts of our innovation ecosystem, the willingness to publicly discuss failure is increasing.[258] A recent statement by Mark Zuckerberg that "making lots of mistakes" was key to his success[259] may indicate that a social change is underway. Law and policy makers should make an effort to support it. This Article, I hope, will assist in this endeavor.

[258] *See* Martin, *supra* note 253 (describing the increasing willingness of entrepreneurs in start-up companies to wear their failures on their sleeves).

[259] Vindu Goel, *Mark Zuckerberg Says Secret of His Success Is Making Lots of Mistakes*, N.Y. TIMES (Dec. 11, 2014, 8:37 PM), http://bits.blogs.nytimes.com/2014/12/11/facebook-chief-says-secret-of-his-success-is-making-lots-of-mistakes/ (quoting Zuckerberg, addressing the issue of learning from mistakes: "If you're successful, most of the things you've done were wrong.").